Landscape and Urban Planning 188 (2019) 80–92

Contents lists available at ScienceDirect

Landscape and Urban Planning

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

What are family forest owners thinking and doing about invasive plants?

Mysha Clarke[a], Zhao Ma[a,*], Stephanie Snyder[b], Kristin Floress[c]

[a] Department of Forestry and Natural Resources, Purdue University, 195 Marsteller Street, West Lafayette, IN 47907-2033, United States
[b] USDA Forest Service Northern Research Station, 1992 Folwell Ave, St. Paul, MN 55108, United States
[c] USDA Forest Service Northern Research Station, 1033 University Place, Suite 360, Evanston, IL 60201, United States

ARTICLE INFO

Keywords:
Invasive species
Non-industrial private forest
Human dimensions
Decision making
Collective action

ABSTRACT

Effectively managing invasive plants across forested landscapes requires voluntary control by 10.7 million family forest owners (FFOs) who own 36% of forestlands in the USA. The literature on individual and collective invasive plant management has focused on farmers, ranchers, urban gardeners and community residents, with less attention on forestlands and the role of FFOs. By analyzing survey data from 1422 FFOs in Indiana, USA, we provide a thorough assessment of their awareness, perceptions, behaviors and intentions towards invasive plants; as well as their needs and challenges. In our study, FFOs reported moderate familiarity with, concern about, and interest in invasive plant control on and around their properties. Despite a lack of confidence in their ability to manage invasive plants, FFOs reported having taken actions on the ground, including inspecting their woodlands, talking to their families and other landowners, and removing invasive plants, all without much input from natural resource professionals. Most FFOs relied on self-directed learning and social networks for invasive plant-related information and advice. They generally had little or no experience or interest in interacting with natural resource professionals. This suggests a need for natural resource professionals to refocus their efforts on developing communication strategies to target specific segments of FFOs, stronger online presence to facilitate self-directed learning, and partnerships with non-profit organizations trusted by FFOs to encourage self-organization and sharing of information and resources. These results from Indiana provide important insights for engaging FFOs to manage invasive plants more broadly.

1. Introduction

Nearly half of the forests in the eastern United States are infested by invasive plants (Oswalt et al., 2015). Invasive plants can displace native plants; reduce wildlife habitat; decrease forest health, productivity and resilience; and reduce the provisioning of various ecosystem services such as water quality protection and recreation (Coyle et al., 2016; Fei, Phillips, & Shouse, 2014; Paini et al., 2016; Pejchar & Mooney, 2009). Several invasive plants such as garlic mustard (*Alliaria petiolata*) and tree of heaven (*Ailanthus altissima*) can also alter soil composition, making it difficult for other seedlings to grow (Peters & Meyer, 2006; Simberloff, 2013). Previous research has focused primarily on the ecological processes of nonnative plants including their reproduction, dispersal, and invasion patterns (e.g., Catford, Jansson, & Nilsson, 2009; Richardson et al., 2000). Studies have also assessed the effectiveness of various control (removal and prevention) strategies in managing specific invasive plant species, mostly on federal and state-owned land (e.g., Mangold & Sheley, 2008; Miller, Chambers, Pyke, Pierson, & Williams, 2013).

Despite an increase in ecological understanding and public awareness about invasive plants (Burt et al., 2007), there is still limited understanding about the social dimensions of nonnative plant invasions (Pejchar & Mooney, 2009; Simberloff, 2013), as evident from the fact that less than 1% of journal articles published from 1980 to 2013 on invasion biology and management examined human values, risk perceptions, resource management behaviors, and the history of invasive plant management (Estévez, Anderson, Pizarro, & Burgman, 2015). A growing number of researchers have recognized that managing invasive species is "as much a social issue, encompassing political and human factors, as it is a scientific one" (Bremner & Park, 2007, p. 307; Kueffer, 2010; Reaser, 2001). As such, it becomes imperative to incorporate the social sciences and humanities to analyze people's conceptualization of invasive versus native plants; their attitudes, values and practices associated with invasive plant management; and the politics and policies underlining such management (Head, 2017). Indeed, in recent years an increasing number of studies have incorporated theories and methods from the social sciences and humanities to examine invasive plant management in the United States and beyond (e.g., Epanchin-Niell

* Corresponding author.
E-mail addresses: mysha.clarke@villanova.edu (M. Clarke), zhaoma@purdue.edu (Z. Ma), stephaniesnyder@fs.fed.us (S. Snyder), kfloress@fs.fed.us (K. Floress).

https://doi.org/10.1016/j.landurbplan.2018.10.024
Received 31 October 2017; Received in revised form 18 September 2018; Accepted 15 October 2018
Available online 20 February 2019

et al., 2010; Ervin & Frisvold, 2016; Hershdorfer, Fernandez-Gimenez, & Howery, 2007; Niemiec, Ardoin, Wharton, & Asner, 2016; Niemiec, Asner, Brodrick, Gaertner, & Ardoin, 2018; Sullivan, York, An, Yabiku, & Hall, 2017; Sullivan, York, White, Hall, & Yabiku, 2017; Yung, Chandler, & Haverhals, 2015).

Specifically, private landowners have been the focus of many such studies. This is because the success of invasive plant prevention and control relies on not only actions of public resource managers, but thousands of private individuals taking actions on their own properties. Failing to engage private landowners will compromise the overall effectiveness of invasive plant management on a landscape scale. Generally, previous landowner studies have highlighted the importance of raising landowner awareness and communicating invasive plant-related information in a way that resonates with landowners and their management objectives (Aslan et al., 2009; Fischer & Charnley, 2012; Ma, Clarke, & Church, 2018; Niemiec, Pech, Norbury, & Byrom, 2017; Niemiec, Ardoin, Wharton, & Brewer, 2017; Steele, Chandran, Grafton, Huebner, & McGill, 2006; Steele, McGill, Chandran, Grafton, & Huebner, 2008). Several studies show that landowners may have widely different perceptions of invasion risks, ranging from a lack of concern, to the belief that nonnative plants can be effectively controlled, to the view that invasions have gotten out of control (Fischer & Charnley, 2012; Yung et al., 2015). Many previous studies have also highlighted a need for locally adapted programs that provide education, technical assistance, and financial incentives to encourage invasive plant management by private landowners (e.g., Epanchin-Niell et al., 2010; Graham, 2013; Hershdorfer et al., 2007; Howle, Straka, & Nespeca, 2010; Larson et al., 2011).

More recently, there has been increased effort to understand landowners' interest and ability to engage in collective and/or cooperative management of invasive plants beyond individual property boundaries (e.g., Epanchin-Niell et al., 2010; Graham, 2013; Graham & Rogers, 2017; Marshall, Coleman, Sindel, Reeve, & Berney, 2016; Niemiec et al., 2016; Niemiec, Pech, et al., 2017; Niemiec, Ardoin, et al., 2017; Sullivan, York, An, et al., 2017; Sullivan, York, White, et al., 2017; Yung et al., 2015). Collective, and/or cooperative, invasive plant management tends to be more effective than individual, uncoordinated management (Epanchin-Niell & Wilen, 2015; Hershdorfer et al., 2007). So far, research has suggested that landowners' willingness to collectively manage invasive species is influenced by their knowledge of invasive species; access to relevant information; joint learning about the interdependent social and ecological systems; as well as time, money, and other resources they must contribute (Graham, 2013; Ravnborg & Westermann, 2002). More importantly, their willingness to engage in collective and/or cooperative management also depends on their relationship with neighbors and a sense of community (Graham, 2013; Graham & Rogers, 2017; Marshall et al., 2016), past management by neighbors (Epanchin-Niell & Wilen, 2015; Hershdorfer et al., 2007; Klepeis, Gill, & Chisholm, 2009; McKiernan, 2017; Yung et al., 2015), and social norms and community reciprocity (Graham, 2013; Marshall et al., 2016; Niemiec et al., 2016; Ravnborg & Westermann, 2002). In government-organized cooperative weed management programs, the level of trust landowners have towards government employees can be a significant deciding factor in terms of landowners' decision to participate (Graham, 2013).

The aforementioned literature provides important insights into individual and collective invasive plant management on private lands; however, the majority of studies have focused on farmers, ranchers, urban gardeners, and community residents (Head, 2017). Few studies have investigated invasive plant management specific to forestlands, particularly the role of family forest owners (FFOs) in the United States. FFOs are an important group to study in the context of invasive plants management in forest ecosystems in the United States because a substantial portion of American forests (36%) are owned by 10.7 million FFOs, a subset of private forest landowners who are mostly forest-owning individuals, families, and family partnerships (Butler et al., 2016a). Although each FFO is only responsible for their property, they can have a strong cumulative influence on the outcome of invasive plant control efforts at the landscape scale. FFOs opting not to control invasive plants would allow their land to act as invader propagule sources, increasing control costs for neighboring private and public landowners (Daab & Flint, 2010; Epanchin-Niell et al., 2010; Hershdorfer et al., 2007).

To date, only a handful of studies have examined FFOs' awareness, risk perceptions, and management intentions and behaviors regarding invasive plants. For example, Howle et al. (2010) reported qualitative results from focus groups with FFOs in South Carolina regarding how they perceived Chinese privet (*Ligustrum sinense*) management, particularly the feasibility of herbicide control and treatment efficiency. Steele et al. (2006 and 2008) both focused on FFOs in West Virginia and found through their qualitative interviews and a mail survey that the majority of FFOs were aware of invasive plant problems, among which the majority had undertaken control measures. In a different study, Fischer and Charnley (2012) also reported results from a mail survey and qualitative interviews of FFOs in Oregon's ponderosa pine zone. Specifically, they show that being aware or concerned about invasive plants and holding a wildlife or biodiversity ownership objective were both important predictors of whether a FFO would control invasive plants on her property. As such, there is a knowledge gap in understanding FFOs' perceptions and actions regarding invasive plants, particularly in the Midwestern United States where no study of invasive plant management on family forests have been conducted.

Beyond invasive plant management, substantially more research has been conducted to identify factors influencing FFO behaviors and decision making in other contexts such as timber harvesting, wildlife habitat improvement, fire management, and participation in government-sponsored assistance programs. Factors include landownership characteristics such as acreage, landowner absentee status, length of land tenure, landownership objectives, having a written forest management plan, and landowner past management activities (e.g., Fischer, 2011; Gill, Klepeis, & Chisholm, 2010; Joshi & Arano, 2009; Ma, Butler, Kittredge, & Catanzaro, 2012; Silver, Leahy, Weiskittel, Noblet, & Kittredge, 2015). Socio-demographic characteristics such as landowner age, education, gender, income, occupation, and membership in a landowner association or environmental organization have also been found to influence FFO behaviors and decision making in some contexts (e.g., Ma, Butler, et al., 2012; Joshi & Arano, 2009). Finally, while knowledge and awareness is a precursor to taking actions, previous research has also shown that knowledge transfer to landowners is not sufficient to influence behavioral change (McLeod, Hine, Please, & Driver, 2015), and that other psychological, cognitive, social, economic, and institutional factors also play important roles such as environmental values (Farmer, Meretsky, Knapp, Chancellor, & Fischer, 2015), social norms (Karppinen & Berghäll, 2015), community structure and diversity (Paveglio, Jakes, Carroll, & Williams, 2009), and having access to financial and technical assistance (Kilgore et al., 2015).

