

Research Article

Invasive plant hitchhikers: Appalachian Trail thru-hiker knowledge and attitudes of invasive plants and leave No trace practices

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ABSTRACT

Hiking and backpacking on American National Scenic Trails has increased in popularity in recent years. To encourage responsible and sustainable outdoor recreation on these much-loved trails, direct and indirect management strategies must be employed by managerial agencies. The Leave No Trace (LNT) education program aims to protect natural resources by promoting minimum-impact behaviours that lessen environmental impacts. The accidental introduction and dispersal of non-native invasive flora by hikers is little studied but can have a detrimental environmental impact on protected areas. The purpose of our study was to understand whether Appalachian Trail thru-hikers are: 1) aware of this problem, 2) adhering to LNT principles to reduce this problem, and 3) willing to learn and adopt minimum-impact behaviours to address this problem. We found that thru-hiker knowledge of invasive plants was limited and that very few thru-hikers adopted low-impact practices to minimise plant introduction and spread. Promisingly, we found that most thru-hikers, once aware of the problems, were willing to learn and apply low-impact practices to minimise plant introduction and spread. We discuss the barriers to their adoption of these behaviours and present a comprehensive list of suggested LNT practices to limit invasive plant introduction and spread. We conclude that, whilst challenging, protected area managers can help deter the spread of invasive plants along trails by improving educational messaging, signage, personal communication, and providing supporting infrastructure that encourages visitors to adopt specific practices to minimise invasive plant introduction and spread within protected areas.

Management implications:

- Protected areas and trail systems worldwide are threatened by human-mediated, non-native plant invasion.
- Most Appalachian Trail (A.T.) thru-hikers generally lack the knowledge and resources to identify invasive plants.
- Few A.T. thru-hikers understand the connection between brushing footwear and managing invasive plants, and even fewer are aware of the various low-impact practices targeting invasive plant introduction and dispersal.
- Along the A.T., information on plant invasion problems and associated low-impact practices is minimal, inconsistent, and only superficially included in most core Leave No Trace (LNT) messaging efforts.
- Public awareness about low-impact practices is a useful tool in invasive plant management. A.T. managers need to better inform visitors about the full range of specific practices they could adopt to reduce invasive plant introduction and spread, e.g., through educational messaging, signage, personal communication, and providing supporting infrastructure.

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1. Introduction

Increasing visitation to protected areas (PAs) and parks worldwide is an ever-present conundrum for managers who must balance natural resource protection and recreation provision (Backman et al., 2018; Marion & Reid, 2007). Recreational trails, including formal and informal visitor-created trails, represent a common type of infrastructure in PAs (Pickering & Norman, 2017; Wimpey & Marion, 2011). Intensified use of these extensive networks, especially informal trails, causes some degree of measurable degradation to PA resources, such as trail erosion, soil compaction, and vegetation trampling (Marion, Leung, Eagleston, & Burroughs, 2016; Marion & Wimpey, 2017; Pickering & Norman, 2017; Rankin, Ballantyne, & Pickering, 2015).

1.1. Invasive plants

One of the most understudied yet detrimental impacts of recreation is the human-mediated passive introduction and dispersal of non-native invasive flora into PAs, often from visitors accessing areas with trails either on foot, horseback, or vehicle (Eagleston & Marion, 2018; Marion et al., 2016; Wichmann et al., 2009). The names used to describe species introduced to a novel area resulting from human behaviours are numerous, including, but not limited to 'exotic', 'alien', 'weed', 'introduced', and 'invasive' (Head, 2017). Here we use the term *non-native invasive plant species* (NNIPS). NNIPS threaten biodiversity and present a ubiquitous environmental management challenge that is exacerbated by socioeconomic globalisation and climate change (Head, 2017; Hulme, 2009). Such threats are magnified in PA trail systems due to high visitation frequencies and areas of concentrated disturbance (Allen, Brown, & Stohlgren, 2009). Visitors can be transportation agents of NNIPS, with propagules or seeds unintentionally attached on clothing, gear, and lodged in shoe or bike and vehicle tyre treads (Anderson, Roccliffe, Haddaway, & Dunn, 2015; Ansong & Pickering, 2014). Concurrent with expanding types and amounts of PA visitation is the further expansion of extensive trail networks that may promote further introduction and dispersal of NNIPS within PAs. This challenges PA managers to prioritise and enact measures to reduce these recreation impacts.

1.2. Leave No trace

Strategies employed to encourage responsible recreation in PAs can be either direct (e.g., regulations and site management) or indirect (e.g., education and communication efforts) (Marion et al., 2016; Marion & Reid, 2007). In the United States (U.S.), indirect methods are generally the preferred choice by managers and visitors (Vagias, Powell, Moore, &

Wright, 2014). The U.S. Leave No Trace (LNT) Center for Outdoor Ethics is the overarching education provider that aims to educate outdoor visitors about their potential resource and social impacts, communicate and promote adoption of low-impact practices and ethics, and enhance the sustainability of outdoor recreation (Marion, 2014; www.LNT.org, 2021). In 1994, federal land managing agencies including the U.S. Forest Service (USFS), National Park Service (NPS), Bureau of Land Management (BLM), U.S. Fish and Wildlife Service (USFWS), along with the National Outdoor Leadership School (NOLS), signed a Memorandum of Understanding (MOU) with the LNT program ensuring federal agency implementation of LNT (Marion & Reid, 2001). LNT information is distilled into seven concise principles (Fig. 1) which is communicated through websites, courses, and media (e.g., brochures, hangtags, and signage).

Hiking in the U.S. has risen in popularity in recent years (Outdoor Foundation, 2022), rating hiking as the second most common recreational activity with 58.7 million participants. Backpacking has also increased substantially, from 6.6 million in 2007 to 10.3 million in 2021. Furthermore, the COVID-19 pandemic caused outdoor recreation participation across the U.S. to surge by approximately 20% in 2020 (Landry, Bergstrom, Salazar, & Turner, 2021; Rice et al., 2020; Taff, Rice, Lawhon, & Newman, 2021). The internationally recognised Appalachian National Scenic Trail (A.T.) in the eastern U.S. receives an estimated three million hikers annually (Appalachian Trail Conservancy (ATC), ATC (2022)). Of these, almost four thousand individuals attempt to *thru-hike* the entire trail in a continuous journey within one calendar year, with only about one in five achieving this. Rising annual footfall (from thru-, section-, and day-hikers) places the A.T. corridor under greater strain, with trail degradation becoming evident despite the growing awareness and use of LNT low-impact practices among visitors (Marion et al., 2016, 2020; Meadema, Marion, Arredondo, & Wimpey, 2020).

