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Research article

The efficacy of combined educational and site management actions in reducing off-trail hiking in an urban-proximate protected area

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ABSTRACT

Park and protected area managers are tasked with protecting natural environments, a particularly daunting challenge in heavily visited urban-proximate areas where flora and fauna are already stressed by external threats. In this study, an adaptive management approach was taken to reduce extensive off-trail hiking along a popular trail through an ecologically diverse and significant area in the Chesapeake and Ohio National Historical Park near Washington DC. Substantial amounts of off-trail hiking there had created an extensive 16.1 km network of informal (visitor-created) trails on a 39 ha island in the Potomac Gorge. A research design with additive treatments integrating educational and site management actions was applied and evaluated using self-reported behavior from an on-site visitor survey and unobtrusive observations of off-trail hiking behavior at two locations along the trail. Study treatments included: 1) trailhead educational signs developed using attribution theory and injunctive-proscriptive wording, 2) symbolic “no hiking” prompter signs attached to logs placed across all informal trails, 3) placement of concealing leaf litter and small branches along initial sections of informal trails, 4) restoration work on selected trails with low fencing, and 5) contact with a trail steward to personally communicate the trailhead sign information. The final, most comprehensive treatment reduced visitor-reported intentional off-trail hiking from 70.3% to 43.0%. Direct observations documented reduction in off-trail hiking from 25.9% to 2.0%. The educational message and site management actions both contributed to the decline in off-trail travel and the two evaluation methods enhanced our ability to describe the efficacy of the different treatments in reducing off-trail travel.

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1. Introduction

Recreation visitation is a traditional, legitimate, and economically important type of ecosystem service of many protected natural areas (Costanza et al., 1997), which are typically established for their significant ecological value. A common strategy to achieve a balance between recreation and conservation goals is through provision of a recreational infrastructure of trails and recreation sites that concentrate traffic on hardened durable substrates (Eagles et al., 2002; Marion, 2016; Marion and Leung, 2004). Many of these facilities are sustainably located and designed to shield and protect sensitive natural resources from visitor pressure (Marion,

2016; Marion and Farrell, 2002). However, the effectiveness of this spatial containment strategy is compromised when visitors travel away from the formal infrastructure in sufficient numbers to create informal trails and sites (Cole et al., 2008).

Indeed, off-trail hiking and the associated creation and proliferation of informal trails present a prime example of this problem, which occurs within most protected areas (Leung et al., 2011; Wimpey and Marion, 2011a). Sometimes referred to as social trails, these undesirable trail segments are often products of heavy visitation coupled with diverse recreation interests and motivations that draw visitors off of formal trails. Their proliferation in number, expansion in length, and resource impacts are perennial management concerns (Marion et al., 2016). Research reporting that a majority of hikers travel off-trail underscores the importance of this issue (Bradford and McIntyre, 2007; Park et al., 2008; Swearingen and Johnson, 1994, 1995).

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Because informal trails are not professionally designed, constructed or maintained they can contribute substantially greater impacts to protected area resources than formal trails (Wimpey and Marion, 2011a). Many informal trail impacts are related to their poor design, including alignments parallel to steep slopes or along shorelines, multiple trails accessing the same destination, routes through fragile vegetation, soils, or sensitive wildlife habitats, and disturbance to rare flora, fauna, or archaeological sites (Cole, 2008; Dumont et al., 2005; Knight, 2000). These design attributes also make informal trails far more susceptible to tread impacts, including expansion in width, soil erosion, and muddiness (Leung and Marion, 1996; Wimpey and Marion, 2011a).

Many past studies of off-trail hiking and informal trails have been conducted in frontcountry zones of large protected natural areas such as Acadia National Park (Park et al., 2008), Mt. Rainier National Park (Rocheftort and Gibbons, 1992), Rocky Mountain National Park (D'Antonio et al., 2013), and Yosemite National Park (Leung et al., 2011), with exceptions such as Boston Harbor Islands (Manning et al., 2005). While informal trails can form anytime visitors travel off-trail to common attraction features like vistas or campsites, they develop most frequently in high-use areas with environmental settings that permit off-trail traffic and have large numbers of off-trail attraction features (Marion et al., 2016; Walden-Schreiner and Leung, 2013). Inexplicably, small urban protected areas, which frequently receive high levels and densities of use, have received far less research attention (Alberti et al., 2003; Kaplan, 1983; Mora-Bourgeois, 2006). The apparent differences in the intensity and patterns of use, visitor characteristics, and resource conditions necessitate focused research on this end of the spectrum of protected areas to support effective management decisions regarding sustainable visitor use (Collins and Brown, 2007; Kyle and Graefe, 2007).

In this study, we investigated the efficacy of educational and site management actions designed to deter off-trail hiking along a popular National Park Service (NPS) trail located within the densely populated Washington D.C. metropolitan area. Previous efforts to deter off-trail hiking were unsuccessful, and an extensive network of informal trails was threatening numerous rare plants. We collaborated with managers to simulate an adaptive management process by developing an experimental design featuring additive treatments where additional site management and visitor education actions were integrated and sequentially applied to achieve the highest-possible reduction in off-trail hiking behaviors.

2. Literature review

The creation and use of informal trails by visitors are considered forms of non-compliant or depreciative behaviors (Gramann and Vander Stoep, 1987; Swearingen and Johnson, 1995). Depreciative behavior is impactful behavior by visitors ranging from unintentional actions to intentional acts of vandalism. The motivation or reason for a depreciative behavior influences the efficacy of interventions applied to reduce the undesired behavior (Gramann and Vander Stoep, 1987). The motivations and context of the visit can also influence the likelihood of depreciative behaviors. For example, there may be differences associated with urban-proximate parks, where urban visitors are engaged in activities such as dog walking, trail running, or short walks near their home that are uncommon in more distant traditional parks. In an effort to reduce impacts to natural resources, flora, and fauna caused by informal trail use, various educational and site management techniques have been evaluated for their efficacy in deterring off-trail travel. Early studies revealed that messages threatening a sanction are more effective in reducing off-trail hiking than ethical, humorous, symbolic, and hybrid messages (Johnson and

Swearingen, 1992; Swearingen and Johnson, 1994). Despite their effectiveness, managers are often hesitant to use “threatening” sanction messages due to their potential to degrade visitor experiences, so research began to focus on the efficacy of alternative educational or interpretive messages in deterring off-trail travel (Lucas, 1983; Winter, 2006).