We draw upon findings from these studies that examined FFO behaviors, intentions and attitudes in a wide range of contexts to examine whether they are also instructive in helping to understand FFO perceptions and actions relative to invasive forest plants. With a focus on FFOs in Indiana, our study asks the following questions: (1) To what extent are FFOs aware of and concerned about invasive forest plants, including herbaceous plants, shrubs and trees? (2) What actions have FFOs taken to prevent and control invasive forest plants on their forestlands? (3) What are the challenges and opportunities FFOs face regarding invasive forest plant management? This study is descriptive in nature, designed to establish a foundational understanding of FFOs' invasive plant-related awareness, risk perceptions, management intentions and behaviors, providing a basis for generating hypotheses for further quantitative investigations and for identifying gaps and tensions for future in-depth qualitative inquiries (Grimes & Schulz, 2002). We chose to conduct descriptive research in our study context because

descriptive research "often illuminates knowledge that we might not otherwise notice or even encounter" and creates opportunities for producing "new knowledge about value systems or practices" that may have not been identified previously (Knupfer & McLellan, 1996, p. 1197).

2. Methods

2.1. Study site

Indiana has approximately 4.9 million acres of forestlands, comprising 20% of the state's land (Gormanson, 2014). Of this land base, 3.6 million acres are owned by FFOs and the average size of family-owned forestlands that are 10+ acres in Indiana is 37.8 acres (15 ha) (Butler et al., 2016b). Hardwoods are the dominant species in Indiana's forests, and oak/hickory forests are the most common, occupying 72% of all forestlands (Gormanson, 2014). Within the state, several federal and state programs are available to provide technical, cost-share, and other financial assistance to help landowners improve wildlife habitat, protect wetlands, protect soil and water quality, and establish conservation easements. Some of these programs also assist landowners who want to control invasive plants, such as the Community and Urban Forestry Assistance Grant program operated by Indiana Department of Natural Resources and the Environmental Quality Incentives Program administered by the USDA National Resources Conservation Service. In addition, Indiana's Classified Forest and Wildlands Program provides landowners with a property tax reduction in exchange for developing and following a professionally written management plan that encourages timber production, watershed protection, and wildlife habitat management on private lands in Indiana.

2.2. Data collection and analysis

The data for this study were collected through a statewide mail survey of FFOs across Indiana. To assemble a sampling frame for the survey, we used statewide forest parcel data available through IndianaMap (http://www.indianamap.org/) and property ownership information from the Indiana Department of Local Government Finance to identify the forested parcels with landowner information. After deleting industrial and organizational owners and other erroneous entries, we obtained a list of 163,666 FFOs who own at least one acre (0.40 ha) of forested property categorized as "woodland" or "classified forest" in the state of Indiana as of 2014. Power calculations suggest that 2600 FFOs will allow us to capture small effect sizes with 80% power assuming a 5% significance level (Cohen, 1988). We then drew a random sample of 2600 FFOs from this list, and administered a mail survey following the Tailored Design Method (Dillman, Smyth, & Christian, 2014). Specifically, we sent out a pre-notification postcard, followed by a survey package that contained a cover letter explaining the purpose of our survey and inviting participation, a copy of the survey questionnaire, a pre-addressed, pre-stamped return envelope, and a $2 bill as a token of appreciation. We followed up with a reminder postcard and two more mailings of the survey package without additional $2 bills. The survey was administered from November to December 2015. Of the 2600 initial FFOs contacted, 112 had inaccurate or unreachable addresses and 64 were deceased or no longer owning woodland, reducing the actual sample size to 2424. Among these 2424 FFOs, 1422 completed the survey questionnaire, representing a response rate of 58.7%.

The questionnaire was informed by 23 face-to-face, semi-structured interviews with selected forestry professionals and FFOs in Indiana between February and May of 2015. The questionnaire contained 43 binary, Likert-scale, and multiple choice questions covering: (1) general characteristics of the woodlands owned by respondents, (2) their familiarity with invasive plants in general, on their properties, and on nearby woodlands, (3) previous invasive forest plant management actions and likelihood to take actions in the future, (4) perceived needs and opportunities for invasive plant management in Indiana, and (5) demographic characteristics of the respondents. We also provided a definition of invasive plants on the cover of the survey questionnaire to ensure a shared understanding of the concept. The study was approved by Purdue University's Institutional Review Board.

Potential non-response bias was examined. As a proxy for detecting differences between respondents and non-respondents, we compared responses from early (first 10%) and late (last 10%) survey respondents (Armstrong & Overton, 1977) with respect to respondents' demographic characteristics, characteristics of their woodlands, familiarity and attitudes towards invasive plants, and their past management actions. No statistically significant differences ($p \leq 0.05$) were detected. Univariate descriptive statistics were computed for all variables to assess their distributions and determine if any outliers existed. Bivariate relationships were examined using the following tests: (1) Pearson Chi-square test, which assesses whether two categorical variables of interest are independent of each other; (2) Kruskal-Wallis H test, which is the nonparametric alternative to the one-way ANOVA; and, (3) Fisher's exact test, which is used when one or more assumptions of performing a chi-square test are violated. These statistical analyses were used to understand the relationships between FFOs' awareness, management actions, concerns, needs and preferences and to identify similarities and differences across FFO types. The software package used for the statistical analyses was Stata 12.0.

3. Results

3.1. Profile of respondents

As shown in Table 1, 63% of the respondents were at least 61 years old. Seventy-nine percent of the respondents were male, almost half were retired (49%), and 36% had a Bachelor's or graduate degree. On average, respondents reported that one percent of their annual household income was derived from their woodland. They also reported owning woodlands mostly for amenity reasons, such as enjoying scenery or protecting wildlife habitat, rather than for the purpose of producing timber products. Respondents owned between 1 and 2000 acres (0.40–809 ha) of woodland (mean = 82 acres; SD = 135.4). More specifically, 11% owned less than 10 acres, 14% owned 10–19 acres, 28% owned 20–49 acres, 22% owned 50–99 acres, and 25% owned 100 or more acres (Table 2). Over half (52%) of respondents shared landownership with their spouse or another individual, 36% had individual ownership, and the remaining 12% had joint ownership with two or more people. On average, respondents owned their woodland for 25 years, although 9% were new owners with five or fewer years of experience and 8% were long-term owners with 50 years or more of experience. Thirty percent of respondents were considered absentee owners who lived more than one mile away from their woodland. Less than a quarter of respondents had a written forest management plan (21%), 35% had participated in the Indiana Classified Forest and Wildlands Program, and 13% were members of an environmental, conservation or woodland owner organization. Seventy-three percent of respondents indicated that their woodland was either currently (57%) or previously (16%) farmed.

3.2. Familiarity with and concern about invasive plants

Respondents had varying levels of familiarity with invasive plants. Forty percent indicated that they could identify some or all invasive plant species around where they live, 26% knew about invasive plants but could not identify specific species, and 34% reported little to no familiarity. The ways FFOs first became aware of invasive plants on their woodland were from forestry or natural resource professionals such as public and private foresters (30%), through forestry newsletters or magazines (29%), through learning about them from newspapers,

Table 1
Demographic and landownership characteristics of survey respondents.

Characteristics (unit if applicable)	Type of variable (categorical or continuous)	% or mean (std. dev.)	n
Age (years)	20–40	3.4%	1317
	41–60	33.6%	
	61–80	52.2%	
	> 80	10.7%	
Retired	Yes	49.0%	1350
Gender	Male	78.8%	1329
Education	Less than high school/GED	2.8%	1332
	High school/GED	33.0%	
	Some college	20.2%	
	Associate's degree	7.5%	
	Bachelor's degree	18.2%	
	Graduate degree	18.3%	
Income	Less than $25,000	9.1%	1108
	$25,000–$49,999	25.5%	
	$50,000–$99,999	34.7%	
	$100,000–$149,999	15.7%	
	$150,000–$199,999	6.3%	
	$200,000 or more	8.7%	
Percent of household's annual income derived from woodland (%)	Continuous (range: 0–100)	0.98 (4.14)	1205
Member of a conservation, environmental, or woodland owners' organization	Yes	12.8%	1331
Size of woodland owned (acres)	Continuous	81.64 (135.44)	1358
No. of people as part of woodland ownership	1	36.3%	1359
	2	52.1%	
	3 or more	11.6%	
Primary residence on or within one mile of woodland	Yes	70.2%	1374
Woodland as part of a farm	Yes, currently farmed	56.7%	1368
	Yes, previously farmed	16.4%	
	No, not part of a farm	26.8%	
Ownership objectives [a]	To enjoy beauty or scenery	78.7%	1325
	To protect nature or biological diversity	69.5%	1304
	To protect or improve wildlife habitat	73.3%	1328
	To protect water resources	59.9%	1293
	For land investment	52.7%	1284
	Is part of my home site/primary residence	57.6%	1293
	Is part of my cabin or vacation home site	19.3%	1168
	Is part of my farm	59.2%	1272
	For privacy	63.3%	1300
	To raise my family	50.5%	1243
	To pass land onto my children or other heirs	68.1%	1315
	For firewood	29.7%	1288
	For timber products	33.3%	1289
	For nontimber forest products	27.9%	1289
	For hunting	49.8%	1322
	For recreation, other than hunting	51.1%	1302
How woodland was acquired (categories not mutually exclusive)	Purchased	84.0%	1374
	Inherited	24.4%	
	Received as a gift	2.3%	
Length of ownership (years)	Continuous	25.48 (15.71)	1324
Having a written management plan	Yes	21.3%	1370
Enrolled in the Indiana Classified Forest and Wildlands Program	Yes	35.4%	1374

[a] The survey question was stated as "How important are the following as reasons for why you currently own wooded land in Indiana?" Options provided to respondents for each line item were: "very important," "important," "moderately important," "of little importance," "not important," and "not applicable." The percentages presented here were the combined percentages of respondents who chose "very important" and "important."

television, radio, and other forms of mass media (22%), and from family and friends (20%). Those who could identify invasive plants reported noticing various species (Table 3): the most common were multiflora rose (*Rosa multiflora*), Asian bush honeysuckle (*Lonicera maacki*), Japanese honeysuckle (*Lonicera japonica*), autumn olive (*Eleagnus umbellata*), and garlic mustard (*Alliaria petiolata*).