1.3. A.T. Case study

Originally envisioned by conservationist Benton MacKaye in 1921, the A.T. was completed as a continuous footpath in 1937. Although MacKaye's vision for the A.T. did not entail thru-hiking, 11 years after it was completed this notion was successfully realised by Earl Schaffer with his first northbound thru-hike in 1948 followed by a southbound thru-hike in 1965 (King, 2012). The A.T. is collaboratively managed by the NPS through partnerships with other federal and state land management agencies, the ATC, and with volunteers in 31 regional hiking clubs. The A.T. is an important eastern U.S. greenway protecting over 250,000 acres in a mostly narrow montane corridor (McKinley, Belote,

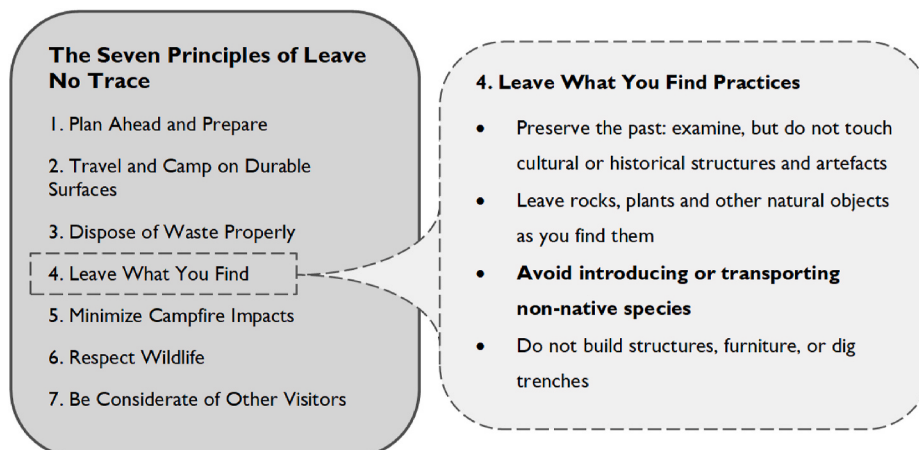


Fig. 1. The Leave No Trace Principles (Leave No Trace Center for Outdoor Ethics, 2021). NNIPS threats are primarily addressed through messaging under the "Leave What You Find" principle.

& Aplet, 2019). This thread of protected land is home to a rich diversity of flora that supports populations of rare threatened, and endangered plants, in addition to over 80 globally rare plant species (ATC, 2022; King, 2012). While considered to be remote, the A.T. is frequently intersected by roads, powerlines, and pipeline corridors, with side trails and access points via trailheads to parking lots and areas of development. All of these areas of human disturbance are potential vectors of NNIPS introduction and spread, and hence the A.T. typifies many PA trail systems that are vulnerable to invasion by non-native plants introduced and dispersed by unknowing visitors. Due to the understudied nature of NNIPS impacts, this research uses the A.T. as a case study to examine thru-hiker knowledge and attitudes of invasive plants and relevant LNT practices, and presents the case that strategies pertinent to managing invasive plants in trail systems are urgently required to preserve and conserve PAs for future generations.

2. Literature review

2.1. Invasive plant hitchhikers

Biological invasions present one of the greatest threats to global biodiversity conservation (Simberloff et al., 2013). While the introduction of invasive fauna are also of substantial concern to PA managers (Gallardo et al., 2017; Schulze et al., 2018; Ziller et al., 2020), our focus is on flora. Pathways for NNIPS introduction and dispersal are numerous and encompass human and natural agents (e.g., birds, mammals, wind, and water) (Anderson et al., 2015; Foxcroft, Spear, van Wilgen, & McGeoch, 2019). Outdoor recreation and tourism are key pathways for movement of NNIPS and present a dire threat to the integrity of PA plant communities (Anderson et al., 2015). Trails are “linear corridors of disturbance” (Ballantyne & Pickering, 2015, p. 54) and their role as a pathway for propagule dispersal has been well documented (Allen et al., 2009; Ansong & Pickering, 2014; Barros & Pickering, 2017; Rankin et al., 2015). Previous studies have explored the roles of hiking (Ansong & Pickering, 2014; Pickering, Mount, Wichmann, & Bullock, 2011; Pickering & Mount, 2010), biking and other forms of motorised transport (Rauschert, Mortensen, & Bloser, 2017; Yang, Pickering, Xu, & Lin, 2021), and horses (Gower, 2008) in facilitating NNIPS dispersal along PA trails. Most NNIPS favour disturbed habitats and sunlight (e.g., along trail corridors and at recreation sites or campsites) and cannot easily outcompete native plants in shady undisturbed settings (Allen et al., 2009). Controlling NNIPS is challenging, particularly for highly invasive species such as Japanese stiltgrass (*Microstegium vimineum*) and Garlic mustard (*Alliaria petiolata*) that are able to replace native species in undisturbed areas (Shriver et al., 2005; Simberloff et al., 2013). The A.T. corridor is threatened by invasive species (ATC, 2022; McKinley et al., 2019; Meadema et al., 2020). Examples of NNIPS found along this trail and its broader landscape include, but are not limited to, Japanese stiltgrass, Garlic mustard, Wavyleaf Basketgrass (*Oplismenus undulatifolius*), Kudzu (*Pueraria montana*), and Tree-of-Heaven (*Ailanthus altissima*) (Clark, Wang, & August, 2014; Shriver et al., 2005). While numerous NNIPS have been documented on the A.T., studies that quantify their extent and impact are few, perhaps owing to the sheer length and jurisdictional complexity of the trail. Clark et al. (2014) assessed the current and projected habitat suitability for Tree-of-Heaven, a fast growing, shade-tolerant, deciduous tree that thrives on a variety of soil conditions and is resistant to herbivore browsing. They revealed that the Tree-of-Heaven distribution will expand significantly under future climate projections, compounded by the 48% increase in suitable habitat area along the A.T. (Clark et al., 2014). Climate change will likely facilitate abundance and distribution shifts of other NNIPS in the future (Poland et al., 2021).

The growing recognition that visitors on foot (e.g., hikers and backpackers) can be prolific agents of NNIPS introduction and dispersal worldwide has led to greater research efforts to quantify seed attachment and retention on clothing (Anderson et al., 2015; Ansong &

Pickering, 2014; Pickering et al., 2011; Pickering & Mount, 2010) and footwear (Wichmann et al., 2009). Antarctica exemplifies a case study where plant propagule introduction by humans on items of clothing and gear has been meticulously studied in a comparatively controlled environment (Huiskes et al., 2014). Propagules are most likely to be found on footwear and packs/bags (Huiskes et al., 2014) but can also stick to wet tent floors and tarps. Other studies exploring propagule attachment rates over long distances suggest that some seeds are most likely to be collected and transported on boots, uncovered socks, laces, and outdoor gear, while others affix at higher rates to trousers (Mount & Pickering, 2009; Pickering & Mount, 2010). To our knowledge, there exists only one study which directly explores visitor behaviour in regard to NNIPS (Ansong & Pickering, 2015).

Long-distance human-mediated NNIPS introduction and dispersal into and within PAs poses significant threats to these valuable areas and is a pressing managerial concern that requires further attention (Auffret & Cousins, 2013; Hulme, 2014; Pickering et al., 2011; Pickering & Mount, 2010; Rankin et al., 2015; Wichmann et al., 2009). Prevention is considered the best method of NNIPS management (Leung et al., 2002). Providing boot brush stations are one biosecurity hygiene practice that can minimise NNIPS introduction (Gill, McKiernan, Lewis, Cherry, & Annunziato, 2020). These can be installed at trailheads with brushes positioned for visitors to clean their shoes before and after recreating, and a plea to also check clothing and gear. Previous studies have explored invasive seed presence in soil substrates from boot brush stations and boot soles (Hardiman, Dietz, Bride, & Passfield, 2017; McFarland, 2011), finding that footwear treads can pick up and transport seeds and that boot brush stations did remove invasive seeds that could be germinated. A recent study by Nishizawa, Kubo, Koyama, and Akasaka (2021) involved germinating seedlings from visitors' footwear, and their results indicated the effectiveness of cleaning footwear, especially footwear with deep treads, in decreasing the introduction of seeds to an area. Yet there is limited research exploring trail user's willingness to engage in invasive plant hygiene practices within PAs (Gill et al., 2020; Kapitza, Zimmermann, Martín-López, & von Wehrden, 2019). It is imperative to address this knowledge gap (Head, 2017) as rising annual visitation to PAs worldwide is intensifying the threat of non-native flora invasion (Allen et al., 2009; Anderson et al., 2015; Foxcroft, Pyšek, Richardson, Genovesi, & MacFadyen, 2017; Hulme, 2014). Research can assist by evaluating the extent to which visitors are aware of the problem, of visitor practices that could address this problem, and of their willingness to learn and adopt such practices.