Educational messages developed to reduce off-trail hiking can include an “awareness of consequence” component, informing visitors about the impact of off-trail hiking on the environment and instructing them about preferred low impact behaviors. An “ascription of responsibility” component is also common in educational messages, instilling a sense of personal responsibility to protect the area’s resources (Schwartz, 1975; Van Liere and Dunlap, 1978). Bradford and McIntyre (2007) reported that an attribution-based educational message (“Your feet have trampled the vegetation on this island. Please stay on the main wood-chipped trail”) was more effective in keeping visitors on formal trails than a non-attribution plea message. Winter (2006) found that a message with injunctive-proscriptive wording telling visitors what they should not do (“Please don’t go off the established paths and trails, in order to protect the Sequoias and natural vegetation in this park”) was more effective than prescriptive (encouraging positive behaviors) or descriptive (telling visitors what other visitors do) messages in deterring off-trail hiking.

The location of signs in relation to when decisions are made to hike off-trail has also been shown to be significant. Bradford and McIntyre (2007) found that 88% of visitors left the main trail when no sign was present; this percentage was not significantly reduced when a sign was placed at an information booth (87%), but a sign placed at the intersection of the informal and formal trails reduced the off-trail hiking rate to 65%.

Site management techniques, such as physical barriers and other site alterations, offer additional options for deterring off-trail hiking but a great majority of studies have focused on signage so there is little empirical evidence of site management efficacy. One common management practice is “brushing” - applying organic materials such as logs, branches, or organic litter, to physically deter hikers, to “hide” trails, or make them look less appealing. However, visitors who routinely use a trail or can still see it may remove obstructing brush, possibly thinking they are helping to maintain the trail. This was reported by Johnson et al. (1987), who also found that visitors dismantled brushings or circumvented them, prompting the creation of new trails that expanded the impacted area.

Various methods of fencing offer another site management option for effectively deterring informal trail use. Swearingen and Johnson (1994) study revealed a yellow rope barrier to be the most effective site management technique. This finding is supported by a recent study at Acadia National Park, which demonstrated that low fencing and signs located near informal trails were highly effective (Park et al., 2008), and by a Mt. Rainier National Park study that showed the presence of a uniformed employee and rope barriers to be the most effective treatment (Rocheftort and Gibbons, 1992).

Several studies have found the presence of a uniformed employee to be effective in deterring depreciative behavior (Widner and Roggenbuck, 2000; Ward and Roggenbuck, 2003; Swearingen and Johnson, 1995). For example, Swearingen and Johnson (1995) reported the use of uniformed personnel to communicate low impact behaviors to be highly effective, attributing that success to employment of the “peripheral route to persuasion” which relies on an authoritative source. They also note that while use of uniformed staff may be viewed as unnecessarily intrusive, that “visitors accepted the uniformed employee presence when there was a perceived need for such a management action

related to information dissemination, visitor safety and resource protection.” However, a study designed to decrease the feeding of wildlife in Zion National Park reported no difference in the efficacy of a message delivered by a uniformed park staff versus a sign, with both contributing to a 21% reduction in wildlife feeding (Marion et al., 2008).

Because people engage in off-trail hiking behaviors for a variety of reasons, we anticipate that individual techniques to discourage these behaviors may have varying levels of efficacy depending on visitor motivations. Therefore, integrating multiple methods into one coordinated management response will likely reduce off-trail travel more than any single method. Support for the use of multiple techniques was found in an Australian study on short-cutting, where a complete program of interpretive messages, the presence of a role model, and verbal appeals was most successful in reducing that depreciative behavior (Littlefair, 2004; Littlefair and Buckley, 2008). Similarly, Widner and Roggenbuck (2000), found that an interpretive sign incorporating multiple messages theoretically grounded in a range of behavior-change strategies was as effective as a uniformed presence in deterring the theft of petrified wood along park trails. In this study, the protection of many species of rare plants was the paramount management concern. In an effort to achieve the greatest possible reduction in off-trail hiking, we employed an additive research design that applied combinations of educational and site management techniques to deter off-trail hiking in a popular urban protected area.

3. Study area

Bear Island, a 39-ha tract of land, served as the study area for evaluating management strategies to reduce off-trail travel. The island lies within the Chesapeake and Ohio Canal National Historical Park (CHOH) in Maryland and is situated between the historic C&O Canal and the Potomac River within easy access (25 km) to Washington D.C. The total population of this metropolitan area was 5.6 million in 2010 (USCB, 2013), and in 2007 CHOH recorded 2.81 million recreational visits (USNPS, 2007). Co-owned and managed by the National Park Service and The Nature Conservancy, the island is home to over 50 of Maryland’s rare, threatened, and endangered plant and animal species (TNC, 2005). The well-known and popular Billy Goat Trail (BGT) traverses the island (also known as BGT-Section A) (Fig. 1). Extensive off-trail travel from the BGT, a strenuous 2.7 km hike known for its challenging rock scrambles and scenic views of the Potomac River Gorge, has resulted in the formation of 155 informal trails (16.1 km aggregate length) on Bear Island (Wimpey and Marion, 2011b). Prior efforts to limit off-trail hiking and close many of the more heavily used informal trails had been largely unsuccessful. Actions to block informal trails with brush (including large logs), educational signs, and fencing failed when visitors removed or vandalized those efforts.

4. Methods

4.1. Study design

The primary study objective was to empirically test the efficacy of an educational message, symbolic “no hiking” prompter signs, and site management actions in reducing off-trail hiking along the BGT on Bear Island. Park managers expressed strong concerns for the ongoing off-trail traffic threats to rare plants and the need for a management approach that protected rare plants while sustaining visitation. Because prior management efforts using brushing to close informal trails had failed, and research has shown that a combination of methods is often more effective than a single approach, we decided that an additive approach, instead of a

complete block design, was necessary to provide the park with the information they needed to maximize plant protection. We collaborated with park staff in designing this research as an adaptive management project that sought the most effective combination of management actions that would deter off-trail travel and be easily implemented with limited impact to visitor experiences. Four treatments, designed as additive and integrative with increasingly intensive management actions were compared against off-trail hiking rates in the Control or baseline condition.

4.2. Site preparation

Several site management actions were taken to establish a clear baseline (Control) condition and to minimize off-trail travel due to more easily preventable reasons prior to the beginning the study. Project staff and volunteers re-painted the existing blue blazes along the BGT and added blazes in confusing sections in an effort to minimize “accidental” off-trail hiking due to unclear formal trail markings. In order to ensure that visitors had ample opportunities to view the Potomac River and scenic gorge (one of the main hypothesized reasons for leaving the formal trail), park managers agreed to formalize six of 29 previously identified informal trails to informal vista sites (with white and blue blazes), based on the quality of the viewscape and geographic conditions that minimized trampling impacts and expansion potential (shown in Fig. 1 with camera symbols). Finally, all informal trails leading into Bear Island from the bordering canal towpath ($n = 9$) were blocked with symbolic fencing and marked with boot print “no hiking” signs. This was done to restrict access to the island to the three formal trailheads where visitors would be exposed to our trailhead treatments (educational sign or trail steward) (Fig. 1).