Some respondents reported little to no concern about invasive plants on their woodlands (23%) or neighboring/nearby lands (32%), but 42% were concerned or very concerned about invasive plants on their own woodland while 35% were concerned or very concerned about invasives on neighboring/nearby lands. Regarding potential negative impacts of invasive plants, half or more respondents were concerned about invasive plants negatively impacting new tree growth, decreasing the beauty of woodlands, reducing timber value and property value, and negatively impacts the use or enjoyment of woodlands. Fewer than half respondents were concerned about invasive plants' impacts on wildlife, hunting, or other recreational values of the woodlands (Fig. 1).

Generally speaking, respondents' familiarity with invasive plants differed based on their socio-demographic characteristics (Table 4). Older and retired respondents were more likely to have little to no familiarity with invasive plants. Those with higher education levels, higher household incomes, and memberships in conservation, environmental or woodland owner organizations, were more familiar with invasive plants, as were those who had more woodlands, who had a written management plan, whose woodlands were enrolled in the Indiana Classified Forest Program, and whose woodlands were currently or previously farmed. Familiarity with invasive plants was not, however, associated with respondents' gender, whether they were absentee landowners, or the length of their landownership.

Respondents' concerns with invasive plants also differed based on their socio-demographic characteristics (Table 4). The same set of

Table 2
A comparison of demographic and landownership characteristics of survey respondents, FFOs in Indiana, and FFOs in the United States.

Demographics of primary owner	FFOs in this study	FFOs in Indiana[a]	FFOs in the United States[a]
Age: < 45	7%	7%	7%
Age: 45–54	16%	24%	20%
Age: 55–64	29%	30%	30%
Age: 65–74	28%	19%	25%
Age: 75+	19%	20%	18%
Retired	49%	51%	51%
Gender: male	79%	82%	79%
Education: less than high school/GED	3%	4%	6%
Education: high school/GED	33%	25%	25%
Education: some college	20%	27%	22%
Education: Associate's degree	8%	9%	9%
Education: Bachelor's degree	18%	20%	21%
Education: graduate degree	18%	15%	18%
Income: < $25,000	9%	8%	13%
Income: $25,000–$49,999	26%	33%	26%
Income: $50,000–$99,999	35%	45%	35%
Income: $100, 000–$199,999	22%	9%	17%
Income: > =$200,000	9%	5%	8%
Size of woodland holdings: 1–9 acres	11%	N/A	N/A
Size of woodland holdings: 10–19 acres	14% (16%)[b]	43%	35%
Size of woodland holdings: 20–49 acres	28% (32%)[b]	36%	35%
Size of woodland holdings: 50–99 acres	22% (25%)[b]	14%	16%
Size of woodland holdings: 100–199 acres	15% (17%)[b]	5%	9%
Size of woodland holdings: 200–499 acres	8% (9%)[b]	1%	4%
Size of woodland holdings: 500–999 acres	1% (1%)[b]	< 1%	< 1%
Size of woodland holdings: 1000+ acres	1% (1%)[b]	< 1%	< 1%
Having a written management plan	21%	7%	13%
No. of people as part of woodland ownership: 1	36%	23%	31%
No. of people as part of woodland ownership: 2	52%	66%	58%
No. of people as part of woodland ownership: 3–5	10%	10%	9%
No. of people as part of woodland ownership: 6+	2%	2%	3%
Primary residence on or within one mile of woodland[c]	70%	72%	63%
Woodland as part of a farm: currently farmed	57%	46%	38%
Woodland as part of a farm: previously farmed	16%	N/A	N/A
Woodland not as part of a farm	27%	N/A	N/A
Length of ownership (years): < 10	17%	15%	19%
Length of ownership (years): 10–24	35%	45%	38%
Length of ownership (years): 25–49	40%	31%	36%
Length of ownership (years): 50+	8%	9%	7%
Eliminated or reduced invasive plants on own woodland in the past five years	28%	30%	24%
Plans to remove invasive plants from own woodland in the next five years	50%[d]	33%[e]	29%[e]

[a] The challenge is that the Indiana and U.S. descriptive statistics are not directly comparable to our sample descriptive statistics. This is because the descriptive statistics of FFOs in Indiana and FFOs in the U.S. are based on the USDA Forest Service, Forest Inventory and Analysis Program, National Woodland Owner Survey (NWOS) results from 2011 to 2013 (https://www.fia.fs.fed.us/nwos/results/). The NWOS summary tables released by the USDA Forest Service are only for family forestlands that are 10+ acres. This needs to be taken into consideration when reading Table 2.

[b] Percentages in parentheses were calculated using our sample of FFOs who own woodlands that are 10+ acres to be comparable with NWOS data in Indiana and nationally.

[c] In our survey this question was stated as "Is your wooded land part of a farm that is currently farmed or that was previously farmed?" Options provided to respondents were: "yes, currently farmed," "yes, previously farmed," and "no, not part of a farm." However, there was no equivalent question asked in the NWOS. The closest question in NWOS was a question about ownership reasons broadly with a line item being "Is part of my farm or ranch." The question was stated as "How important are the following as reasons for why you currently own your wooded land in Indiana?" Options provided to respondents for each line item were: "very important," "important," "moderately important," "of little importance," "not important," and "not applicable." The percentage presented here for Indiana and the U.S. were the combined percentages of respondents who chose "very important" and "important."

[d] In our survey this question was stated as "Generally speaking, how likely are you to undertake activities to remove invasive plants from your wooded land in Indiana in the next five years?" Options provided to respondents were: "very likely," "likely," "undecided," "unlikely," "very unlikely," and "not applicable." The percentage presented here was the combined percentages of respondents who chose "very likely" and "likely."

[e] There was no equivalent question asked in the NWOS. The closest question in NWOS was stated as "How important are the following as reasons for why you currently own your wooded land in Indiana?" with a line item being "Eliminate or reduce invasive species." Options provided to respondents were: "extremely likely," "likely," "undecided," "unlikely," and "extremely unlikely." The percentage presented here was the combined percentages of respondents who chose "extremely likely" and "likely."

variables are associated with both concerns about invasive plants on their own woodlands and concerns about invasive plants on neighboring or nearby woodlands. Specifically, respondents with higher levels of education and memberships in conservation, environmental or woodland owner organizations were more likely to be concerned about invasive plants. Those who had more woodlands, who had a written management plan, and whose woodlands were enrolled in the Indiana Classified Forest Program, were also more likely to be concerned about invasive plants. Respondents' levels of concerns about invasive plants on their own or neighboring/nearby woodlands were not, however, associated with respondents' age, retirement status, gender, income, resident/absentee status, the length of their landownership, or whether their woodlands were currently or previously farmed. Generally speaking, respondents who were more familiar with invasive plants were more concerned about them on both their own and neighboring/nearby woodlands.

Table 3
Invasive plant species that survey respondents reported noticing on their woodlands in Indiana.

Invasive plant species identified	% of respondents
Multiflora rose *(Rosa multiflora)*	64%
Asian bush honeysuckle *(Lonicera maackii)*	33%
Japanese honeysuckle *(Lonicera japonica)*	29%
Autumn olive *(*Eleagnus umbellata*)*	28%
Other written-in examples: Russian olive *(Elaeagnus angustifolia)*, wild grape *(Vitis vinifera)*, canary grass *(Phalaris canariensis)*, etc.	23%
Garlic mustard *(Alliaria petiolata)*	20%
Tree of heaven *(Ailanthus altissima)*	19%
Burning bush *(Euonymus alatus)*	13%
Common buckthorn *(Rhamnus cathartica)*	8%
Japanese stilt grass *(Microstegium vimineum)*	6%
Periwinkle *(Vinca minor)*	6%
Winter creeper *(Euonymus fortunei)*	5%
Japanese barberry *(Berberis thunbergii)*	4%
Callery pear or Bradford pear *(Pyrus calleryana)*	4%
Privet *(Ligustrum vulgare)*	4%
Glossy buckthorn *(Rhamnus frangula)*	2%
Paulownia *(Paulownia tomentosa)*	1%

3.3. Past and future invasive plant management actions

Of the 14 possible invasive plant-related actions respondents could have taken in the past five years, the three most common were: pulling or cutting invasive plants on their woodlands (39%), inspecting their woodlands for invasive plants (34%), and applying herbicides to kill invasive plants on their woodlands (31%) (Fig. 2). In contrast, only 2% of respondents had worked with their neighbors to remove invasive plants from both owners' woodlands, although some had initiated discussions among peers about invasive plants. Specifically, 14%, 8%, and 10% of respondents, respectively, had talked to their family, neighboring landowners, and other non-neighboring landowners about invasive plants. Overall, 38% of respondents reported having done no invasive plant management in the past five years.

Forty-three percent of respondents reported that they were likely or very likely to undertake activities to prevent invasive plants from establishing on their woodlands in the next five years, while 50% were likely or very likely to remove invasive plants from their woodlands. Specifically, respondents reported that they were likely or very likely to inspect their woodlands for invasive plants (66%), pull or cut invasive plants on their woodlands (59%), and search for information on the Internet (47%) in the next five years (Fig. 2). Additionally, larger proportions of respondents (43%, 26%, and 27% respectively) indicated plans (likely or very likely) to talk to their family, neighboring landowners, and other non-neighboring landowners about invasive plants than the proportions of respondents who had done so in the past five years.

A number of landowner socio-demographic characteristics were associated with respondents having managed invasive plants in the past five years (Table 4). Specifically, younger and male respondents were more likely to report having eliminated or reduced invasive plants on their properties. Respondents with more education, higher household income, or membership in a conservation, environmental or woodland owner organization, were also more likely to report having managed invasive plants. Additionally, respondents who owned more woodlands, who had a written management plan, or whose woodlands were enrolled in the Indiana Classified Forest Program, were more likely to have managed invasive plants.

Regarding future plans, the likelihood that respondents would remove invasive plants in the next five years was associated with a larger set of socio-demographic characteristics compared to their past efforts (Table 4). Specifically, older, retired, and longer-tenure respondents were less likely to report plans to remove invasive plants on their woodlands in the next five years. Respondents with higher education levels, higher household incomes, or memberships in a conservation, environmental or woodland owner organization, were more likely to report plans to remove invasive plants, as were males and those who lived on or near their woodlands. Additionally, respondents who owned more woodlands, who had a written management plan, or whose woodlands were enrolled in the Indiana Classified Forest Program, were more likely to report plans to remove invasive plants. In terms of preventing invasive plants from establishing on one's woodlands, the likelihood of respondents taking actions in the next five years was associated with a similar set of socio-demographic characteristics as the likelihood of removing invasive plants (Table 4). The only difference was that resident/absentee status was not associated with likelihood of prevention. Overall, respondents' plans for prevention and removal were not associated with whether their woodlands were currently or previously farmed, but were associated with their past experience of eliminating and reducing invasive plants.