Rather than merely a set of rules, LNT advocates an environmental ethic focused on human relationships with the environment, distilled into seven principles that aim to prevent and reduce harmful recreational behaviours before they leave a lasting impact. The roots of this educational program can be traced back to the 1960s when the U.S. Forest Service promoted the minimum-impact mantra “pack it in-pack it out” in response to rising levels of wilderness recreation (Marion & Reid, 2001). Prior studies have explored visitors understanding of LNT in the context of wilderness, backcountry and frontcountry settings using self-reported measures (Backman et al., 2018; Blye & Halpenny, 2020; Lawhon, Taff, Newman, Vagias, & Miller, 2019; Vagias et al., 2014). While such studies focus on LNT principles and specific practices, the practice “Avoid introducing and transporting non-native species” under Principle 4. Leave What You Find, has never been examined. As such, PA managers are unaware of whether visitors have knowledge of or practice specific behaviours in line with the LNT Principle 4 to limit the introduction and spread of NNIPS along trail systems.

2.2. Theoretical foundation

As human behaviour can accentuate environmental problems, PA managers seek to modify damaging behaviours to achieve biodiversity and habitat conservation. The greatest outcomes for conservation psychology are behavioural changes towards activities that encourage

environmental sustainability, either at the individual or system level (Saunders, 2003). Here *behaviour* encompasses any intent-orientated action that an individual may perform (Saunders, 2003; Stern, 2018). Many theories to explain human behaviour explore synergistic determinants such as attitudes, beliefs, knowledge, and values. The relationship between knowledge and behaviour is complex, and acquiring knowledge doesn't necessarily translate into behaviour change (Settina, Marion, & Schwartz, 2020; Vagias & Powell, 2010).

Developed to explain general behaviours, the Theory of Planned Behaviour (TPB) dictates that human behaviour is strongly influenced by three variables: attitudes, subjective norms and perceived behavioural control, the latter extending from the Theory of Reasoned Action that refers to an individual's perceptions to perform a particular behaviour (Ajzen, 2011; Miller, 2017; Prinbeck, Lach, & Chan, 2011). The TPB has been widely applied to conservation behaviours; from research examining factors that influence outdoor recreational behaviours (Hughes, Ham, & Brown, 2009), LNT-specific research (Lawhon et al., 2019; Schwartz, Taff, Lawhon, Hodge, et al., 2018; Vagias et al., 2014), conservation psychology research (Osbaldeston, 2013), and indirect exploration of stakeholder attitudes and beliefs regarding invasive species (Prinbeck et al., 2011). In addition, the model has been used to explore the effects of education messaging on visitor compliance with recommended minimum-impact behaviours (Miller, 2017). Guo, Smith, Moore, and Schultz (2017) highlighted that educational messaging encouraged compliance among hikers, especially when the messaging occurs prior to when recreationists began their trip. More recent LNT studies have emphasised the need for a consistent and targeted LNT education effort that could be implemented across a range of natural resource settings to encourage the adoption of low-impact behaviours (Backman et al., 2018; Blye & Halpenny, 2020). LNT principle 4 "Leave What You Find" has been examined previously with a focus on the other nested three practices (Fig. 1) (Schwartz, Taff, Lawhon, Hodge, et al., 2018; Schwartz, Taff, Lawhon, & VanderWoude, 2018; Ward & Roggenbuck, 2003). More recently, LNT principles have been adapted to encompass other forms of recreation, from running race events (Mueller, Taff, Wimpey, & Graefe, 2018), to bouldering (Schwartz, Taff, Pettebone, & Lawhon, 2016), and whitewater rafting and trekking (Serenari, Bosak, & Attarian, 2013).

Persuasive communication is imperative to visitor education efforts by promoting the need for individuals to learn and apply behaviours that support conservation (Marion & Reid, 2007). These authors review studies that examine persuasion as conceptualised through theoretical models, such as the Elaboration Likelihood Model (Petty & Cacioppo, 1986). In particular, McGuire (1985) provides a conceptual framework for information-processing that reveals the challenges managers must overcome in using persuasion to induce behaviour change (Daniels & Marion, 2005; Marion & Reid, 2007). Visitors must first be exposed to, read, and comprehend an educational message. The message must provide compelling arguments to change a visitor's attitude, causing them to both accept and "yield" to the message, and retain it until they encounter a situation where they must behave in accordance with their changed attitude (Marion & Reid, 2007; McGuire, 1985). This model posits that impacts can be reduced only when visitors successfully negotiate each step in the model and voluntarily choose to replace "high-impact" behaviours with new "low-impact" practices.

Cole, Hammond, and McCool (1997) applied McGuire's model to evaluate the efficacy of messages communicated on trailsides signs, evaluating various steps in the model. For example, backpackers paid more attention to the sign than horseback riders or day hikers, but comprehension and knowledge levels were influenced by a diversity of variables. This and other studies indicate that a high density of displayed information can reduce attention and message comprehension, and that clear, easy-to-understand, attractive visuals are most compelling to visitors (Cole et al., 1997; Davis, Caffrey, Coughlan, Dick, & Lucy, 2018).

2.3. Research purpose

The objective of our study was to explore thru-hiker's knowledge and behaviours of low-impact practices that minimise unintentional NNIPS introduction and dispersal. Specifically, whether A.T. thru-hikers are: 1) aware of the NNIPS problem, 2) adhering to LNT principles to reduce this problem, and 3) willing to learn and adopt minimum-impact behaviours to address this problem. Comprising less than half of all visitors, thru-hikers are not the largest A.T. user group; however, members of this community spend up to six months on the trail and are heralded by other visitors. Previous research suggests that A.T. thru-hikers have a very strong concern for the protection of biodiversity and habitats (Bratton, 2012), and most are considerably well-informed about low-impact practices (Newman, Manning, Bacon, Graefe, & Kyle, 2003).

Finally, the seven LNT principles (Fig. 1) promote a broad range of minimum-impact behaviours from "Pack it in, pack it out" to "Observe wildlife from a distance" and "Keep campsites small" (www.LNT.org, 2021). It is important to note that messaging about NNIPS is a *less emphasised* marginal component of the core content. For example, a standard core set of LNT messages includes only a single relevant statement: "Avoid introducing and transporting non-native species" under the principle 'Leave What You Find'. Some common forms of LNT messaging omit even this statement while other more comprehensive forms of messaging, like the Skills and Ethics booklets and the official book (Marion, 2014), contain more complete treatment.