4.3. Intervention treatments

The first treatment (Signs) consisted of an educational sign placed at each of the three trailheads (Fig. 2) informing visitors of the impacts of informal trail use on Bear Island and asking them to stay on the formal paint-blazed trails. The sign text was developed using attribution theory (Bradford and McIntyre, 2007; Rees et al., 2005) to ascribe a sense of personal responsibility and make visitors aware of the consequences of off-trail hiking to rare plants (Schwartz, 1975; Van Liere and Dunlap, 1978). Injunctive-proscriptive wording was used as it has been shown to be the most effective in altering visitor behavior (Cialdini et al., 2006; Winter, 2006). A map (Fig. 1), showing the BGT and formal vista locations, was posted below the educational sign. In addition to the trailhead signs, symbolic “no hiking” prompter signs were screwed onto logs placed across every informal trail junction with the BGT ($n = 155$) (Fig. 3). These prompter signs clarified where it was not appropriate to hike and reminded visitors of the trailhead educational message. Attachment to logs instead of posts was used to: 1) include a symbolic physical barrier to accessing the informal trails, 2) keep the messages rustic in appearance and low to the ground to minimize “sign pollution,” and 3) reduce sign vandalism as small signs and posts are easier to remove and discard or hide.

In the second treatment (Brushing), small branches and organic litter (e.g., tree leaves or needles) were added to naturalize and camouflage the first 3–5 m of each informal trail; trailhead educational signs and informal trail prompter signs remained in place. Unlike other more common attempts to block a trail with large debris, the purpose of this brushwork was not to physically block the trails, but to remove the “releaser-cue” of seeing them (Gramann and Vander Stoep, 1987). A well-used informal trail suggests there is something worth seeing down it and that its use is acceptable since there are clear visual cues of continual use. We

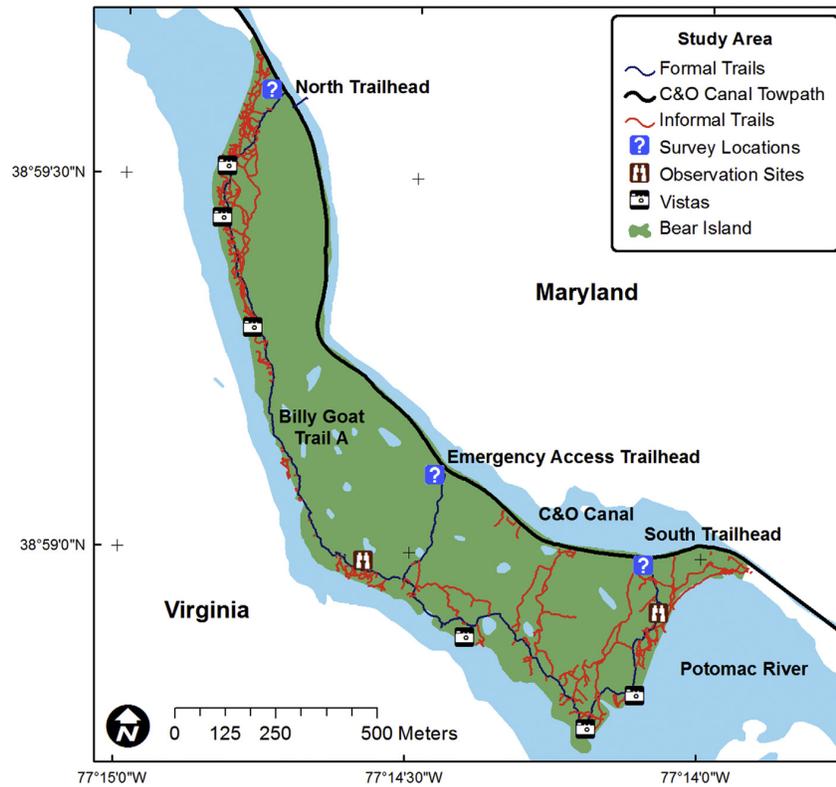


Fig. 1. Study area map of Bear Island located between the Potomac River and the C&O Canal. The Billy Goat Trail, Section A, is shown in blue, surrounded by the red informal (visitor-created) trails. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Please Do Not Leave Paint-Blazed Trails

Protect Our Rare Plants

<p>Your footsteps could be deadly:</p> <p>Over 50 rare species call this island home.</p> <p>Your off-trail footsteps have created miles of unofficial tracks that harm these species.</p> <p>Managers want to close and restore these tracks.</p>	<p>What you can do:</p> <p>Please do not leave paint-blazed trails.</p> <p>To protect rare plants everyone’s cooperation is needed.</p> <p>Even a few footsteps can prevent recovery.</p>
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Fig. 2. Trailhead educational sign placed at the three trailheads for the Billy Goat Trail.

intended the ‘light’ camouflaging work to somewhat hide the informal trails from hikers or at least make them appear to be little used and less attractive. This allowed visitors who were more motivated to use them to do so without removing brush or creating

additional paths around it (which would harm the rare plants these actions were taken to protect).

The third treatment (Restoration & Fencing) left the signs and brushing in place and added symbolic restoration sites to 14 of the



Fig. 3. Symbolic “no hiking” prompter sign of boot print superimposed with a red circle and slash secured to logs placed across informal trails adjacent to their intersections with the Billy Goat Trail (photo by author). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

more highly used informal trailheads, consisting of about 5 m of jute matting and organic material placed on the tread, a symbolic low rope fence (0.5 mm white nylon rope attached to 1.5 mm white fiberglass posts), and a restoration sign (Fig. 4). This treatment differs from the others because it was only applied to 9% ($n = 14$) of the informal trails. This strategy was employed to evaluate the



Fig. 4. Photo and sign illustrating the restoration treatments applied to 15 informal trails (photo by author).

efficacy of additional management practices that could be effective in closing high use informal trails that were expected to resist standard trail closure actions.

The fourth treatment (Personal Contact) was designed to compare the relative efficacy of the trailhead educational signs versus personal communication in conveying the awareness of consequences and personal responsibility messages. The trailhead educational signs were covered and the same educational message was conveyed to all hiking groups by volunteer trail stewards, who were in uniform and stationed at trailheads during this treatment. All other treatments remained in place (i.e., prompter signs, brushing, restoration sites).

Two complementary methods, a visitor survey and direct observation of off-trail hiking behaviors, were used to evaluate the efficacy of each treatment in reducing off-trail travel. Surveys were administered to hikers exiting the BGT from May 10, 2007 through June 10, 2007; unobtrusive observations of off-trail behavior occurred simultaneously. Each treatment and the Control were applied to two weekday evenings (4:30 p.m. to 7:30 p.m.) and two weekend days (10:00 a.m. to 7:00 p.m.), which were the busiest times of the day.