3.4. Confidence in taking actions and potential barriers

Respondents were asked to indicate their levels of confidence in their ability to manage invasive plants. Fifty-nine percent felt little or no confidence in their ability to prevent invasive plants from establishing on their woodlands, while 49% felt little or no confidence in their ability to remove invasive plants from their woodlands. Respondents' levels of confidence were associated with various socio-demographic variables. Specifically, respondents who were male, who were members in conservation, environmental or woodland owner organizations, or who had a written management plan, were more

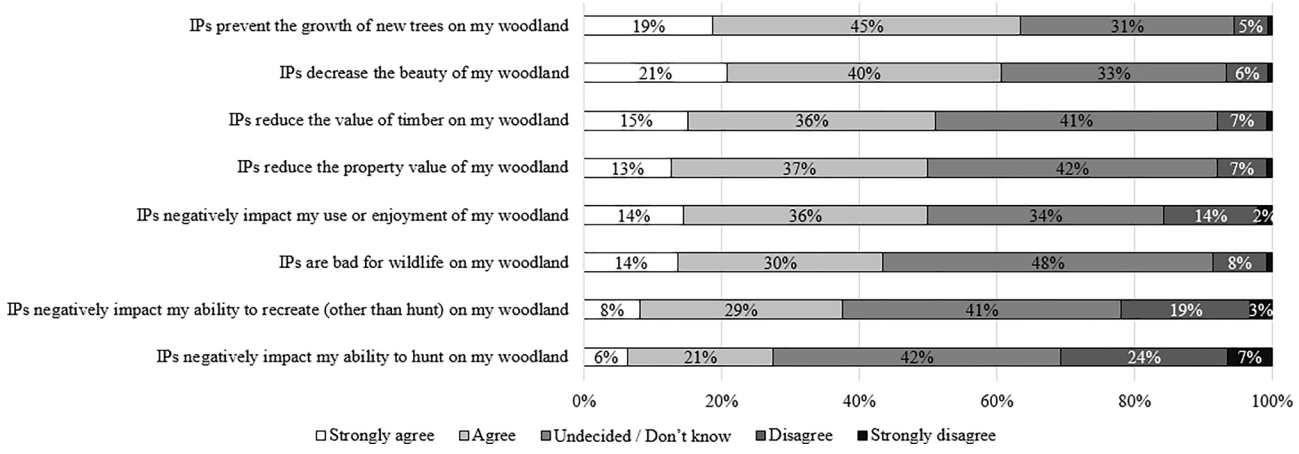

Fig. 1. Survey respondents' perceptions of potential negative impacts of invasive plants (*Note:* IP stands for invasive plant).

Table 4
Summary of statistical relationships between landowner/landownership characteristics and FFOs' familiarity with and concern about invasive plants (IPs), as well as their level of confidence in, interest in and support for invasive plant management.

	Familiarity with IPs	Concerns about IPs on own woodlands	Concerns about IPs on neighboring/ nearby woodlands	Confidence in own ability to prevent IPs	Confidence in own ability to remove IPs	Having eliminated or reduced IPs in the past five years	Likelihood to prevent IPs in the next five years	Likelihood to remove IPs in the next five years	Agreement with statement "removing IPs from privately-owned wooded land should be required by law in Indiana"
Age (older)	− [a] $\chi^2 = 18.836$, $p < 0.001$	NS [b] $\chi^2 = 1.649$, $p = 0.800$	NS $\chi^2 = 4.632$, $p = 0.327$	NS $\chi^2 = 0.299$, $p = 0.584$	− $\chi^2 = 28.085$, $p < 0.001$	− $\chi^2 = 4.738$, $p = 0.030$	− $\chi^2 = 32.398$, $p < 0.001$	− $\chi^2 = 41.459$, $p < 0.001$	NS $\chi^2 = 0.773$, $p = 0.942$
Retired	− $\chi^2 = 22.3968$, $p < 0.001$	NS $\chi^2 = 5.0290$, $p = 0.284$	NS $\chi^2 = 6.3225$, $p = 0.176$	− $\chi^2 = 13.6854$, $p = 0.008$	− $\chi^2 = 41.3686$, $p < 0.001$	NS $\chi^2 = 2.7271$, $p = 0.099$	− $\chi^2 = 23.2414$, $p < 0.001$	− $\chi^2 = 32.7863$, $p < 0.001$	NS $\chi^2 = 4.9419$, $p = 0.293$
Gender (male)	NS $\chi^2 = 9.3770$, $p = 0.052$	NS $\chi^2 = 6.5567$, $p = 0.161$	NS $\chi^2 = 5.9983$, $p = 0.199$	+ [c] $\chi^2 = 42.8470$, $p < 0.001$	+ $\chi^2 = 68.8369$, $p < 0.001$	+ $\chi^2 = 15.9963$, $p < 0.001$	+ $\chi^2 = 29.6457$, $p < 0.001$	+ $\chi^2 = 33.3318$, $p < 0.001$	NS $\chi^2 = 6.0556$, $p = 0.195$
Education (higher)	+ $\chi^2 = 92.4097$, $p < 0.001$	+ $\chi^2 = 16.0492$, $p = 0.042$	+ $\chi^2 = 27.4547$, $p = 0.001$	− $\chi^2 = 24.4106$, $p = 0.002$	NS $\chi^2 = 9.6451$, $p = 0.291$	+ $\chi^2 = 21.5930$, $p < 0.001$	+ $\chi^2 = 20.5394$, $p = 0.008$	+ $\chi^2 = 28.9215$, $p < 0.001$	− $\chi^2 = 16.7236$, $p = 0.033$
Income (higher)	+ $\chi^2 = 17.5420$, $p = 0.025$	NS $\chi^2 = 12.5245$, $p = 0.251$	NS $\chi^2 = 14.2528$, $p = 0.817$	NS $\chi^2 = 8.1727$, $p = 0.147$	NS $\chi^2 = 11.9872$, $p = 0.152$	+ $\chi^2 = 11.1372$, $p = 0.049$	+ $\chi^2 = 48.4664$, $p < 0.001$	+ $\chi^2 = 18.4035$, $p = 0.018$	NS $\chi^2 = 13.5328$, $p = 0.095$
Membership in a conservation, environmental or woodland owner organization	+ Fisher's exact $p < 0.001$	+ $\chi^2 = 61.1601$, $p < 0.001$	+ $\chi^2 = 60.6541$, $p < 0.001$	+ $\chi^2 = 12.9728$, $p = 0.011$	+ $\chi^2 = 24.9652$, $p < 0.001$	+ $\chi^2 = 75.5487$, $p < 0.001$	+ $\chi^2 = 68.5322$, $p < 0.001$	+ $\chi^2 = 92.1092$, $p < 0.001$	+ $\chi^2 = 22.2126$, $p < 0.001$
Acreage (larger)	+ $\chi^2 = 84.934$, $p < 0.001$	+ $\chi^2 = 53.481$, $p < 0.001$	+ $\chi^2 = 31.077$, $p < 0.001$	NS $\chi^2 = 2.164$, $p = 0.141$	+ $\chi^2 = 6.297$, $p = 0.012$	+ $\chi^2 = 68.223$, $p < 0.001$	+ $\chi^2 = 25.338$, $p < 0.001$	+ $\chi^2 = 33.785$, $p < 0.001$	NS $\chi^2 = 3.516$, $p = 0.4755$
Being a resident owner (not an absentee owner)	NS $\chi^2 = 6.0899$, $p = 0.193$	NS $\chi^2 = 4.7069$, $p = 0.319$	NS $\chi^2 = 1.7963$, $p = 0.773$	NS $\chi^2 = 8.0573$, $p = 0.090$	+ $\chi^2 = 10.2937$, $p = 0.036$	NS $\chi^2 = 3.2681$, $p = 0.071$	NS $\chi^2 = 5.9195$, $p = 0.205$	+ $\chi^2 = 10.0517$, $p = 0.040$	NS $\chi^2 = 0.3738$, $p = 0.985$
Length of ownership (longer)	NS $\chi^2 = 1.843$, $p = 0.1747$	NS $\chi^2 = 1.395$, $p = 0.498$	NS $\chi^2 = 0.838$, $p = 0.658$	NS $\chi^2 = 0.020$, $p = 0.8865$	− $\chi^2 = 6.052$, $p = 0.014$	NS $\chi^2 = 0.192$, $p = 0.661$	− $\chi^2 = 5.845$, $p = 0.016$	− $\chi^2 = 4.265$, $p = 0.039$	NS $\chi^2 = 3.836$, $p = 0.4286$
Woodlands previously or currently farmed	+ $\chi^2 = 15.3930$, $p = 0.004$	NS $\chi^2 = 2.1713$, $p = 0.704$	NS $\chi^2 = 2.4183$, $p = 0.659$	NS $\chi^2 = 0.4831$, $p = 0.975$	NS $\chi^2 = 1.2524$, $p = 0.869$	NS $\chi^2 = 0.5070$, $p = 0.476$	NS $\chi^2 = 3.4066$, $p = 0.492$	NS $\chi^2 = 4.5352$, $p = 0.338$	NS $\chi^2 = 2.1610$, $p = 0.706$
Having a written management plan	+ $\chi^2 = 137.6236$, $p < 0.001$	+ Fisher's exact $p < 0.001$	+ $\chi^2 = 51.5573$, $p < 0.001$	+ $\chi^2 = 19.9943$, $p = 0.001$	+ $\chi^2 = 34.1177$, $p < 0.001$	+ $\chi^2 = 175.6569$, $p < 0.001$	+ $\chi^2 = 106.4275$, $p < 0.001$	+ $\chi^2 = 140.1035$, $p < 0.001$	+ $\chi^2 = 10.5485$, $p = 0.032$
Enrolled in the Indiana Classified Forest Program	+ $\chi^2 = 82.0214$, $p < 0.001$	+ $\chi^2 = 45.4454$, $p < 0.001$	+ $\chi^2 = 32.3284$, $p < 0.001$	NS $\chi^2 = 7.0642$, $p = 0.133$	+ $\chi^2 = 14.3237$, $p = 0.006$	+ $\chi^2 = 139.1240$, $p < 0.001$	+ $\chi^2 = 52.5860$, $p < 0.001$	+ $\chi^2 = 72.2611$, $p < 0.001$	NS $\chi^2 = 9.2182$, $p = 0.056$
Familiarity with IPs (more familiar)	TNR	+ $\chi^2 = 127.4896$, $p < 0.001$	+ $\chi^2 = 142.5994$, $p < 0.001$	+ $\chi^2 = 100.1690$, $p < 0.001$	+ $\chi^2 = 302.1841$, $p < 0.001$	TNR [d]	+ $\chi^2 = 140.6344$, $p < 0.001$	+ $\chi^2 = 195.6997$, $p < 0.001$	− $\chi^2 = 17.5321$, $p = 0.002$
Concerns about IPs on own woodlands	TNR	TNR	TNR	TNR	TNR	TNR	+ $\chi^2 = 175.9711$, $p = 0.056$	+ $\chi^2 = 204.7526$, $p < 0.001$	+ Fisher's exact $p < 0.001$
Concerns about IPs on neighboring/ nearby woodlands	TNR	TNR	TNR	TNR	TNR	TNR	TNR	TNR	+ Fisher's exact $p < 0.001$