3. Methods

3.1. Study area

Traversing the Appalachian Mountains, the A.T. stretches for nearly 3540 km (2200 miles) from the southern terminus at Springer Mountain, Georgia, to the northern terminus at Mount Katahdin, Maine (Fig. 2). Spanning 14 states, this hiking-only footpath travels through eight National Forests, six National Parks, two National Wildlife Refuges, over 70 State Parks, Forests and Game Land, and numerous local jurisdictions (ATC, 2022). The majority of the A.T. passes through backcountry and undeveloped frontcountry lands, with only 7% of the trail in federally designated wilderness areas (Marion, Wimpey, Arredondo, & Meadema, 2020). Trail management and land ownership is complex, with A.T. administration guided by a Cooperative Management System established under the responsibility of the NPS in 1981 (ATC, 2022). There is a synergistic partnership between public and private organisations who collaborate on land protection and trail management, including the ATC, NPS, USFS, state agencies, and the 31 volunteer Trail Maintaining Clubs. As the primary management collaborator, the ATC's mission is to "protect, manage, and advocate for the" A.T. (ATC, 2022). Trail stewards and volunteers are central in this and responsible for routine footpath maintenance, shelter upkeep, blaze painting (2 × 6 rectangles of white paint that mark the trail), and invasive species monitoring and management (King, 2012).

3.2. Survey design

We used printed self-administered survey questionnaires to collect data. The survey questionnaire had a total of 27 questions contained in four separate sections: LNT and hiking behaviour (1–7), invasive plants (8–17), boot brush stations (18–22), and concluding with general demographic information (23–27). The survey collected nominal and ordinal data, including 21 closed-questions with 14 five-point Likert scale questions (e.g., 1 = Strongly Disagree, 5 = Strongly Agree) and 7 dichotomous questions. There were six open questions to elicit more detailed responses and assess deeper knowledge, e.g., asking respondents to name any plant that would be considered invasive on the A.T., or specify where they recall seeing information about NNIPS and boot brush stations. In addition, thru-hikers were asked to identify

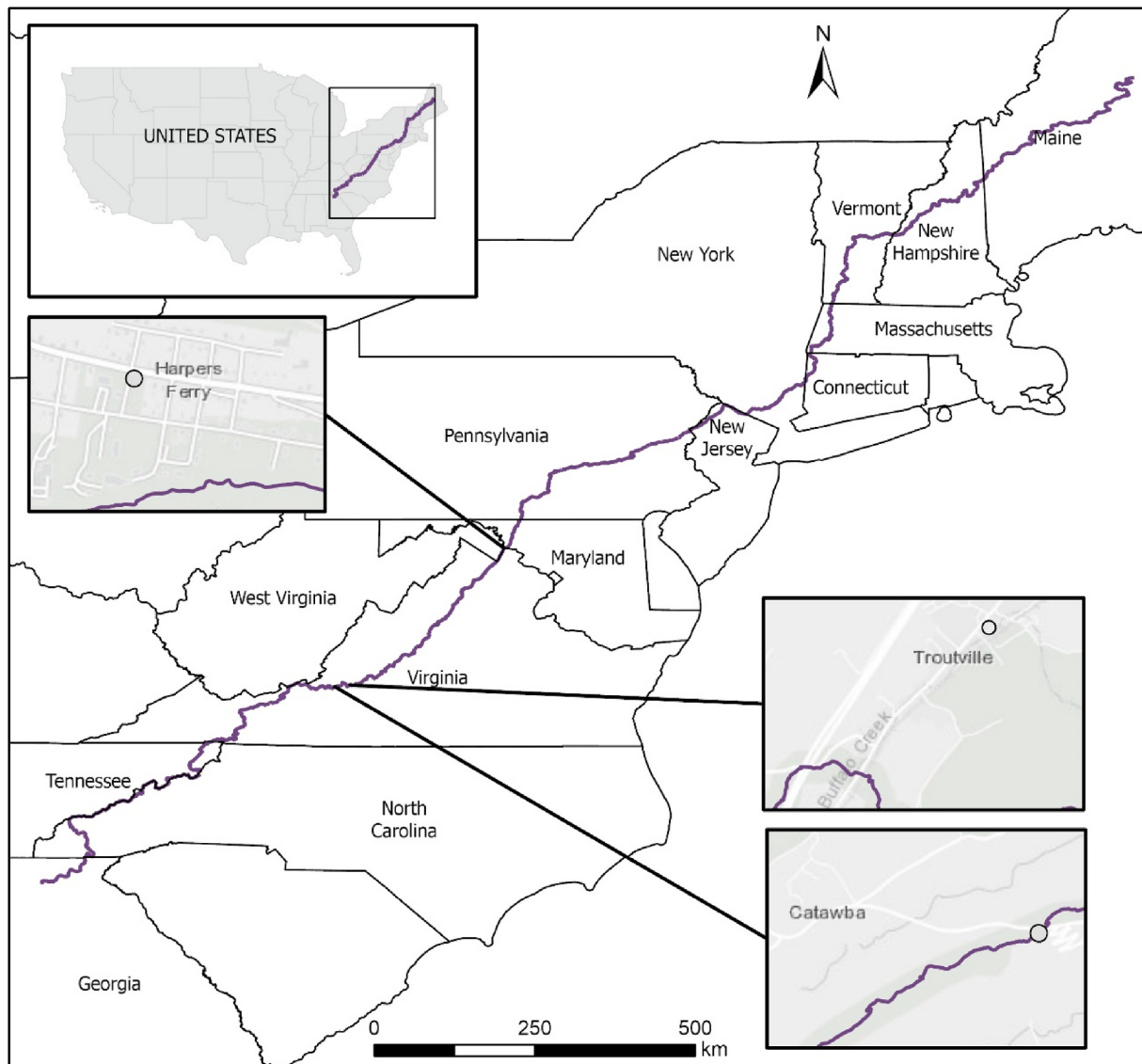


Fig. 2. Map of the Appalachian Trail (A.T.; purple line), with insets of three study sites in Virginia and West Virginia, U.S.

images of three NNIPS; all of which pose a high threat to A.T. ecosystems and are widely distributed, being present in all 14 states the A.T. passes through (Fig. 3). These are just 3 of many NNIPS found along the trail (Shriver et al., 2005).

Previous studies have used survey questionnaires when investigating adoption and knowledge of LNT and attitudes toward NNIPS (Ansang & Pickering, 2015; Blye & Halpenny, 2020; Lawhon et al., 2013; Newman et al., 2003; Vagias & Powell, 2010). The survey instrument was

developed and adapted from similar measures employed in these studies. Pre-testing the survey questionnaire on individuals from the 2018 thru-hiking cohort determined the average completion time as 8 min.

3.3. Deployment

Using a convenience-based sampling approach (Newing, 2011), we



Fig. 3. Justification for the selection three non-native invasive plant species (NNIPS) for inclusion in the survey.

deployed the survey to A.T. thru-hikers between 8th June 2019 and 20th June 2019, including weekdays and weekends. The total sample size was 154 and the response rate was quite high (96%). Participants under the age of 18 were excluded. Thru-hiking direction (northbound, southbound, flipflop) was not considered, but it was expected that most potential respondents would be northbound, corresponding with the 'bubble': a denser cluster of thru-hikers who depart from Georgia between late March and early April.