The seven-page visitor survey collected information on visitor demographics, trip characteristics, self-reported off-trail hiking behaviors, awareness of off-trail hiking impacts on rare plants, and opinions of alternative management actions for deterring off-trail hiking. Survey administrators wearing college T-shirts approached all exiting hiking groups during the sampling period and asked the adult (18 years and older) who had had the most recent birthday to participate.

In order to assess changes in off-trail hiking rates from self-reports, the survey instrument first described the difference between the paint-blazed “official” formal trails designated by managers, and “unofficial” (visitor-created) informal trails. Hikers were asked if they left the formal trails for any of 15 reasons (checking each one that applied). For example, respondents were asked if they left the formal trail to take a picture, to get around poor trail conditions (e.g. mud, rocky areas, etc.), to move past others on the trail, to get to a fishing spot, to view wildlife/birds, or accidentally because the trail was poorly marked (see Hockett et al., 2010 for a complete list). This approach was used because we believed visitors would be more willing to report reasons for going off-trail than if we asked them directly if they left the formal trail. We also thought they would more easily remember how many times they left the formal trail if asked to recall their behavior in the context of why they might have left the trail. For an additional measure of efficacy, visitors were also asked to indicate all reasons from a list why they chose on some occasions not to hike off-trail.

Visitor behavior was observed at two locations along the BGT. The specific observation sites were selected because they provided several characteristics for unobtrusive observation, including an elevated vantage point, high observer concealment, and multiple ($n = 5$) informal trails within each site’s viewing area. The symbolic restoration areas with fences were constructed at a higher use informal trail at each observation site during that treatment. Off-trail hiking behavior of each visitor was recorded for each informal trail and by direction of travel.

4.4. Data analysis

Before conducting statistical analyses to compare visitor survey responses across treatments, it was necessary to establish that respondents in the various treatments were similar. Chi-square analyses confirmed that gender proportions and educational attainment were similar among treatments; however, there were significant differences in age, group size, and the proportion who

had previously visited the BGT. Among the variables that showed differences, only age was found to be significantly related to off-trail hiking behavior, with the youngest visitors being more likely to report hiking off-trail ($\chi^2 = 11.451$, $p = 0.01$, $df = 3$). In order to eliminate the effect of age differences on the comparison of treatments, the data were weighted by age category so that each treatment would have a similar age distribution (Pike, 2007; Vaske, 2008).

Survey responses were input into an Excel spreadsheet and then imported into the SPSS statistical package for analyses. A Chi-square analysis was performed on each survey question to determine a significant difference among treatments. The Tukey's HSD test for post-hoc comparisons was used to determine statistical differences between pairs of treatments.

5. Results

5.1. Visitor characteristics

A total of 1205 surveys were completed, with a response rate of 66.0%. Respondents were 53.0% male, and most were well educated (39.2% had earned a Bachelor's degree and an additional 46.4% had advanced degrees). The majority of respondents (70.0%) were between the ages of 25 and 49; 15.0% were under 25, and 15.0% were 50 or older. Most survey respondents had hiked the BGT before (73.3%), and 41.2% reported hiking the trail 3 or more times in the previous 12 months. Many (43.7%) had first hiked the BGT more than 6 years ago (i.e., prior to 2001), so most hikers were familiar with the BGT.

The majority of BGT trail hikers were local residents; 76.7% traveled 30 min or less to reach one of the two main trailheads (calculated from home zip codes using the Network Analyst tool in ESRI ArcMap®). The vast majority of visitors hiked on weekends (92.2%), and most (69.6%) hiked the entire 2.7 km of the BGT. Most hiking groups were small, with about half hiking in pairs (49.0%), 25.5% hiking in groups of 3–4, and 15.1% hiking by themselves.

5.2. Observed off-trail hiking behaviors

The off-trail hiking behavior of 8045 hikers was recorded at the two sampling locations during 121 h of observation. Because the treatments differed in the proportions of hikers observed at each site and by direction of travel, an average off-trail rate was calculated for each treatment.

During the Control, an average of 25.9% of BGT hikers left the BGT within the two short observation sections (approximately 90 m total). The rate was significantly reduced to 6.5% following the

addition of the trailhead educational signs and prompter signs in the Signs treatment (Table 1). Off-trail hiking was reduced to 2.0% after the initial sections of informal trails were naturalized in the Brushing treatment. The Restoration & Fencing treatment did not further reduce the average observed off-trail rate; however, recall that this treatment was applied to only two of the 10 observed informal trails. No hikers were observed to use the two informal trails that received the Restoration & Fencing treatment, but the off-trail rate on those trails was already reduced to 0.5% from the Brushing treatment, so it was not possible to detect a statistically significant decline. No hikers were observed leaving the BGT at the observation sites during the Personal Contact treatment, but this result should be treated with caution because unanticipated staffing problems resulted in only 55 hiker observations for this treatment (Table 1).

Observers not only documented the use of existing informal trails within the study sites but also kept track of visitors who walked off-trail at locations other than informal trails within the two observation zones. Because of the risk to rare plants, management actions were designed to deter but not prevent use of informal trails to minimize the chance that adjacent duplicate trails would be created by visitors who nonetheless choose to go off-trail. This strategy was successful, with cross-country off-trail rates declining even as the prompter signs, brushing, and restoration areas were added (Table 1).

5.3. Self-reported off-trail hiking behaviors

Each hiker was categorized as never leaving the BGT, only leaving it "accidentally because the trail was poorly marked," or as intentionally leaving the trail for at least one of 15 potential reasons; these categories are mutually exclusive.

During the Control, 70.3% of hikers reported leaving the BGT intentionally for at least one reason, which is considerably higher than the observed off-trail rate (Table 1). This is likely because hikers were considering their entire hike for the survey, during which they had the opportunity to leave the BGT on any of 155 informal trails (or anywhere else), as compared to the subset of 10 informal trails located within the observation areas. Unlike the findings of the observation component, there was no reduction in self-reported off-trail hiking during the Signs treatment (off-trail rate = 70.6%) (Table 1). The Brushing and Restoration & Fencing treatments significantly reduced off-trail hiking to 60.2% and 58.6%, respectively. The final and most comprehensive treatment, which used Personal Contact to convey the covered trailhead educational sign message was the most effective, reducing self-reported off-trail hiking to 43.0% (Table 1). The proportion of visitors in the

Table 1
Self-reported and observation reported off-trail rates.

Evaluation method	Control	Signs	Brushing	Restoration & fencing	Personal contact
Observed ^a					
Sample size	2527	2461	2239	763	55
Off-trail rates (%)	25.9 ¹	6.5 ²	2.0 ³	2.0 ³	0.0
Cross-country rate (%) ^c	1.3	1.1	0.5	0.7	0.0
Self-reported ^b					
Sample size	294	257	270	161	159
Intentional off-trail rate (%)	70.3 ¹	70.6 ¹	60.2 ²	58.6 ²	43.0 ³
Only went off-trail accidentally (%)	4.2	4.0	4.2	2.5	8.9
Never left the trail (%)	25.5	25.4	35.6	38.9	48.1

^a $\chi^2 = 889.0$, $p < 0.001$, $df = 3$ (not including Personal Contact treatment because of a small sample size). Rates with different superscripts are significantly different ($p < 0.05$).