(*continued on next page*)

Table 4 (*continued*)

	Familiarity with IPs	Concerns about IPs on own woodlands	Concerns about IPs on neighboring/nearby woodlands	Confidence in own ability to prevent IPs	Confidence in own ability to remove IPs	Having eliminated or reduced IPs in the past five years	Likelihood to prevent IPs in the next five years	Likelihood to remove IPs in the next five years	Agreement with statement "removing IPs from privately-owned wooded land should be required by law in Indiana"
Confidence in own ability to prevent IPs	TNR	TNR	TNR	TNR	TNR	TNR	+ $\chi^2 = 215.1334$, $p < 0.001$	TNR	TNR
Confidence in own ability to remove IPs	TNR	TNR	TNR	TNR	TNR	TNR	TNR	+ $\chi^2 = 284.5136$, $p < 0.001$	+ $\chi^2 = 21.0667$, $p < 0.001$
Having eliminated or reduced IPs in the past five years	TNR	TNR	TNR	TNR	TNR	TNR	+ $\chi^2 = 217.3093$, $p < 0.001$	+ $\chi^2 = 301.3028$, $p < 0.001$	+ $\chi^2 = 24.2681$, $p < 0.001$
Likelihood to prevent IPs in the next five years	TNR	TNR	TNR	TNR	TNR	TNR	TNR	TNR	TNR
Likelihood to remove IPs in the next five years	TNR	TNR	TNR	TNR	TNR	TNR	TNR	TNR	+ $\chi^2 = 30.9326$; $p < 0.001$

[a] − indicates a statistically significant negative relationship.
[b] NS indicates a non-statistically significant relationship.
[c] + indicates a statistically significant positive relationship.
[d] TNR indicates test that was not run.

confident in their own ability to manage (prevent and remove) invasive plants, whereas those who were retired were less confident. Respondents' levels of confidence in their own ability to prevent or remove invasive plants were not, however, associated with respondents' income or whether their woodlands were currently or previously farmed. Several variables had different relationships with respondents' levels of confidence in preventing versus removing invasive plants. For example, owning more woodlands, being a resident owner, and having land enrolled in the Indiana Classified Forest Program, were not significantly associated with respondents' confidence in preventing invasive plants from establishing on their properties; however, they were significantly associated with higher levels of confidence in removing invasive plants. Similarly, being older and owning woodlands for a longer period of time were not associated with respondents' confidence in preventing invasive plants, but were associated with lower level of confidence in removing invasive plants. Interestingly, while education level was not associated with respondents' confidence in their own ability to remove invasive plants, higher education level was significantly associated with lower level of confidence in preventing invasive plants from establishing on one's property.

Respondents' level of confidence and their likelihood to act were significantly associated (Table 4). The more confident respondents were in their own ability to prevent or remove invasive plants, the more likely they reported having plans to take preventative or removal actions in the next five years. Furthermore, respondents' levels of confidence and their likelihood to act were both significantly associated with their familiarity with invasive plants (Table 4). The more familiar respondents were with invasive plants, the more confident they felt in their own ability to prevent or remove invasive plants and the more likely they were to report plans to prevent or remove invasive plants.

Respondents rated ten factors that might limit their confidence levels regarding invasive plant management (Fig. 3). More than half of respondents (52% and 55%, respectively) agreed or strongly agreed that they had sufficient time to inspect their woodlands for invasive plants and knew who to contact if they had questions about them. However, the majority of respondents disagreed or strongly disagreed that they knew about county, state or federal programs that assist woodland owners in removing invasive plants (82%); had sufficient knowledge to prevent and remove invasive plants (69%); or had sufficient money to remove invasive plants from their woodlands (64%).

3.5. Perceived responsibility and opportunities for invasive plant management

Nearly all respondents disagreed with the statement that "Indiana as a whole is doing enough about preventing and removing invasive plants" from woodlands owned by private individuals and public entities (94% and 94%, respectively). While most (57%) respondents agreed or strongly agreed that Indiana needs some sort of coordinated effort to control invasive plants on publicly-owned woodlands, fewer (43%) agreed or strongly agreed about a similar need for privately-owned woodlands and an equal number of respondents (42%) were undecided. When asked about who should be responsible for managing invasive plants, most respondents believed that private woodland owners themselves should be responsible for prevention (78%) and removal (77%).

In terms of potential effort that the government could make, respondents were most supportive of educating woodland owners (82%) and school children (80%) about invasive plants in Indiana. Fewer respondents (40%) agreed or strongly agreed that removing invasive plants from publicly-owned woodlands should be required by law in Indiana, and only 11% were supportive of such a law for privately-owned woodlands. Respondents were more likely to agree to a law requiring private woodland owners to remove invasive plants if they were concerned or very concerned about invasive plants on their woodlands, felt very confident in their own ability to remove invasive

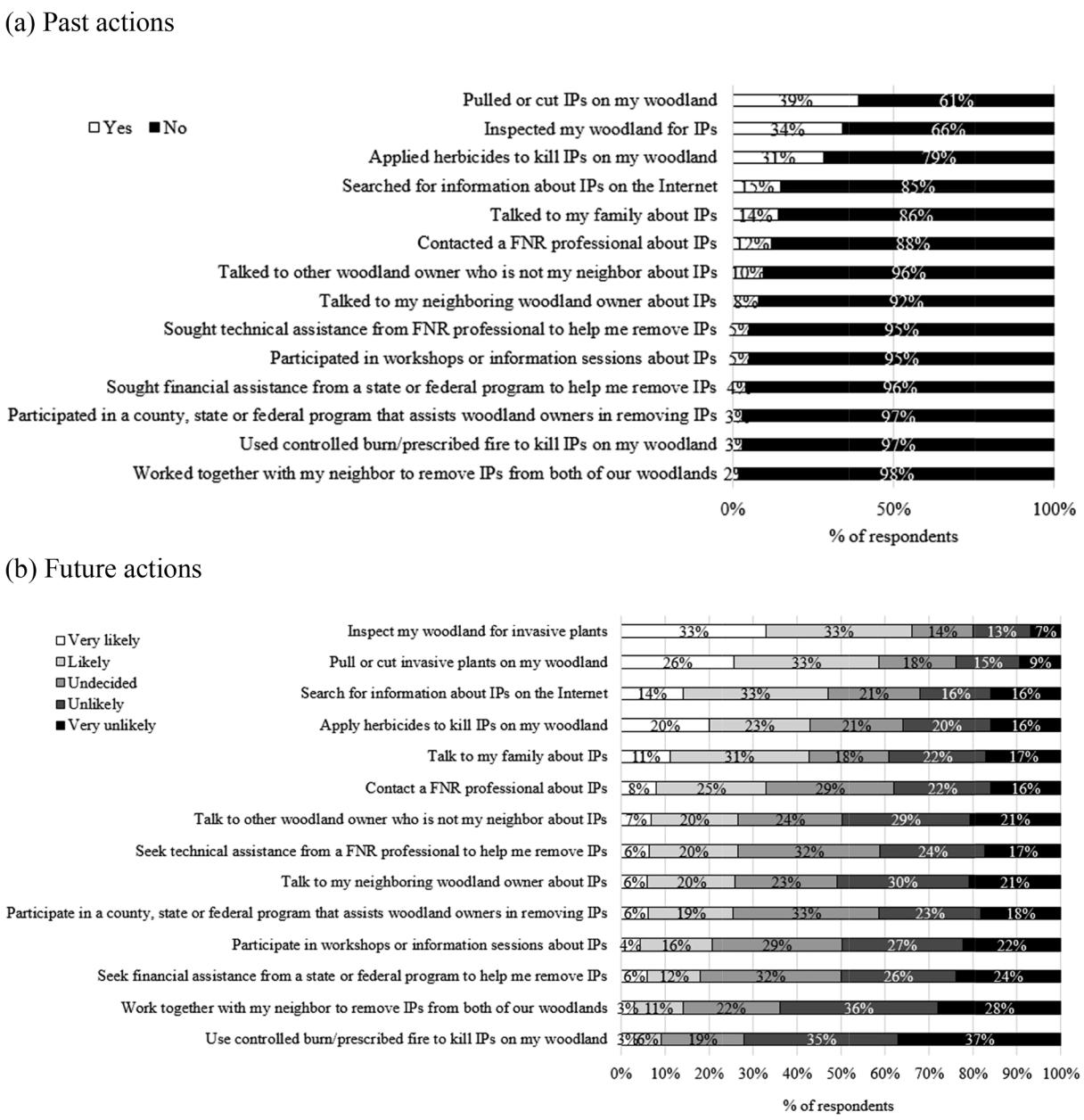

Fig. 2. Survey respondents' self-reported (a) invasive plant management-related activities in the past five years, and (b) their likelihood to undertake these activities in the next five years (*Note:* FNR stands for forestry and natural resources; IP stands for invasive plant; 'None of above' stands for not having taken any action listed in this survey question).

plants, had experience removing invasive plants in the past five years, were more likely to remove invasive plants in the next five years, were members of a conservation, environmental or woodland owner organization, or had a written management plan. It is also worth noting that respondents with more education and respondents who were moderately to very familiar with invasive plants were less supportive of requiring private woodland owners to remove invasive plants. In contrast, respondents were more supportive of regulations targeting the landscaping industries, specifically with laws preventing the sale of invasive plants by nurseries, greenhouses, and retail stores (69%) and requiring businesses to label plants for sale as native or non-native to Indiana (80%). Most respondents (74%) also believed that people should not buy plants that are invasive to Indiana.

When asked about working with others to manage invasive plants, respondents (50%) found working with a non-profit organization, such as a land conservation organization or woodland owner association, to control invasive plants on privately-owned woodlands appealing or very appealing. This was closely followed by working with their neighbors (49% and 47% on prevention and removal, respectively) and other woodland owners in their town, city or county (46% and 43% on prevention and removal, respectively). Working with their town, city, county government (37%) or a state agency (41%) to control invasive plants were viewed slightly less favorably by respondents.