Surveys were conducted at three locations chosen by the researchers from prior thru-hiking experience to (i) minimise encroaching on respondent hiking time, i.e., locations where thru-hikers would naturally rest, (ii) maximise respondent sample size by targeting the large annual 'bubble' of Northbound thru-hikers, and (iii) reduce interference with the thru-hiking experience.

The 8th Annual Troutville Trail Days, Troutville, Virginia, provided the first event and location (Fig. 2). This free outdoor annual festival celebrates the A.T., local, and thru-hiking communities. Compared to other annual A.T. festivals (e.g., Damascus), the Troutville event is smaller but maintains good attendance by current and previous thru-hikers and thus was chosen for random sampling and participant recruitment. The second location was the McAfee Knob parking lot near Roanoke, Virginia, where the A.T. crosses Virginia State Route 311 (Fig. 2). The ATC headquarters and visitor center, located in Harpers Ferry, West Virginia, provided the third and final location (Fig. 2). Stationed here since 1972, the ATC marks the psychological, though not quite physical, halfway point for A.T. thru-hikers. The center offers a voluntary yet unmissable 'ritual' to each hiker by taking their picture and assigning them a number of passage according to hiking direction. Up to 50 thru-hikers/day stop here at the height of the 'bubble'.

To participate, prospective participants had to be either a current or recent thru-hiker. We approached all prospective participants and provided them with an oral introduction and information sheet. We obtained written consent from willing participants, and then distributed the printed survey. The predetermined average completion time of 8 min was consistent in the field. The lead author secured permissions, handed out, and collected all surveys at the three survey locations.

3.4. Analysis

Data from the surveys were analysed in Excel and R Studio version 4.2.1. Responses to open-ended questions were coded and analysed for themes to provide data depth. Anecdotal comments written on surveys were also recorded, along with thru-hiker (TH) survey number, e.g., TH1-154. We calculated the percentage of respondents according to each survey question. We performed i) descriptive statistics; describing and exploring data characteristics of thru-hikers and their attitudes towards LNT and invasive species (Newing, 2011), (ii) Chi-square test (χ^2); exploring the probability of obtaining the observed results if there is no population effect (Newing, 2011), and (iii) Fisher's Exact test (FET); determining the relationship between variables, appropriate for small sample sizes (Newing, 2011). In addition to cross tabulation, we used these tests of independence to determine which socio-demographic variables were associated with A.T. thru-hiker knowledge and perception of NNIPS, and their adoption of low-impact practices to minimise NNIPS introduction and spread. Our analyses are listed below according to research question:

- 1) *Are A.T. thru-hikers aware of the NNIPS problem?* We converted the responses about whether respondents had heard of NNIPS prior to the study and whether they thought hikers can both introduce and spread NNIPS from categorical to numerical variables.
- 2) *Are A.T. thru-hikers adhering to LNT principles to reduce this problem?* We converted the responses about whether thru-hikers brush all vegetation before both getting off and getting on trail, whether if they saw a boot brush they used it, and whether they thought boot brushes can remove NNIPS from categorical to numerical variables.

- 3) *Are A.T. thru-hikers willing to learn and adopt minimum-impact behaviours to address this problem?* Respondent responses to whether, if advised, they would brush their boots, were converted from categorical to numerical variables.

4. Results

4.1. Respondent characteristics

Male participants (68.8%) outnumbered females (31.2%) in a ratio of 2:1. Most of the respondents were aged between 21 and 30 (50.0%), with 7.1% aged under 20, 18.9% aged between 31 and 40, 6.5% aged between 41 and 50, 11.7% aged between 51 and 60, 5.8% aged between 61 and 75. No respondents were above 75 years of age. Respondents tended to be highly educated, with 63.6% having a university degree, 20.8% having some college education, and 15.6% having some high school education. Although nine different countries of current residence were represented in this group, 90.9% of participants were from the U.S. Other countries represented were Canada (2.6%), New Zealand, United Kingdom (1.3%), Australia, Germany, Italy, Ireland, and Slovenia (0.6%).

4.2. LNT and hiking behaviour

Using Likert scales from 1 to 5, thru-hikers were asked to self-report their familiarity with low-impact LNT principles (1 = Not familiar, 5 = Extremely familiar) and knowledge of LNT practices (1 = No knowledge, 5 = Expert). All thru-hikers reported being *moderately familiar* or higher with LNT principles, with 40.9% self-reporting as *extremely familiar*, 50.7% *quite familiar*, and 8.4% *moderately familiar*. Knowledge of LNT practices among all thru-hikers was *average* or higher, with 27.9% self-reporting to have *expert* knowledge, 52.0% *above average* knowledge, and 20.1% *average* knowledge.

From a provided list of the seven LNT principles (Fig. 4), thru-hikers chose two principles, one they considered to be of most importance and one of least importance. Only 1.3% of thru-hikers perceived principle 4 "Leave What You Find" to be the most important LNT principle, while 25% considered it the least important principle (Fig. 4).

Thru-hikers self-reported their current behaviour in response to hiking activities based on LNT practices underpinning the seven principles. Table 1 provides responses for principle 4. 35.1% of thru-hikers reported that they sometimes "remove objects from the area, even a small item like a rock, plant, stick, or feather", a behaviour that is discouraged by principle 4. In relation to weed hygiene practices, only 1.3% of thru-hikers reported *always* brushing all vegetation and dirt off boots at trailheads both before leaving and rejoining the A.T., with the modal responses indicating that the majority of thru-hikers never adopt either behaviour (Table 1). Of those who reported that currently they *never* brush vegetation and dirt off their boots both before leaving and rejoining, the majority self-reported as being *quite familiar* with LNT principles and having an *above average* knowledge of LNT practices.

4.3. Invasive species

Prior to being surveyed, 94.8% of the 154 respondents had encountered the term *invasive species*, however deeper knowledge and awareness was found to be extremely limited. Only 18.8% of thru-hikers could provide a common name of a plant considered invasive within the A.T. corridor, and indeed, invasive to North America. Across these responses, the common names for 17 different NNIPS were given. Reported in 41.4% of responses, the most frequently named plant was Kudzu. When asked as part of the questionnaire to visually identify three NNIPS present along the A.T. (Japanese stiltgrass, Garlic mustard, and Purple loosestrife), this question was answered extremely poorly, with each image correctly identified by less than 3% of thru-hikers. 86.4% of thru-hikers were unable to identify any correctly, either leaving the

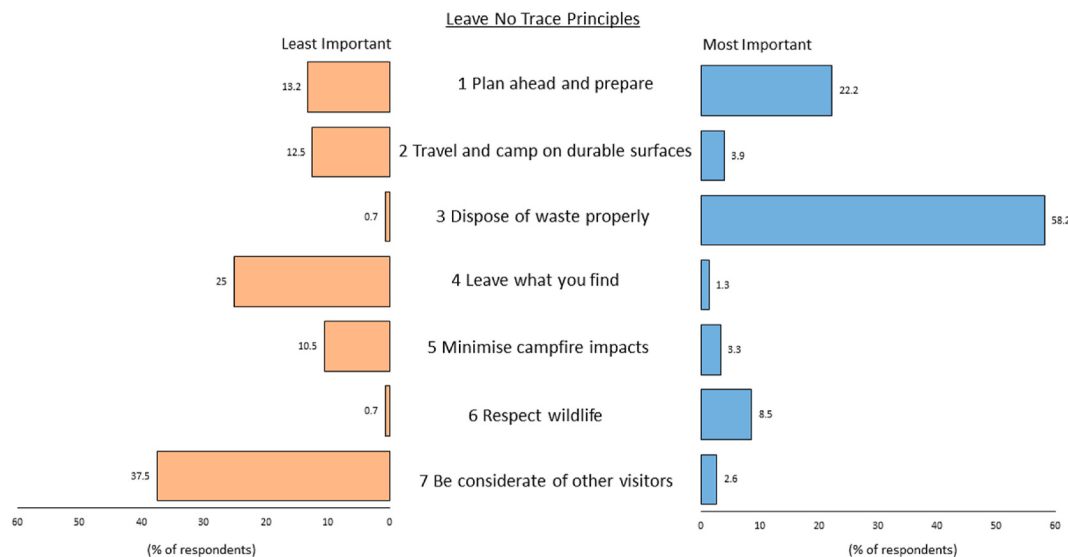


Fig. 4. Thru-hiker Leave No Trace (LNT) perceived importance.