^b $\chi^2 = 41.4$, $p < 0.001$, $df = 8$; The Chi-square test combined "never left the trail" and "only left accidentally" categories. Rates with different superscripts are significantly different ($p < 0.05$).

^c Percentage of visitors who walked off-trail at locations other than informal trails within the observation zones. This percentage is included in the total off-trail rate figure located above it.

Personal Contact treatment who said they only hiked off-trail accidentally was slightly higher than the other treatments, which might suggest a social desirability bias against reporting off-trail travel because of their contact with the steward. Nonetheless, the percentage of visitors who indicated they hiked off-trail accidentally “because the trail was poorly marked” remained similar (ranging from 34.3% in the Signs treatment to 27.8% in the Personal Contact treatment).

5.4. Visitor attitudes and beliefs about off-trail hiking

Survey respondents were asked a series of questions to measure the efficacy of the educational message (Fig. 2) in informing visitors about the negative consequences of off-trail travel along the BGT and encouraging a sense of personal responsibility to stay on the formal trails. Despite 70.3% of Control hikers reporting that they hiked off-trail at some point along the BGT, only 30.4% agreed that it was acceptable to leave the paint-blazed trails, even if visitors stayed on unofficial trails already created by other visitors (Table 2). That number was reduced to 17.8% after the trailhead educational signs and prompter signs were added and to 5% when the educational message was received from a volunteer trail steward.

It is not possible to directly separate the impact of the trailhead educational message vs. the prompter signs because they were applied at the same time. However, the trailhead educational signs failed to significantly increase the percentage who agreed with more specific awareness-of-consequences information contained in the message over the Control, including “there were many rare plants along the BGT,” “there was an extensive network of informal visitor-created trails on Bear Island,” and “even limited use of those trails would have adverse impacts” (Table 2).

Delivery of the message on the trailhead educational signs by trail stewards was more effective in changing off-trail hiking attitudes and beliefs. A direct comparison of the efficacy of the sign vs. personal communication can be made by comparing the Fencing & Restoration treatment to the Personal Contact treatment because the only difference in those two treatments was delivery method. Fewer in the Personal Contact treatment (5.1%) felt it was “acceptable to walk off the paint-blazed trails, if visitors stay on the unofficial trails created by other visitors,” compared to the Fencing & Restoration treatment (12.5%). The trail stewards also achieved a significant increase in the percentage of visitors who agreed that

the continued use of unofficial trails was a serious threat to rare plants over those receiving the message from the educational trailhead signs (79.2% vs. 57.4%).

Another goal of the educational message was to instill a sense of personal responsibility and commitment to protect the natural resources along the BGT (Fig. 2). Even in the Control, the vast majority of respondents (81.0%) indicated feeling responsible for the care of the BGT, and helping to protect the special plants along it (88.5%) (Table 2). The majority of hikers during the Control also indicated they were willing to stay on the trails to protect rare plants (90.5%). The trail stewards tended to be more successful than the educational signs in increasing a sense of personal responsibility, but the differences were often not statistically significant, in part due to the relatively high level of agreement with the statements already present in the Control (Table 2).

An additional measure of message and treatment efficacy is to consider reasons visitors chose not to hike off-trail. In the Signs treatment, 61.3% indicated they chose not to hike off-trail because they didn’t want to step on any rare plants by mistake, a reason given in the educational message (Table 3); the percentage increased to 87.7% among respondents who heard the educational message from trail stewards. Nearly three-quarters (74.8%) said they chose not to hike off-trail at some point because of the symbolic “no hiking” signs, that were located at each informal trail junction. Overall, 61.2% indicated they chose not to hike off-trail because they “could see that the park had tried to re-naturalize off-trail areas with brush and leaves” when the Brushing treatment was added, but the brushing was relatively subtle and may not have been noticed. There was a gradual and in most cases significant trend for more respondents to indicate they chose to stay on the formal trail for each of the reasons listed as management actions were added (Table 3).

5.5. Acceptability of management actions

Because of the extensive nature of the treatment interventions we asked hikers to express the acceptability of our treatments and other potential management actions to reduce off-trail hiking. The majority of visitors, averaged across treatments, were supportive of educational signs “about the damage that can be caused by walking off-trail on rare plants” (79.2%), “no hiking” signs posted at unofficial trails (76.4%), “blocking unofficial trails with brush and logs”

Table 2
Message effectiveness in communicating the impacts of off-trail travel and instilling a sense of personal responsibility.

Awareness of consequence statements	Agree (%) ^a				
	Control (n = 288)	Signs (n = 246)	Brushing (n = 263)	Restoration & Fencing (n = 158)	Personal Contact (n = 154)
It is acceptable to walk off the paint-blazed trails, if visitors stay on the unofficial trails already created by other visitors. ^{b **}	30.4 ¹	17.8 ²	16.2 ³	12.5 ²³	5.1 ⁴
Visitors have created many miles of trails on Bear Island	34.2	41.7	32.7	34.6	43.4
Even limited use of visitor-created trails can prevent their recovery.*	60.8 ¹²	54.7 ¹²	67.3 ¹	64.8 ¹	72.7 ¹
There are many special and rare plants that live near the BGT.	39.7	41.2	45.4	41.6	57.0
The continued use of unofficial visitor-created trails is a serious threat to rare plants along the BGT.**	49.2 ¹	59.7 ²	61.3 ²	57.4 ¹²	79.2 ³
Ascription of Responsibility Statements					
I feel responsible for the care of the BGT.	81.0	78.2	79.3	81.9	86.7
I feel a responsibility to help protect the special plants and ecosystems along the BGT.	88.5	84.4	88.3	88.3	89.9
I am willing to stay on the paint-blazed trails to protect rare plants.	90.5	91.0	90.8	90.1	96.9
The soils and plants along the BGT should be protected even if visitors are not allowed to explore off trail.*	82.1 ¹	85.9 ¹	86.8 ¹²	83.2 ¹	93.7 ²
I am willing to give up hiking or running in some areas of Bear Island in order to protect rare plants	77.7	80.9	79.9	77.9	90.6

^a % Agree category includes individuals who “agreed” and “strongly agreed” to each statement on a 5-point Likert type scale.

^b Chi-square test significance levels. *p < 0.05; **p < 0.001. Pairwise comparisons were conducted on significant items; percentages with different superscripts are significantly different (p < 0.05). The tests compared the percentage who agreed, were neutral, and disagreed with the statements.

Table 3
Reasons for not hiking off-trail by treatment.