4. Discussion

Generally speaking, our survey respondents are similar to the average FFOs in Indiana and nationwide in terms of their socio-demographic characteristics with two possible meaningful differences (Table 2). First, a larger proportion of our respondents (21%) have a written management plan, in contrast to 13% nationally (for family forestlands that are 10 + acres; Butler et al., 2016b). We will discuss the potential implications of this difference later in this section. Second, a large proportion of our respondents (57%) owned woodlands as part of

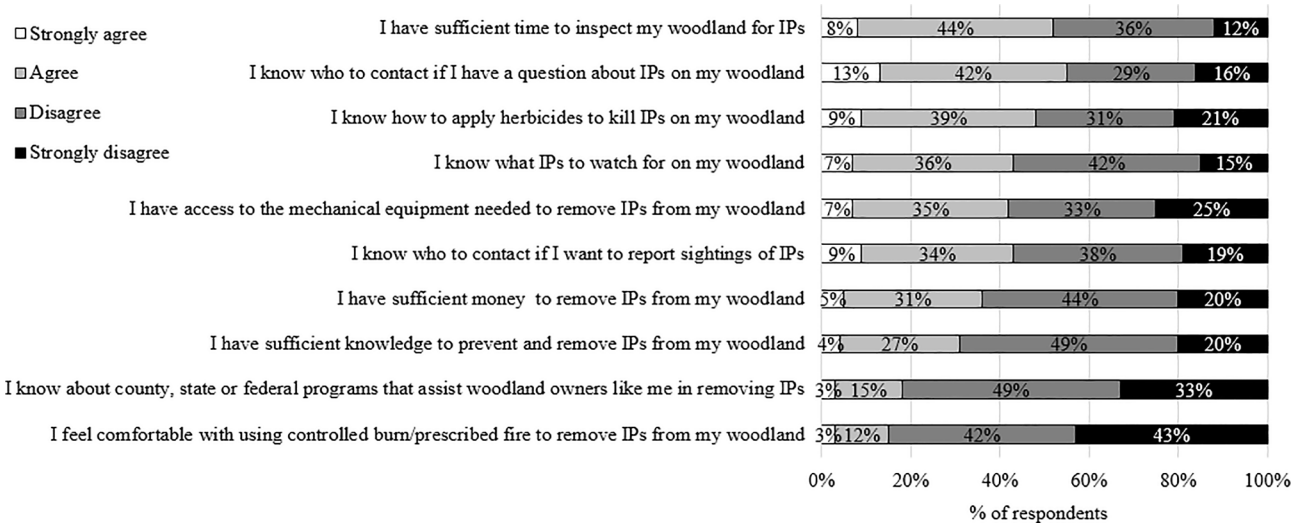

Fig. 3. Factors that might limit the level of confidence survey respondents had with regard to managing invasive plants (*Note:* IP stands for invasive plant).

a current farm, in contrast to 38% nationally (for family forestlands that are 10+ acres; Butler et al., 2016b). Regarding this difference, previous research has been inconclusive about the similarities and differences between FFOs whose woodlands are/were part of a farm and FFOs without connections to farming (e.g., Authors, In review; Erickson, Ryan, & De Young, 2002; Fortney, Arano, & Jacobson, 2011; Hendee & Flint, 2013; Jagnow et al., 2006; Ma, Butler, et al., 2012; Sandberg & Jakobsson, 2018; Silver et al., 2015; Snyder & Butler, 2012; Steele et al., 2006). Our results show that FFOs whose woodlands were previously farmed, or currently part of a farm, were more likely to be familiar with invasive plants; however, they exhibited similar levels of concern, confidence, and past and future actions regarding invasive plant management as those whose woodlands were not part of a farm. As such, our study highlights the need to further explore how FFOs perceive and manage invasive forest plants based on their association with farming. Anecdotally, FFOs with farmlands may have more familiarity with and/or opportunities to participate in government-sponsored outreach and assistance programs by virtue of owning two types of lands, each of which have different programs available to them, as well as peer and professional networks. Therefore, it will be important to empirically test these assumptions and assess the opportunities, as well as equity concerns, associated with potentially uneven access to resources among FFOs.

Overall, our results suggest that many FFOs in Indiana are familiar with invasive forest plants and are already taking management actions, particularly through physical or chemical removal (Fig. 2). This level of awareness and activity may be higher than what forestry professionals in the state have realized, as they generally estimated that less than 20% of FFOs would be aware of invasive plant problems and less than 5% would have done anything at all (Ma et al., 2018). While it is encouraging that many respondents reported awareness and activity around invasive forest plants, 69% of our respondents also reported insufficient knowledge to prevent or remove them. This may be an indication that many FFOs in our study are managing invasive plants even though they do not necessarily know how; a potentially worrisome finding considering the number of FFOs who have used or are contemplating using herbicides to control invasive plants, and the potential impacts of incorrect herbicide applications on ecosystem and human health. Further, our results show that few respondents have interacted with forestry or other natural resource professionals about invasive plant management (Fig. 2). With half of the respondents indicating that they were likely or very likely to prevent and remove invasive plants in the next five years, efforts are needed to ensure that appropriate, scientifically-based information and professional advice reaches FFOs *before* management occurs—a critical decision point identified by Kittredge (2004).

In addition to documenting a general interest in preventing and removing invasive plants among Indiana FFOs, our study suggests that such interest is associated with certain socio-demographic and land-ownership characteristics of FFOs. Specifically, our results suggest that older, retired, and longer-tenure FFOs may have little interest in invasive plant management, which may relate to how physically demanding managing some invasive plant species can be (Ma et al., 2018). This contention is potentially concerning because at least half of the Indiana FFOs fall into these demographic categories. On the other hand, newer and younger FFOs may be more receptive to information about invasive forest plants and relevant management programs. As discussed in Cooke and Lane (2015), there is great potential in promoting experiential learning among newer and younger FFOs, particularly as part of wider social engagement with other experienced FFOs. Such learning through observation, hands-on experiences, and interactions with others can facilitate stewardship development among newer FFOs (Cooke & Lane, 2015). Our finding also furthers current debates about the relationship between length of land tenure and invasive plant management. For example, several studies have found that landowners with longer tenure were less likely to express interest in collectively managing invasive species (McKiernan, 2017; Niemiec, Pech, et al., 2017), while Niemiec, Ardoin, et al. (2017) documented a positive but statistically insignificant relationship between longer-term residency and past invasive plant removal experience in the Puna District of Hawai'i.

We found that FFOs with higher income were more likely to have plans to remove invasive plants, consistent with what other studies have found (Gulezian & Nyberg, 2010; Niemiec et al., 2018). This may be explained by the fact that invasive plant management is generally costly, and landowners with higher incomes may be better able to acquire assistance and services from forestry professionals and to purchase necessary equipment and herbicides for treatment. Like previous studies (Klepeis et al., 2009; Niemiec, Ardoin, et al., 2017; Yung et al., 2015), our result shows that where FFOs live relative to their woodlands is associated with their interest in invasive plant management, with resident FFOs more likely to report having a plan to remove invasive plants on their property in the next five years. However, we did not find a significant relationship between where FFOs live and their level of familiarity with invasive plants or their past invasive plant management. Because invasive plants in forest ecosystems are still relatively new to FFOs (Ma et al., 2018), there might have not been sufficient time for resident and absentee FFOs to differ in their

knowledge and past actions. Additionally, FFOs who are already members in a conservation, environmental or woodland owner organization, and those who have enrolled in the Indiana Classified Forest Program, may be prime audiences for invasive plant-related outreach. These individuals are sometimes referred to as "model" owners, as they tend to be already connected with natural resource professionals and programs (Ma, Kittredge, & Catanzaro, 2012). Nonetheless, they may need a nudge through outreach to prioritize invasive plant problems among other land management activities they consider. Once engaged, these individuals have the potential to serve as influencers to communicate through their networks and encourage invasive plant management in the broader FFO community (Kueper, Sagor, & Becker, 2013; Ma, Kittredge, et al., 2012).

Our results also highlight that FFOs with written forest management plans tend to have greater invasive plant awareness and interest in management, although it is unclear whether invasive plant management was an explicit element of these written plans or if respondents became more aware of invasive plant problems through working with a professional forester to prepare a written plan. Our results confirm previous research showing that FFOs with management plans tend to be more engaged in forest management and conservation (Joshi & Arano, 2009; Ma, Butler, et al., 2012). While it is unrealistic to assume that every FFO will develop a written plan, it may still be an important pathway to enhance invasive plant management among FFOs. For example, when communicating with FFOs about developing written forest management plans, natural resource professionals may consider incorporating specific examples of how invasive plants reduce the beauty, health, and values of woodlands that they would pass on to their children—an important landownership objective for many FFOs.

Our results suggest that FFOs have a relatively low level of confidence in their ability to manage invasive plants on their properties. Although helping FFOs become more familiar with invasive plants and related management techniques may help boost confidence, our study shows that additional factors such as lack of money and limited knowledge about landowner assistance programs may also influence FFOs' self-confidence and self-efficacy. Similar factors have been identified by landowners in California's Sierra Nevada when discussing limitations to their ability to manage an invasive plant, yellow starthistle (*Centaurea solstitialis*), on their rangelands (Aslan et al., 2009). Noteworthy from our study, however, is that although over 60% of respondents reported being constrained by knowledge or money to control invasive plants, only a quarter expressed an interest in participating in a workshop, information session, financial assistance program, or technical assistance program. Such a mismatch between FFOs' needs and interests seems to suggest that conventional models of financial assistance, technical assistance, and outreach or education programs to FFOs may not be effective for motivating FFOs to participate in these programs (Hershdorfer et al., 2007; Howle et al., 2010; Kapler, Thompson, & Widrlechner, 2012; Sharp, Larson, & Green, 2011).

This low interest in government-sponsored programs is not unique to the management of invasive plants or FFOs in Indiana, as the USDA Forest Service's National Woodland Owner Survey (Butler et al., 2016b) also shows low participation rates in landowner assistance programs and interactions with forestry professionals among FFOs nationwide. These results could be explained by FFOs' lack of awareness about such programs, particularly among newer landowners, or their disinterest or distrust in engaging in government-sponsored programs and activities. Specifically, previous research shows that FFOs who are aware of forest management and conservation programs might be reluctant to participate if the application process is cumbersome or unclear (e.g., Gan, Onianwa, Schelhas, Wheelock, & Dubois, 2005), eligibility criteria or participation requirements are hard to meet (e.g., Markowski-Lindsay et al., 2011), incentives are minimal (e.g., Thomas, White, Kittredge, & Dennis, 2002), program and landowner goals are misaligned, or landowners distrust government program goals (Rouleau, Lind-Riehl, Smith, & Mayer, 2016). Thus, more research is needed to identify the specific reasons that underlie the mismatch we observed between FFOs' stated need for information and financial resources but little interest in outreach opportunities and assistance programs. For example, if distrust in government is identified as a limiting factor (Graham, 2013; Graham & Rogers, 2017), more effort would be needed to identify other entities that FFOs would trust as messengers and partners for invasive plant management. Since half of our respondents found it appealing or very appealing to work with a non-profit organization, it may be beneficial for natural resource agencies to work with a land conservation organization or a woodland owner association to motivate and assist FFOs to work on the invasive plant problems on their properties and in their communities.