Table 1

Thru-hiker self-reported behaviour, with modal responses in **bold**. (N = 154).

LNT Principle 4: Leave What you Find	Never (%)	Sometimes (%)	Always (%)
Remove objects from the area, even a small item like a rock, plant, stick or feather	64.9	35.1	0.0
Brush all vegetation and dirt off boots at trailheads before getting off the A.T.	61.0	37.7	1.3
Brush all vegetation and dirt off boots at trailheads before getting back on the A.T.	66.9	31.8	1.3

question blank or writing 'no'. Of those thru-hikers who, prior, had provided a common name of a plant invasive to the A.T., only 4.5% subsequently correctly identified at least one of the three invasive species pictured. Two thirds (66.9%) reported seeing information about invasive plant species while hiking on the A.T. This information was most frequently observed on signage (information boards at trailheads and shelters). There was no significant association between whether respondents had heard of NNIPS prior to the survey and socio-demographic characteristics ($p > 0.05$), nor between respondents' knowledge that hikers can spread NNIPS and socio-demographic characteristics ($p > 0.05$). However, there was a significant association between respondents' knowledge that hikers can introduce NNIPS and highest education level ($p = 0.02$, FET = 0.03).

Thru-hikers were asked to indicate their level of agreement to a series of statements about NNIPS and their management on the A.T. (Table 2). Compared to other statement sets in the questionnaire survey, fewer thru-hikers expressed strong opinions either way, with responses concentrated within the three central Likert scale categories. There was awareness that A.T. plant communities are threatened by NNIPS and agreement that managing these within the trail corridor is difficult (53.0%, and 69.6% respectively). In addition, three quarters of thru-hikers agreed that hikers both introduce and spread "invasive plant species via their clothing, shoes and gear" (74.8% and 78.1% respectively). 'Neither Agree nor Disagree' was the modal response for four of the statements (Table 2).

4.4. "Avoid introducing or transporting non-native species"

Thru-hikers were asked about boot brush stations along the A.T., pertaining to the LNT Principle 4 practice "Avoid introducing or transporting non-native species". 73.2% of thru-hikers agreed that "boot

brush stations can remove non-native vegetation and invasive plant seeds from boots" (Table 3). The majority of thru-hikers disagreed with the statements "the only use of boot brush stations is to clean dirt from boots" and "routinely brushing off boots at boot brush stations is time consuming". 'Neither Agree nor Disagree' was second highest response category for all three of the statements (Table 3).

Although scarce along the A.T., thru-hikers were asked to name locations where they had observed boot brush station infrastructure. Boot brush stations were commonly seen at hostels and trailheads, with Hot Springs, North Carolina, the most frequently named location identified in 29 responses. Of the 78 thru-hikers who reported seeing boot brush stations along the A.T., 65.4% also reported using them. There was a significant association between both respondents' knowledge that boot brushes remove NNIPS, and respondent self-reported boot brush use along the A.T. with age ($X^2 p = 0.01$, 0.03, respectively).

Thru-hikers demonstrated willingness to adopt weed hygiene to "Avoid introducing or transporting non-native species" on the A.T. with 83.0% stating that, if advised, they would *likely* always brush their boots at a trailhead before and after hiking, with 12.4% stating they would *unlikely* do this and 4.6% responding as *neutral*. There was a significant association between respondents' brushing their boots if advised and age ($p = 0.002$, FET = 0.001), gender ($p = 0.02$, FET = 0.01), and highest education level ($p = 0.05$, FET = 0.04).

Thru-hikers would be willing to change their behaviour if they learned that their actions whilst hiking damaged the environment on the A.T. (Table 4). In fact, 80.1% of thru-hikers agreed or strongly agreed that they would change their behaviour if they learned that their actions whilst hiking damaged the environment *and*, that if advised, they would be somewhat or very likely to always brush their boots at a trailhead before and after hiking (Table 4, qualifying responses indicated in bold).

5. Discussion

5.1. Management implications

The purpose of our study was to explore whether A.T. thru-hikers are 1) aware of the NNIPS problem, 2) adhering to LNT principles to reduce this problem, and 3) willing to learn and adopt minimum-impact behaviours to address this problem. We found that A.T. thru-hikers are generally aware of the term *invasive species* and understand that the A.T. is threatened from NNIPS and managing these along this corridor is a complex challenge. However, further knowledge of NNIPS along the A.T., and indeed in the Eastern U.S., was found to be very limited; "I know

Table 2Thru-hiker agreement towards attitudinal statements on non-native invasive plant species (NNIPS) and their management, with modal responses in **bold**. (N = 151).

Attitudinal Statement	Strongly Disagree (%)	Disagree (%)	Neither Agree nor Disagree (%)	Agree (%)	Strongly Agree (%)
<i>Invasive plant species are a global threat to biodiversity</i>	0.0	0.7	19.2	57.0	21.2
<i>Invasive plant species can pose a threat to human health</i>	0.7	6.0	35.1	43.0	13.2
<i>Invasive plant species cause economic damage</i>	0.0	2.0	20.5	48.3	27.2
<i>The A.T. is threatened by invasive plant species</i>	0.7	4.0	41.1	40.4	12.6
<i>Hikers can introduce invasive plant species via their clothing, shoes and gear</i>	1.3	3.3	17.9	49.0	25.8
<i>Hikers can spread invasive plant species via their clothing, shoes and gear</i>	0.7	1.3	17.2	52.3	25.8
<i>All invasive plant species should be eradicated completely</i>	6.6	15.2	50.3	20.5	6.0
<i>Invasive plant species have as much right to exist within the A.T. corridor as native plants</i>	11.3	45.7	36.4	4.6	1.3
<i>Managing invasive plant species in the A.T. corridor is difficult</i>	0.0	2.0	27.2	41.1	28.5
<i>Chemical management is the best method of control</i>	20.5	28.5	43.7	6.0	0.7
<i>Manually pulling up invasive plants is not effective</i>	7.9	23.2	60.3	7.3	0.7

Table 3Thru-hiker agreement towards attitudinal statements on boot brush stations, with modal responses in **bold**. (N = 153).