I chose not to hike off an official paint blazed trail because ...	Agreed (%)					χ^2	p
	Control (n = 282)	Signs (n = 247)	Brushing (n = 260)	Restoration & fencing (n = 158)	Personal contact (n = 155)		
General							
I had no reason to hike off-trail	73.7	69.8	77.5	81.4	75.3	8.193	0.085
I didn't want to cause any soil erosion or compaction	49.6	65.6	67.0	73.2	87.1	66.940	<0.0005
Sign Related							
of the signs with "no hiking" symbols	N/A	74.8	80.8	82.9	86.4	9.062	0.028
I didn't want to step on and damage any rare plants by mistake	47.0	61.3	67.2	75.8	87.7	83.108	<0.0005
It is not fair for me to walk off the paint-blazed trails when many other visitors don't	35.7	45.5	54.8	58.7	62.7	41.337	<0.0005
Brushing Related							
I could see the park had tried to re-naturalize off-trail areas with brush and leaves	N/A ^a	N/A ^a	61.2	N/A ^a	N/A ^a	N/A	N/A
Personal Contact Related							
I was afraid I would be reprimanded or confronted by a trail steward	3.9	8.5	10.8	11.4	17.4	22.960	<0.0005

^a This question was only asked on surveys during the "Brushing" treatment.

(76.7%), and "the restoration of unofficial, non-blazed trails to an undisturbed state" (80.6%), regardless of treatment or Control conditions. Interestingly, support grew for the prompter signs, brushing unofficial trails, and using trail stewards to ask visitors to stay on the BGT as those interventions were applied to the trail (Table 4). Not only did 69.7% of the hikers find it acceptable to have the trail steward intervention during the Personal Contact treatment, but these contacts with the stewards also increased the proportion who found it acceptable to have rules against off-trail hiking and increased ranger presence along the trails (Table 4). Few in any treatment (22.8%–35.9%) supported having a monetary fine for hiking off-trail.

6. Discussion

6.1. Treatment efficacy

During Control (baseline) conditions a majority of visitors (70.3%) reported that they hiked off-trail at least once during their BGT hike (Table 1). Observed off-trail rates (25.9%) were lower than self-reported rates because visitors were only observed along two short BGT segments, while survey respondents were reporting on their entire hike. Both methods provide valuable insights and

complement each other, providing a more complete characterization of treatment efficacy. Observations provide site-specific data that are presumably accurate and precise, but use of individual informal trails was highly variable, so results may not be generalizable to all trails or situations. Surveys provide more comprehensive information on treatment efficacy because they consider the entire hike. Still they rely on self-reported behaviors, the accuracy of which depends on a subject's willingness to be truthful and their ability to recall their actions and to differentiate between formal and informal trails. However, surveys have the added advantage of providing a variety of other useful data, including information on motives and measurement of the persuasive ability of the treatments to influence beliefs and attitudes. This information can provide valuable insights into the mechanism by which the treatments acted to alter behaviors.

Direct visitor observations attributed the most substantial reductions in off-trail hiking to the Signs and Brushing treatments (Table 1) with off-trail rates remaining very low in the Restoration & Fencing and Personal Contact treatments. The survey self-report data attributed the most substantial reduction in off-trail hiking to the Personal Contact treatment, followed by the Brushing and Restoration & Fencing treatments, with no effect attributable to the Signs treatment (Table 1). We believe the two findings do not

Table 4
Hiker perceptions of the acceptability of potential management actions that could be taken to reduce off-trail travel along the BGT by treatment.

Potential management action	Finding action acceptable (%) ^a				
	Control (n = 277–296)	Signs (n = 246 –257)	Brushing (n = 261–271)	Restoration & fencing (n = 159–161)	Personal contact (n = 153–158)
Educational signs along the trail about the damage that can be caused by walking off trail on rare plants	80.7	79.4	77.5	76.4	81.8
Signs directing visitors to remain on the official paint-blazed trails	77.7	81.6	78.1	75.2	79.5
Restoration of unofficial, non-blazed trails to an undisturbed state	75.4	80.2	82.6	82.5	85.4
"No Hiking" signs posted at unofficial, non-blazed trails ^{b***}	68.5	77.4	79.3	78.3	82.8
Blocking unofficial trails with brush and logs ^{***}	65.7	79.3	82.8	78.0	81.0
Improve trail conditions (eliminate mud, downed trees, etc.)	59.3	62.4	67.8	70.2	67.7
Rules prohibiting visitors from hiking off of the official paint-blazed trails ^{**}	56.7	66.1	67.2	66.7	72.8
Volunteer trail stewards asking visitors to stay on official paint-blazed trails ^{***}	47.3	52.5	57.8	57.8	69.7
Increased ranger presence along trails ^{**}	45.1	47.5	53.8	52.8	65.4
A monetary fine for visitors who walk off the official paint-blazed trails ^{**}	22.8	23.5	35.9	34.2	33.8

^a Response scale ranged from 1=Unacceptable to 5=Acceptable; % Acceptable combined respondents answering a 4 or 5 on the scale.

^b Chi-square test significance levels. *p<0.05; ** p<0.01; ***p<0.001.

conflict and in fact, highlight the utility of employing both observation and survey assessment methods. Observations indicated Signs and Brushing reduced traffic significantly on some (and perhaps most) informal trails, but surveys confirmed considerable off-trail travel continued on at least some other informal trails along the 2.7 km BGT. Because off-trail rates declined to such low rates in the observation sections, observations were unable to detect further reductions as later management actions were added. In contrast, the survey showed that the Personal Contact treatment was the most effective in reducing off-trail travel across the entire study area.

To summarize, while Signs and Brushing achieved a significant reduction in off-trail travel, more complete compliance was only achieved when all site management actions (Brushing and Restoration & Fencing) and prompter signs were in place and the trailhead educational message was orally delivered to all hiking groups (Personal Contact). This finding corroborates with past research that utilized the personal contact approach (Rocheffort and Gibbons, 1992; Swearingen & Johnson, 1995; Ward and Roggenbuck, 2003; Widner and Roggenbuck, 2000). Additional evidence that substantial reductions in the number of off-trail excursions occurred even when the majority said they hiked off trail at least once is in the responses to the question about why one decided not to hike off-trail (Table 3). As the treatments were introduced, a majority of visitors indicated that action caused them not to hike off-trail, at least in some situations. We believe visitors continued to hike off-trail only when strongly motivated to do so, but the message, prompters, brushing, and restoration areas reduced the number of times visitors left the trail.