Beyond a concern about invasive plants on their own properties, our study shows that FFOs are also concerned about invasive plants on neighboring or nearby woodlands. Most FFOs seem to be unsatisfied with what Indiana as a whole is doing about invasive plants. Furthermore, a large proportion also see a need for coordinated efforts to control invasive plants on privately-owned woodlands. These results are particularly insightful considering that only a very small proportion of FFOs have talked about or worked with their neighbors to manage invasive plants, yet a large proportion find it appealing or very appealing to work with their neighbors and other woodland owners in their town/city/county on invasive plant problems. These results highlight an opportunity to explore collective and/or cooperative invasive plant management across property boundaries. Specifically, our results suggest that there may be a role for both government agencies and non-profit organizations in facilitating coordination and cooperation among FFOs to generate landscape-level invasive plant management outcomes (Graham & Rogers, 2017; McKiernan, 2017). Indeed, in Indiana there has been an emerging effort to promote the Cooperative Invasive Species Management Areas (CISMAs) model to facilitate landowner coordination and cooperation. The Southern Indiana Cooperative Invasives Management (SICIM) was initially established in 2008 with a 35-county coverage region. In late 2017, SICIM and the USDA Natural Resources Conservation Service "entered into a contribution agreement for the purpose of developing local CISMAs throughout Indiana" (Southern Indiana Cooperative Invasives Management (SICIM), 2018). After over 10 years of continuous effort and the 2017 agreement, 10 of Indiana's 92 counties has established a CISMA under the leadership of government agencies, non-profit organizations, and landowners and citizen groups. The CISMA model, first known as the Cooperative Weed Management Areas (CWMAs) model, has been widely used in the Western and Midwestern United States, as well as Australia, to address weed management challenges through private and public partnerships across ranching and farming landscapes (Barrett, Soteres, & Shaw, 2016; Donaldson & Mudd, 2010; Epanchin-Niell et al., 2010; Ervin & Frisvold, 2016; Graham & Rogers, 2017). Within the forestry sector, this type of effort has been sparse (Schelhas, Miller, & Chambers, 2012). There is a need to better understand the potential for and barriers to CISMAs across more fragmented forested landscapes, and SICIM may present an opportunity for such research.

Beyond the specific CWMA and CISMA models, previous research has identified opportunities for collective and cooperative invasive plant management. For example, Graham and Rogers (2017) highlight that community leaders and supportive government staff that serve as a liaison between local groups and government agencies are pivotal to effective collective action. Locally-situated forestry and natural resource professionals (e.g., county Extension specialists), grassroots conservation organizations, and landowner associations may be able to use their existing social networks within local communities to facilitate FFO meetings, creating an environment of trust, a sense of shared understanding and responsibility, and an opportunity for social learning about invasive plant management. As local FFO networks develop, there might be additional opportunities to facilitate sharing of labor, tools, and other resources necessary for invasive plant removal.

However, as pointed out by McKiernan (2017), while grassroots effort to collectively manage invasive plants is important; it can also become rigid and insular, preventing the integration of new values and collaborations with new landholders within local communities (McKiernan, 2017). As such, strategies are needed to maintain conservation-oriented social norms and to obtain buy-in from newly arrived residents regarding community commitments to invasive plant management (McKiernan, 2017). Particularly, it is important to understand how newly arrived residents, often associated with amenity migration, view and experience their forested properties and where invasive plant management may fit in their property ownership objectives and individual circumstances (Cooke & Lane, 2015; Gill et al., 2010).

Finally, our results suggest that FFOs' social networks (including families and friends), mass media (e.g., newspapers, television, radio), and the Internet are important sources of information about invasive plants, similar to what has been found previously regarding landowner use of information (e.g., Ikutegbe, Gill, & Klepeis, 2015; Knoot & Rickenbach, 2011; Kueper et al., 2013; Ma, Kittredge, et al., 2012). Specifically, previous research suggests that a strong landowner social network is important for effective invasive plant management (Fischer & Charnley, 2012; Graham & Rogers, 2017; Marshall, Friedel, van Klinken, & Grice, 2011; Niemiec et al., 2016; Niemiec, Pech, et al., 2017). FFOs may prefer to use the Internet, mass media, and their social networks to learn about invasive species and their control (Bodin & Crona, 2009; Ikutegbe et al., 2015; Ma, Kittredge, et al., 2012), as these sources tend to be more convenient, less time consuming, and cheaper to access than seeking advice from natural resource professionals or traveling to workshops and information sessions. As such, natural resource agencies and organizations may need to consider innovative ways to develop their online presence to facilitate FFOs' learning, which is often self-directed and/or social in nature. For example, as a complement to current in-person or paper-based outreach and educational offerings, web-based learning opportunities that incorporate videos, virtual reality, and social media may attract FFOs who have not participated in traditional Extension or government outreach events.

5. Conclusion

The literature on individual and collective invasive plant management, so far, has largely focused on farmers, ranchers, urban gardeners, and community residents (Head, 2017). Relatively little is known about invasive plant management specific to forestlands, particularly the role of family forest owners (FFOs) in the United States. This paper provides a detailed description of FFOs' awareness, concerns, past actions, future plans, needs, and challenges related to invasive plant management. Such in-depth understanding is not only necessary for informing further development and testing of hypotheses associated with individual and collective invasive plant management but provides important insight into potential invasive plant-related policies and programs targeting FFOs.

What is both encouraging and concerning is that FFOs in our study are generally familiar with and concerned about invasive plants and they are taking actions to address their perceived problems. However, much of the on-the-ground management occurs without professional inputs. Although tailored communication and outreach can be used to target FFOs who are younger and newer, who are involved in farming, and who have interacted with forestry and natural resource professionals and programs previously, most FFOs in our study have little experience or interest in interacting with natural resource professionals and programs. As such, natural resource agencies may consider ways to partner with local conservation organizations and landowner associations to motivate and assist FFOs. In particular, efforts to facilitate neighboring landowners and landowners within a community to work together—sharing information and resources and motivating and assisting each other when needed, may prove effective as a way to promote collective action and coordinated management. Both self-directed research and information seeking through social networks are important means of learning for FFOs. As such, natural resource agencies and non-profit organizations may need to consider developing a stronger online presence and identify effective strategies to facilitate FFOs' learning. The goal is not only to make easily-accessible, scientifically-based, and trustworthy information available to FFOs, but more importantly, to communicate such information with FFOs at various critical decision points as they consider their options for dealing with invasive plants.

References

Armstrong, J. S., & Overton, T. (1977). Estimating nonresponse bias in mail surveys. *Journal of Marketing Research, 14*(3), 396–402.

Aslan, C. E., Hufford, M. B., Epanchin-Niell, R. S., Port, J. D., Sexton, J. P., & Waring, T. M. (2009). Practical challenges in private stewardship of rangeland ecosystems: Yellow star thistle control in Sierra Nevadan foothills. *Rangeland Ecology and Management, 62*(1), 28–37.

Authors. (In review). Where farm and forest meet: Comparing agricultural and non-agricultural National Woodland Owner Survey respondents. Environmental Management.

Barrett, M., Soteres, J., & Shaw, D. (2016). Carrots and sticks: Incentives and regulations for herbicide resistance management and changing behavior. *Weed Science, 64*(sp1), 627–640.

Bodin, Ö., & Crona, B. I. (2009). The role of social networks in natural resource governance: What relational patterns make a difference? *Global Environmental Change, 19*(3), 366–374.

Bremner, A., & Park, K. (2007). Public attitudes to the management of invasive non-native species in Scotland. *Biological Conservation, 139*, 306–314.

Burt, J., Muir, W., Piovia-Scott, A., Veblen, A., Chang, J., Grossman, K., & Weiskel, E. (2007). Preventing horticultural introductions of invasive plants: Potential efficacy of voluntary initiatives. *Biological Invasions, 9*(8), 909–923.

Butler, B. J., Hewes, J. H., Dickinson, B. J., Andrejcyk, K., Butler, S. M., & Markowski-Lindsay, M. (2016a). Family forest ownership in the United States, 2013: Findings from the USDA Forest Service's national woodland owner survey. *Journal of Forestry, 114*(6), 638–647.

Butler, B. J., Hewes, J. H., Dickinson, B. J., Andrejczyk, K., Butler, S. M., & Markowski-Lindsay, M. (2016b). *USDA Forest Service National Woodland Owner Survey: National, regional, and state statistics for family forest and woodland ownerships with 10+ acres, 2011-2013. Res. Bull. NRS-99* (pp. 39). Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station.

Catford, J. A., Jansson, R., & Nilsson, C. (2009). Reducing redundancy in invasion ecology by integrating hypotheses into a single theoretical framework. *Diversity and Distributions, 15*(1), 22–40.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Erlbaum.

Cooke, B., & Lane, R. (2015). How do amenity migrants learn to be environmental stewards of rural landscapes? *Landscape and Urban Planning, 134*, 43–52.

Coyle, D. R., Green, G. T., Barnes, B. F., Klepzig, K. D., Nowak, J. T., & Gandhi, K. J. K. (2016). Landowner and manager awareness and perceptions of pine health issues and southern pine management activities in the southeastern United States. *Journal of Forestry, 114*(5), 541–551.

Daab, M. T., & Flint, C. G. (2010). Public reaction to invasive plant species in a disturbed Colorado landscape. *Invasive Plant Science and Management, 3*, 390–401.

Dillman, D. A., Smyth, J. D., & Christian, L. M. (2014). *Internet, phone, mail and mixed-mode surveys: The tailored design method* (4th ed.). Hoboken, NJ: John Wiley and Sons.

Donaldson, S., & Mudd, T. (2010). Sustaining Cooperative Weed Management Areas in the long-term. In E. Rindos (Ed.). *Plant Invasions: Policies, politics, and practices. Proceedings of the 5th Biennial Weeds Across Borders Conference, Shepherdstown, June 1-4, 2010*. Center for Invasive Plant Management.

Epanchin-Niell, R. S., Hufford, M. B., Aslan, C. E., Sexton, J. P., Port, J. E., & Waring, T. M. (2010). Controlling invasive species in complex social landscapes. *Frontiers in Ecology and the Environment, 8*(4), 210–216.

Epanchin-Niell, R. S., & Wilen, J. E. (2015). Individual and cooperative management of invasive species in human-mediated landscapes. *American Journal of Agricultural Economics, 97*, 180–198.

Erickson, D. L., Ryan, R. L., & De Young, R. (2002). Woodlots in the rural landscape: Landowner motivations and management attitudes in a Michigan (USA) case study. *Landscape and Urban Planning, 58*, 101–112.

Ervin, D. E., & Frisvold, G. B. (2016). Community-based approaches to herbicide-resistant weed management: Lessons from science and practice. *Weed Science, 64*(sp1), 609–626.

Estévez, R., Anderson, C., Pizarro, J., & Burgman, M. (2015). Clarifying values, risk perceptions, and attitudes to resolve or avoid social conflicts in invasive species management. *Conservation Biology, 29*(1), 19–30.

Farmer, J. R., Meretsky, V., Knapp, D., Chancellor, C., & Fischer, B. C. (2015). Why agree to a conservation easement? Understanding the decision of conservation easement granting. *Landscape and Urban Planning, 138*, 11–19.

Fei, S., Phillips, J., & Shouse, M. (2014). Biogeomorphic impacts of invasive species. *Annual Review of Ecology, Evolution and Systematics, 45*, 69–87.