Attitudinal Statement	Strongly Disagree (%)	Disagree (%)	Neither Agree nor Disagree (%)	Agree (%)	Strongly Agree (%)
<i>The only use of boot brush stations is to clean dirt from boots</i>	13.7	41.8	27.5	14.4	2.6
<i>Routinely brushing off boots at boot brush stations is time consuming</i>	11.1	47.1	29.4	12.4	0.0
<i>Boot brush stations can remove non-native vegetation and invasive plant seeds from boots</i>	0.0	0.7	26.1	56.2	17.0

nothing about invasive species" [TH100]; "I was unaware of problems with invasive plants in/along the A.T." [TH03]. This is reflected in Table 2, where 'Neither Agree nor Disagree' was the modal response to four of the eleven NNIPS attitudinal statements. Only a fifth of respondents could correctly name a plant considered invasive on the trail, and alarmingly, just seven of the 154 respondents could visually identify at least one of the three pictured invasive species, two of which are common in the trail corridor between Georgia and West Virginia. Prior to the survey, thru-hikers would have unknowingly passed NNIPS for over 1,000 miles which suggests that there is a limited understanding of the plant assemblages and ecosystems through which they hike. These findings suggest that most hikers, including those who spend months on the trail, generally lack the knowledge and resources to identify NNIPS, nor the conservation threats they pose for native plant communities and land managers. Thus, land and trail managers seeking to address the increasing threats posed by NNIPS first need to better inform hikers about the introduction and dispersal of NNIPS and provide compelling reasons why hikers should learn about and apply new low-impact practices to minimise their further spread.

"Leaving No Trace is very important for our nature experience" [TH14] and whilst all LNT principles are of consequence, a quarter of respondents were of the attitude that principle 4 "Leave what you find" is the *least important* (Fig. 4). This is the only LNT principle that has practices pertaining to NNIPS. In line with previous research, most respondents were aware of the role that hikers can have as agents of NNIPS introduction and dispersal (Ansong & Pickering, 2015) and agreed that "boot brush stations can remove non-native vegetation and invasive plant seeds". However, these attitudes were not reflected in respondents' self-reported behaviour, as over two thirds *never* brushed vegetation and dirt off their boots before leaving and rejoining the trail

(Table 1). Few thru-hikers understand the connection between brushing boots and managing NNIPS, and even fewer are aware of the various low-impact practices targeting NNIPS introduction and dispersal. Although this is contrary to the majority of respondents self-reporting being *quite familiar* with LNT principles and having an *above average* knowledge of LNT practices. It is important to emphasise that this likely stems from the common omission of NNIPS-specific low-impact practices, such as boot brushing, in LNT materials that are distributed to visitors and thru-hikers (LNT ethics cards and leaflets).

As noted previously, messaging related to NNIPS problems and associated low-impact practices have not historically been part of core LNT messaging. For example, the core LNT material has a single statement: "Avoid introducing or transporting non-native species" – and includes no specific low-impact practices. While the series of LNT Skills & Ethics booklets (www.LNT.org) and official book (Marion, 2014) do contain more in-depth information about the problem and corrective low-impact practices, these more comprehensive sources are generally not seen by most outdoor visitors. Thus, it is not surprising that relatively few thru-hikers attach great importance to the problems presented by NNIPS and visitor-related control practices. Furthermore, a review of the most common A.T. LNT educational materials found that the single statement detailed above is often omitted (e.g., ubiquitous LNT ethics cards, leaflets, and trailhead kiosk information). Additionally, these findings indicate a strong need for communication of the full range of actions that visitors could adopt to more effectively address NNIPS introduction and dispersal. Towards that end, Table 5 assembles a more comprehensive listing of these practices found in the LNT literature and in scientific and land management literature. Included are practices designed for both visitors and agency staff to illustrate the wide range of practices available to individuals involved in the stewardship of PAs and

Table 4Correlated responses of thru-hiker willingness to change behaviours and brush boots, if advised. Modal responses in **bold**. (N = 153).

		"If you were advised to brush your boots at a trailhead before and after hiking, how likely would you be to do this all the time?" (%)			
		Unlikely	Neutral	Likely	Total
"If I learned that my actions whilst hiking damaged the environment I would change my behavior" (%)	Disagree	0.0	0.0	0.7	0.7
	Neither Agree nor Disagree	2.0	0.0	2.5	4.5
	Agree	10.5	4.6	79.7	94.8
	Total	12.5	4.6	82.9	100.0

Table 5

Best low-impact practices for reducing the introduction and dispersal of non-native invasive plant species (NNIPS) into and within PAs.

Best Low-Impact Practices to Deter Invasive Plant Dispersal: A Comprehensive Listing	
NNIPS Introduction (Outside PAs)	NNIPS Dispersal (Inside PAs)
Visitors: • Thoroughly clean footwear, hooves, tire treads to remove all mud/seeds. Also inspect and remove mud/seeds from the tops of footwear, all clothing and pet or livestock fur, and from vehicles. • Shake out tents, ground tarps, packs or other gear to remove seeds at home when preparing for a trip. • Don't bring livestock feed that contains viable seeds into a PA. • Avoid livestock pasturage or feed containing noxious weeds/seeds for 2–3 days prior to entering a PA. • Don't transport firewood or plant materials into or within a PA. Agencies: • Develop effective visitor, agency, volunteer, and contractor staff education programs, practices, and regulations that deter the introduction of NNIPS. • Provide and advocate the use of seed removal educational signs, boot brushes, and cleaning stations at trailheads. Develop and require mud/seed removal practices for agency staff. • Control/remove NNIPS in proximate areas and at all access points. • Obtain and use locally available native species and the purest seed mixes in all restoration work.	Visitors: • Stick to marked formal trails to reduce dispersal of NNIPS to new areas. Off-trail traffic can disperse NNIPS or create disturbed areas that support them. • Camp on designated or well-established campsites to restrict or contain the spread of NNIPS. • Wear gaiters and other clothing (e.g., trousers without cuffs and open pockets) that minimise seed attachment and dispersal. • During travel periodically check and remove mud/seeds from footwear, hooves, tires, clothing (particularly fleece and Velcro), pet or livestock fur, and vehicles. • When packing up at a campsite shake out tarps, tents, and other camping gear to remove any mud/seeds. Note that wet surfaces cause seeds to stick tight and need to be physically brushed off. Agencies: • Develop and implement effective visitor, agency, volunteer, and contractor staff education programs, practices, and regulations that deter the dispersal of NNIPS. • Educate agency and volunteer staff to recognise and remove NNIPS from footwear, clothing, and equipment when traveling within PAs. • Implement NNIPS monitoring, control, removal, and restoration programs with staff and volunteers. • Minimise vegetation and soil disturbance as many NNIPS are disturbance-associated species. • Implement an early-detection NNIPS program to locate and remove small and isolated populations before they spread more widely. • Include NNIPS risk evaluations into project planning and work to prevent dispersal by altering the timing of work or the practices employed. Implement PA zoning to prioritise areas of greatest management concern based on NNIPS risk evaluations.

Source documents: (Ansong, Pickering, & Arthur, 2015; Ansong & Pickering, 2014; Cal-IPC, 2012; Lukács & Valkó, 2021; Mount & Pickering, 2009; Pickering & Mount, 2010)

their visitors.