6.2. Evaluation of individual treatments

The Sign treatment was composed of both an educational message delivered by a large sign at each trailhead and 155 symbolic “no-hiking” prompter signs located at each formal trail/informal trail junction. Because both were added at the same time it is not possible to directly compare the contributions of each component in reducing off-trail hiking, but survey results suggest that the trailhead educational signs had little impact in reducing the off-trail hiking rate. Agreement with statements taken directly from the educational sign barely increased from Control levels after placement of the educational signs (Table 2). A more dramatic shift in agreement levels occurred when trail stewards delivered the same message. This suggests that while the injunctive-proscriptive message was persuasive it may simply not have been read by a majority of visitors. In fact, previous studies have shown that the majority of visitors do not often read trailhead signs (Cole, 1987; Park et al., 2008). We note that although trailhead signs were placed less than 1 m from the formal trail at locations with single file traffic to maximize their reading rate, such placement appears to have had little effect. The tendency of visitors to not read signs might be especially true of BGT hikers, who tend to be repeat visitors who have hiked the trail many times and do not require signs to orient themselves.

The symbolic “no hiking” prompter signs could have reduced off-trail hiking for several reasons that we are not able to differentiate in this study. Firstly, they serve the purpose of clearly defining the formal trail for those who might be confused about which path to take when confronted with an informal trail junction. The prompter signs clearly and succinctly informed visitors not to travel on the informal trails. For visitors who had read the trailhead educational signs, they served as a reminder and clearly defined what the park meant by an informal trail (Bradford and McIntyre, 2007; Park et al., 2008).

Both evaluation methods found a significant decline in off-trail

hiking following light brushing (the Brushing treatment) (Table 1). We suggest that naturalizing the initial portions of an informal trail effectively reduces the “releaser cue” that a well-used trail represents (Gramann and Vander Stoep, 1987) by providing a subtle visual cue that the trail is lightly used (so it must not lead to an interesting destination). When also combined with the prompter signs and log barriers, this treatment may also help to establish or reinforce a norm that off-trail travel is unacceptable behavior along the BGT.

Neither evaluation method found a significant reduction in off-trail hiking from the Restoration & Fencing treatment (Table 1). We had intended to rely on observation data to evaluate this treatment because only 14 of the 155 informal trails were treated. One higher use informal trail was treated at each observation site. However, the preceding Signs and Brushing treatments had already reduced the use of these two trails to just 11 of the 2239 hikers observed in the Brushing treatment. While the Restoration & Fencing treatment eliminated all use on these two trails, the difference was too small to be statistically significant. While it would have been better to test the efficacy of this management action to fence and restore all trails, doing so would have substantially altered visitor hiking experiences and park staff decided that this was an unrealistic and unsustainable action given the large number of informal trails (N = 155). Regardless, we believe this treatment is a highly effective practice, particularly for higher-use informal trails that land managers have difficulty closing. However, it should be used with caution as a short fence could prompt the creation of new paths around it (Johnson et al., 1987).

An unanticipated staffing shortage that led to a low sample size combined with the already reduced off-trail rates at the observation sites in the Restoration & Fencing treatment focused our evaluation of the Personal Contact treatment to the survey data. These data suggest that the Personal Contact treatment (which included all preceding treatments) was the most successful in reducing off-trail travel. We attribute the substantial drop in self-reported off-trail rates, from 58.6% to 43.0%, to three sources. Most importantly, nearly all respondents in this treatment received the educational message on the day of their hike. Secondly, some studies have found that verbally communicated messages are more effective than sign or text-based messages (Fazio, 1979; Oliver et al., 1985). Personally delivered messages likely have a greater impact and ensure that visitors hear all parts of the message, with an opportunity to discuss or clarify components that are not well-understood. Survey results support both of these possibilities. The Personal Contact treatment had the greatest number of hikers agreeing to the awareness of consequences statements from the message content (Table 2). Visitors who received the message from trail stewards also were more likely to find management actions to reduce off-trail travel to be acceptable. This suggests that the personal nature of the communication did more than simply convey facts; it may also have served to convey the importance of the message and issue because someone was making the effort to personally reach out to visitors.

Study treatments were less successful in addressing “accidental” off-trail hiking due to poor formal trail marking. This was a surprising finding given that BGT paint blazes were refreshed prior to the study, with many blazes added to clearly mark the trail for both directions of travel. Treatment prompter signs, logs, and brushing further clarified the BGT’s alignment and where one should or should not go. We believe this finding suggests that what constitutes “overblazing” to park managers and trail maintainers may yet be insufficient to many urban visitors who may be less experienced at following primitive native-surfaced trails. It is likely that the challenging rocky areas caused visitors to spend more time focused on their footing than looking for blazes.

A Blue Ridge Parkway study investigating the use of heavy “obstruction” type brushing (without signs) to close informal trails that threatened rare plants documented continued visitor use, visitor removal of brush, and circumvention of the brushed sections, which created new parallel trails in rare plant habitats (Johnson et al., 1987). As noted, our intent was to naturalize and hide, not physically obstruct traffic, on informal trails if visitors chose to use them. Observations confirmed that our strategy was successful because the cross-country hiking rate did not increase as brushing and fencing was added (Table 1).

6.3. Integrating education and site management

Most previous studies have investigated alternative educational messages or message delivery methods for their influence on visitor behavior. After initial site visits, consideration of off-trail hiking motives and behaviors in the study area and findings from past research (e.g., Park et al., 2008), we concluded that efficacy could be enhanced by integrating educational and site management actions. Visitors are less likely to ignore a sign (and its message) when it is combined with site manipulations, such as a log or low fence that symbolically blocks access to the trail, or light brushing that camouflages the trail. Similarly, as shown by Johnson et al. (1987), visitors may fail to see or misunderstand the meaning of those same site management actions if placed without signs that communicate management intent or rationales.

These considerations were addressed in this study by thoroughly integrating educational and site management actions. Every site management action was accompanied by a sign, and we sought to link the signs to one another by incorporating the boot print with the universal red circle and slash symbol on all three signs. Our intent was to tie site management actions and trailside signs back to the trailhead educational signs, which were sufficiently large to communicate a more compelling behavioral plea and rationale message (Figs. 2 and 3). The core theme of this interpretive message was that visitors were harming rare plants by travelling off-trail and creating many kilometers of informal trails that managers sought to close and restore.

6.4. Costs and benefits of treatments

Managers must weigh the costs and benefits of various treatment options when deciding upon the strategy to employ to reduce off-trail hiking rates. The protection of rare or endangered resources and the conservation importance of the impacted resource will likely influence the aggressiveness of the management action taken. Other considerations include cost to the managing agency (material, personnel, cost-share with local stakeholders) and cost to visitor experiences. Ideally, through adaptive management and local partnership, managers would be able to identify and implement the least costly management action that reduces off-trail travel to acceptable rates necessary to protect the resource.