Boot brushing is just one example of a low-impact practice that visitors can adopt to reduce NNIPS introduction and dispersal. Table 5 lists others such as recreating only on formally marked trails, wearing gaiters to limit NNIPS attachment and not transporting firewood or plant material into a PA. This research also reveals that the LNT principle 4 practice to “Avoid introducing and transporting non-native species” is challenging for thru-hikers to adopt due to the lack of a supporting infrastructure such as boot brush stations at trailheads, or in one case the station was “old and broken, with no brush” [TH109]. Over eighty percent (83%) of respondents stated that if advised, they would likely *always* brush their boots at a trailhead before and after hiking. The social nature of the A.T. facilitates a cohesive thru-hiking community and therefore such behavioural homogeneity is plausible (Fondren & Brinkman, 2019). In support of Gill et al. (2020), this research considers the relative absence, and disrepair of existing infrastructure as the greatest barrier to trail user LNT compliance and NNIPS management as well as constraining the potential willingness of hikers: “nobody would mind brushing feet to protect the trail” [TH151]; “I would definitely use a boot brush station assuming that one exists on the A.T.!” [TH136]; “I would use boot brush stations if they were provided at trailheads” [TH27]. Some of the other low impact practices included in Table 5 could also be communicated at boot brush stations.

Other actions noted in Table 5 do not require any infrastructure, such as asking hikers to check their footwear, clothing, packs, tents, and tarps to remove clinging seeds before leaving campsites each day. As noted, seeds can readily cling to wet tents or tarps and if not removed are transported to the next campsite where they fall off when the items dry. NNIPS that line the trail, like Japanese stiltgrass and Garlic mustard, can drop hundreds of seeds that are easily transported longer distances on the tops of damp shoes. If visitors could learn to recognise the most common NNIPS they could periodically stop and remove seeds when hiking past them.

It is critical to inform PA and recreational trail visitors about the risk

of human-mediated NNIPS dispersal (Lukács & Valkó, 2021). Effective information dissemination methods include personal communication with managers, staff and volunteers, maps, brochure guides and signage (Cole et al., 1997; Davis et al., 2018; He, Blye, & Halpenny, 2022; Kidd et al., 2015, 2019; Lukács & Valkó, 2021). Although two-thirds of respondents reported observing information on NNIPS on signage at A.T. trailheads, the minimal content and infrequency of this information along the trail, compounded by limited supporting infrastructure, potentially constrains any meaningful behavioural change among this group in response to these educational messages. This research suggests that A.T. thru-hikers are a willing audience regarding changing their behaviour as a consequence of learning that their actions whilst hiking damaged the environment (Table 4). Alongside “more frequent info boards about invasive species” [TH62], signage should contain succinct information about specific LNT practices that could more effectively reduce NNIPS introduction and dispersal (Table 5), in addition to being visually appealing (L. R. Kidd et al., 2019). Furthermore, such information should also be included on LNT leaflets, ethics cards and other materials that are distributed to trail users.

The A.T. provides one example where educational messaging needs revamping to include information about NNIPS introduction and dispersal and the practices that trail users can adopt to combat this. While this case study reveals that thru-hikers are not aware of their role in introducing and spreading NNIPS, we believe that most hikers to PAs are concerned about the impacts of their recreational use, and are willing to practice LNT, as shown in previous studies (Lawhon, Taff, Newman, Vagias, & Newton, 2017). We suggest more attention to be given to the specific LNT Principle 4 practice: “avoid introducing and transporting non-native species”. Table 5 also details practices that PA agencies could consider in addition to visitor education, like implementing NNIPS monitoring, control, removal and restoration schemes, prioritising areas of greatest management concern through PA zoning, and NNIPS risk evaluation. Ultimately this research raises important questions: how many PAs worldwide communicate to visitors about

their role as transportation agents? How many PAs are limited in their capacity to inform, educate, and provide infrastructure to target human-mediated NNIPS introduction and dispersal?

5.2. Limitations and suggestions for further research

The absence of existing literature on NNIPS in the context of LNT from thru-hiker perceptions and self-reported behaviours makes this exploratory study the first of its kind. This study was challenging owing partly to the aforementioned knowledge gap, and to that end we acknowledge that this study has several limitations. Firstly, our findings are specific to A.T. case study and thru-hiking community, and given our small sample size comparability amongst the sample is limited, despite our excellent response rate. While previous LNT studies used 7-point scales (Backman et al., 2018; Lawhon et al., 2019; Schwartz, Taff, Lawhon, & VanderWoude, 2018), 5-point scales have been used in LNT studies centered on Principle 4 (Schwartz, Taff, Lawhon, Hodge, et al., 2018) and also for exploring people's perception, attitude, and behaviour towards NNIPS and minimum-impact knowledge (Ansong & Pickering, 2015; D'Antonio, Monz, Newman, Lawson, & Taff, 2012; Nishizawa et al., 2021). As such, we chose to use a 5-point Likert scale in our novel study on LNT Principle 4 and people's knowledge and behaviour towards NNIPS. Differences of opinion exist regarding the optimal number of Likert-scale points; however, there is no one perfect approach (Blye & Halpenny, 2020). Minimal differences exist between 5- and 7-point scales, and simply rescaling the data can allow comparability (Dawes, 2008).

We posit that our results be viewed as a basis for future research. Replicating this study on other long-distance trails would provide a more comprehensive understanding of the thru-hiking community knowledge of NNIPS and their adoption of low-impact practices to avoid introducing and spreading NNIPS. In addition, further surveys with users outside of the thru-hiking community, such as locals and day hikers, should be undertaken to explore whether perceptions and behaviours we found present in the long-distance hiking community are different for those who live locally to recreational trails. Additional research is needed on other recreational trails within PAs to address the gap in knowledge of visitors and their low-impact practices pertaining to limiting NNIPS introduction and spread through biodiverse and ecologically valuable areas. Further research will help PA managers better manage visitor use and prioritise visitor-mediated NNIPS introduction and spread by improving educational messaging, signage, personal communication, and providing supporting infrastructure that allows visitors to adopt specific low-impact practices.

6. Conclusion

This study extends our knowledge of visitor understanding of NNIPS introduction and dispersal in trail systems and protected areas. Our A.T. case study findings reveal that hiker knowledge of NNIPS was limited and very few individuals had adopted LNT behaviours to minimise NNIPS invasion. In addition, few hikers understand the connection between boot brushing and managing NNIPS, and even fewer are aware of the full range of low-impact practices that address NNIPS invasion. While hikers in this study recognise the importance of LNT and largely adhere to LNT practices, only 1.3% of hikers considered LNT Principle 4, the only principle encompassing practices pertaining to NNIPS management, as most important. The advocacy of seed removal through focused messaging education boards accompanied with boot cleaning stations is just one method for reducing NNIPS introduction and spread within PAs (Gill et al., 2020).

PA implementation of NNIPS management strategies and policy requires much improvement globally (Davis et al., 2018; Foxcroft et al., 2017). Addressing the intensifying threat of NNIPS invasion facing PAs requires encouraging visitors to change their behaviour. Our research reveals that hikers (and indeed other visitors) are a receptive audience

for adopting low-impact practices in line with NNIPS management (e.g., boot brushing, shaking out gear, and not moving firewood). PA agencies need to spend additional effort and prioritise resource allocation to convey the significance of NNIPS problems and present visitors with compelling reasons for learning about NNIPS, their threats to native plant assemblages, and of the wider range of LNT practices.

CRedit authorship contribution statement

Megan R. Dolman: Conceptualization, Methodology, Formal analysis, Investigation, Writing – original draft, Visualization, Project administration, Funding acquisition. **Jeffrey L. Marion:** Writing – review & editing, Supervision.

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