A concern of this study was the potentially negative impact on visitors' experiences from the extensive signs and site management practices that the treatments employed. However, survey results revealed that visitors were highly supportive of both interpretive and symbolic signs, and brushing and restoration site management practices (Table 4). Support actually grew with the addition of symbolic “no hiking” signs (68.5%–77.4%) and logs and brushing (65.7%–82.8%) to the 155 informal trail intersections, and remained high for the remaining treatments. Although managers have not considered rules prohibiting off-trail hiking, visitor support for such a regulation grew from 56.7% to 72.8% over the course of the study. Visitor support for trail stewards, who had traditionally enforced rules along the BGT, also grew from 47.3% to 69.7%,

revealing support for an enhanced public contact and educational role for these staff. These findings are very similar to those of Park et al. (2008) who also noted that support grew as they experienced the management practices employed during the study. All these changes in hiker's perceptions of the acceptability of management actions were found to be significant, trail stewards having the biggest effect (22.4%). This is followed by blocking unofficial trails by brushing (17.1%), applying rules for prohibiting of trail hiking (16.1%), and “no hiking” signs (8.9%).

Other potential costs are the time and materials necessary to maintain the signs, prompters, brushing, restoration sites, and personal communication efforts. While beyond the scope of this paper, we did document the volunteer efforts and materials necessary to maintain the brushing, prompter signs, and restoration sites throughout the study and remainder of the summer. These data have been reported elsewhere (Widman, 2010).

The critical question remaining is: How much off-trail hiking can be allowed in order to protect the critical resource? In other words, do the most effective treatments reduce informal trail use to levels that permit natural resource recovery (Marion and Reid, 2007)? Recreation ecology trampling studies consistently reveal that trail formation occurs with relatively low levels of traffic, and that once created, such trails persist over time unless nearly all traffic is removed (Bayfield, 1979; Cole, 1987, 1995). These studies also reveal the importance of other factors related to recovery, including vegetation and soil type, sunlight exposure, and climatic factors. To address this concern, we assisted park managers in continuing the Brushing treatment (including trailhead and prompter signs) for an additional year to investigate actual changes to informal trail conditions. Preliminary data from this companion study reveal a 21% reduction in the lineal extent of the informal trail network, and a 29% reduction in the total area of disturbance following the first year of implementation. Data from a representative sample of informal trail transects reveal decreased trail width and soil exposure, and increased organic litter and vegetation cover (Widman, 2010). Based on these collective findings park managers permanently implemented these treatments.

Overall, survey data indicate that the additive treatments reduced intentional off-trail hiking along the entire trail from 70.3% to 43.0% (Table 1). Many visitors continue to hike off-trail, although observation data suggest the number of times each did was reduced. While 43.0% of visitors continue to hike off-trail intentionally (and 8.9% accidentally), that could mean a single off-trail excursion during a 2.7 km, 2-h hike. This contention is supported by the observed off-trail rate that fell from 25.9% in the Control to 2.0% in the Brushing and Restoration & Fencing treatments. This suggests that the off-trail travel was largely eliminated except on the most commonly used informal trails.

Off-trail rates along the BGT in the Control are in the range of those reported in other studies, but the self-reported overall rate (43.0%) and observation site rate ($\leq 2.0\%$) achieved by the combined site management and educational messages were lower. For example, the majority (88.3%) of visitors to Camelot Island in the St. Lawrence Islands National Park, Ontario, were observed to hike on an informal trail (Bradford and McIntyre, 2007); this rate was reduced to 45% when a sign was placed at the junction of the formal and informal trails. In a front-country site, 30.9% of visitors were observed hiking off trail at four locations along a paved trail winding through a Giant Sequoia grove in Sequoia and Kings Canyon National Parks (Winter, 2006); an injunctive-proscriptive message similar to ours reduced the off-trail rates from between 31% and 5%. Park et al. (2008) observed that 73.7% of visitors to Cadillac Mountain in Acadia National Park hiked off-trail. A trailhead educational sign combined with symbolic “no hiking” prompter signs at informal trail junctions reduced off-trail hiking

from 74% to 24% (Park et al., 2008). These studies and our results illustrate that educational messages can significantly reduce, but not eliminate off-trail travel. None of these studies employed light brushing or restoration sites, other key components to achieving the off-trail reduction seen in this research. Based on the results of this study we conclude that trailhead signs with injunctive-proscriptive and attribution wording, combined with prompter signs and brushing at the sites where most off-trail hiking decisions are made, are an effective management program for deterring off-trail hiking. Efficacy is significantly improved when educational messages are communicated in person.

7. Research implications and conclusions

Off-trail hiking impacts remain a significant issue in many protected natural areas, and additional research evaluating the efficacy of both educational and site management actions are needed. In particular, evaluations are needed to examine the relative efficacy of alternative educational and site management actions, and of their combined effects. We highlight the efficacy and benefits of implementing combined treatments applied in an adaptive management program, and suggest this topic for additional research. As applied in this study, the combined educational and site management treatments significantly reduced observed off-trail hiking from 25.9% to 2.0% and visitor reported off-trail hiking from 70.3% to 43.0%. Park staff have continued all treatments, though staffing limitations have prevented as thorough an implementation as occurred during the study. The park continues to rely on the assistance of volunteers, such as those provided by the Potomac Appalachian Trail Club, to implement the site management actions and to convey messages to hikers during their regular patrols (though not at the trail-heads). Experience has supported the practice of attaching the symbolic “no-hiking” signs to logs, which visitors may shift to the trailside but are easily moved back by volunteers. Unfortunately, floods have periodically carried away some of these, which are not always replaced. Hiding the initial visible sections of informal trails with organic litter has also been an efficient and effective practice.

Variations in off-trail observation rates for individual trails and survey data suggest that off-trail travel is not random but based on motivations to achieve recreation-related goals. A deeper understanding of off-trail hiker motivations is needed to develop more effective and targeted interventions, which likely vary between protected areas. Another largely unexplored issue is the identification of any unique characteristics of urban protected areas or visitors to those areas that would suggest fundamentally different strategies to reducing off-trail hiking than what has been developed in more natural settings. For example, urban users may view a nearby park simply as a place to exercise outdoors instead of as a nationally significant resource set aside for its ecological significance. The large number of repeat and frequent users to urban protected areas also may limit the ability of managers to alter existing behaviors as past experience tends to solidify attitudes (Petty and Cacioppo, 1986; Schreyer et al., 1984). These factors present challenges to controlling off-trail travel that may require methodologies untested in other areas where visitors might be more receptive to management pleas to stay on formal trails.

Finally, efficacy in behavior change studies is commonly evaluated through self-reported or directly observed behaviors. We applied both evaluation methods and found each method contributed significant insights to the understanding of the research problem. Each method also had its weaknesses and we would have drawn very different conclusions on treatment efficacy if only one method had been used. We suggest further experimentation to compare both evaluation methods. Furthermore,

managers are primarily interested in achieving measurable improvements in protecting natural resource conditions, yet behavior modification studies very rarely include evaluations of coincidental resource change (Marion and Reid, 2007). Where possible, evaluation of resource changes could also be incorporated into behavior modification studies to provide a more comprehensive evaluation of their efficacy and management utility.

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