Fischer, A. P. (2011). Reducing hazardous fuels on nonindustrial private forests: Factors influencing landowner decisions. *Journal of Forestry, 109*(5), 260–266.

Fischer, P., & Charnley, S. (2012). Private forest owners and invasive plants: Risk perception and management. *Invasive Plant Science and Management, 5*(3), 375–389.
Fortney, J., Arano, K. G., & Jacobson, M. (2011). An evaluation of West Virginia's managed timberland tax incentive program. *Forest Policy and Economics, 13*(1), 69–78.
Gan, J. B., Onianwa, O. O., Schelhas, J., Wheelock, G. C., & Dubois, M. R. (2005). Does race matter in landowners' participation in conservation incentive programs? *Society and Natural Resources, 18*, 431–445.
Gill, N., Klepeis, P., & Chisholm, L. (2010). Stewardship among lifestyle oriented rural landowners. *Journal of Environmental Planning and Management, 53*(3), 317–334.
Gormanson, D. D. (2014). *Forest of Indiana, 2013. Resource Update FS-8.* Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station.
Graham, S. (2013). Three cooperative pathways to solving a collective weed management problem. *Australasian Journal of Environmental Management, 20*(2), 116–130.
Graham, S., & Rogers, S. (2017). How local landholder groups collectively manage weeds in South-Eastern Australia. *Environmental Management, 60*, 396–408.
Grimes, D. A., & Schulz, K. F. (2002). Descriptive studies: What they can and cannot do. *The Lancet, 359*(9301), 145–149.
Gulezian, P. Z., & Nyberg, D. W. (2010). Distribution of invasive plants in a spatially structured urban landscape. *Landscape and Urban Planning, 95*(4), 161–168.
Head, L. (2017). The social dimensions of invasive plants. *Nature Plants, 6*(3), 17075.
Hendee, J. T., & Flint, C. G. (2013). Managing private forestlands along the public–private interface of Southern Illinois: Landowner forestry decisions in a multi-jurisdictional landscape. *Forest Policy and Economics, 34*, 47–55.
Hershdorfer, M. E., Fernandez-Gimenez, M. E., & Howery, L. D. (2007). Key attributes influence the performance of local weed management programs in the southwest United States. *Rangeland Ecology and Management, 60*, 225–234.
Howle, M., Straka, T., & Nespeca, M. (2010). Family forest owners' perceptions on chemical methods for invasive species control. *Invasive Plant Science and Management, 3*(3), 253–261.
Ikutegbe, V., Gill, N., & Klepeis, P. (2015). Same but different: Sources of natural resource management advice for lifestyle oriented rural landholders. *Journal of Environmental Planning and Management, 58*(9), 1530–1543.
Jagnow, C. P., Stedman, R. C., Luloff, A. E., San Julian, G. J., Finley, J. C., & Steele, J. (2006). Why landowners in Pennsylvania post their property against hunting. *Human Dimensions of Wildlife, 11*(1), 15–26.
Joshi, S., & Arano, K. G. (2009). Determinants of private forest management decisions: A study on West Virginia NIPF landowners. *Forest Policy and Economics, 11*, 118–125.
Kapler, E., Thompson, J., & Widrlechner, M. (2012). Assessing stakeholder perspectives on invasive plants to inform risk analysis. *Invasive Plant Science and Management, 5*(2), 194–208.
Karppinen, H., & Berghäll, S. (2015). Forest owners' stand improvement decisions: Applying the theory of planned behavior. *Forest Policy and Economics, 50*, 275–284.
Kilgore, M. A., Snyder, S. A., Eryilmaz, D., Markowski-Lindsay, M., Butler, B. J., Kittredge, D., & Andrejczyk, K. (2015). Assessing the relationship between different forms of landowner assistance and family forest owner behaviors and intentions. *Journal of Forestry, 113*(1), 12–19.
Kittredge, D. B. (2004). Extension/outreach implications for America's family forest owners. *Journal of Forestry, 102*(7), 15–18.
Klepeis, P., Gill, N., & Chisholm, L. (2009). Emerging amenity landscapes: Invasive weeds and land subdivision in rural Australia. *Land Use Policy, 26*(2), 380–392.
Knoot, T. G., & Rickenbach, M. (2011). Best management practices and timber harvesting: The role of social networks in shaping landowner decisions. *Scandinavian Journal of Forest Research, 26*(2), 171–182.
Knupfer, N. N., & McLellan, H. (1996). Descriptive research methodologies. In D. H. Jonassen (Ed.). *Handbook of research for educational communications and technology*. New York, NY: Lawrence Erlbaum Associates.
Kueffer, C. (2010). Transdisciplinary research is needed to predict plant invasion in an era of global change. *Trends in Ecology and Evolution, 25*(11), 620–621.
Kueper, A. M., Sagor, E. S., & Becker, D. R. (2013). Learning from landowners: Examining the role of peer exchange in private landowner outreach through landowner networks. *Society & Natural Resources, 26*(8), 912–930.
Larson, D. L., Phillips-Mao, L., Quiram, G., Sharpe, L., Stark, R., Sugita, S., & Weiler, A. (2011). A framework for sustainable invasive species management: Environmental, social, and economic objectives. *Journal of Environmental Management, 92*(1), 14–22.
Ma, Z., Butler, B. J., Kittredge, D. B., & Catanzaro, P. (2012). Factors associated with landowner involvement in forest conservation programs in the U.S.: Implications for policy design and outreach. *Land Use Policy, 29*(1), 53–61.
Ma, Z., Clarke, M., & Church, S. P. (2018). Insights into individual and cooperative invasive plant management on family forestlands. *Land Use Policy, 75*, 682–693.
Ma, Z., Kittredge, D. B., & Catanzaro, P. (2012). Challenging the traditional forestry extension model: Insights from the Woods Forum program in Massachusetts. *Small-scale Forestry, 11*(1), 87–100.
Mangold, J. M., & Sheley, R. L. (2008). Controlling performance of bluebunch wheatgrass and spotted knapweed using nitrogen and sucrose amendments. *Western North American Naturalist, 68*, 129–137.
Markowski-Lindsay, M., Stevens, T., Kittredge, D. B., Butler, B. J., Catanzaro, P., & Dickinson, B. J. (2011). Barriers to Massachusetts forest landowner participation in carbon markets. *Ecological Economics, 71*, 180–190.
Marshall, G. R., Coleman, M. J., Sindel, B. M., Reeve, I. J., & Berney, P. J. (2016). Collective action in invasive species control, and prospects for community-based governance: The case of serrated tussock (*Nassella trichotoma*) in New South Wales, Australia. *Land Use Policy, 56*, 100–111.
Marshall, N. A., Friedel, M., van Klinken, R. D., & Grice, A. C. (2011). Considering the social dimension of invasive species: The case of buffel grass. *Environmental Science and Policy, 14*(3), 327–338.
McKiernan, S. (2017). Managing invasive plants in a rural-amenity landscape: The role of social capital and Landcare. *Journal of Environmental Planning and Management,* 1–19.
McLeod, L., Hine, D., Please, P., & Driver, A. (2015). Applying behavioral theories to invasive animal management: Towards an integrated framework. *Journal of Environmental Management, 161*, 63.
Miller, R. F., Chambers, J. C., Pyke, D. A., Pierson, F. B., & Williams, C. J. (2013). Gen. Tech. Rep. RMRS-GTR-308 *A review of fire effects on vegetation and soils in the Great Basin Region: Response and ecological site characteristics* (pp. 136). Fort Collins, CO: USDA Forest Service, Rocky Mountain Research Station.
Niemiec, R., Ardoin, N., Wharton, C., & Asner, G. (2016). Motivating residents to combat invasive species on private lands: Social norms and community reciprocity. *Ecology and Society, 21*(2), 1.
Niemiec, R. M., Ardoin, N. M., Wharton, C. B., & Brewer, F. K. (2017). Civic and natural place attachment as correlates of resident invasive species control behavior in Hawaii. *Biological Conservation, 209*, 415–422.
Niemiec, R. M., Asner, G. P., Brodrick, P. G., Gaertner, J. A., & Ardoin, N. M. (2018). Scale-dependence of environmental and socioeconomic drivers of albizia invasion in Hawaii. *Landscape and Urban Planning, 169*, 70–80.
Niemiec, R., Pech, R., Norbury, G., & Byrom, A. (2017). Landowners' perspectives on coordinated, landscape-level invasive species control: The role of social and ecological context. *Environmental Management, 59*(3), 477.
Oswalt, C. M., Fei, S., Guo, Q., Iannone, B. V., Oswalt, S. N., Pijanowski, B. C., & Potter, K. M. (2015). A subcontinental view of forest plant invasions. *NeoBiota, 24*, 49–54.
Paini, D. R., Sheppard, A. W., Cook, D. C., De Barro, P. J., Worner, S. P., & Thomas, M. B. (2016). Global threat to agriculture from invasive species. *Proceedings of the National Academy of Sciences, 113*(27), 7575–7579.
Paveglio, T., Jakes, P., Carroll, M., & Williams, J. (2009). Understanding social complexity within the wildland-urban interface: A new species of human habitation? *Environmental Management, 43*(6), 1085–1095.
Pejchar, L., & Mooney, H. (2009). Invasive species, ecosystem services and human well-being. *Trends in Ecology and Evolution, 24*(9), 497–504.
Peters, W., & Meyer, M. H. (2006). Minnesota horticultural survey on invasive plants. *Euphytica, 148*, 75–86.
Ravnborg, H. M., & Westermann, O. (2002). Understanding interdependencies: Stakeholder identification and negotiation for collective natural resource management. *Agricultural Systems, 73*(1), 41–56.
Reaser, J. K. (2001). Invasive alien species prevention and control: The art and science of managing people. In J. A. McNeely (Ed.). *The Great reshuffling: Human dimensions of invasive alien species* (pp. 89–104). IUCN.
Richardson, D. M., Pysek, P., Rejmanek, M., Barbour, M. G., Panetta, F. D., & West, C. J. (2000). Naturalization and invasion of alien plants: Concepts and definitions. *Diversity and Distributions, 6*, 93–107.
Rouleau, M., Lind-Riehl, J., Smith, M., & Mayer, A. (2016). Failure to communicate: Inefficiencies in voluntary incentive programs for private forest owners in Michigan. *Forests, 7*(9), 199.
Sandberg, M., & Jakobsson, S. (2018). Trees are all around us: Farmer's management of wood pastures in light of a controversial policy. *Journal of Environmental Management, 212*, 228–235.
Schelhas, J., Miller, J. H., & Chambers, J. (2012). Non-native plants and adaptive collaborative approaches to ecosystem restoration in the United States. In J. Stanturf, P. Madsen, & D. Lamb (Eds.). *A goal-oriented approach to forest landscape restoration. World Forests (WFSE volume16)*. Dordrecht: Springer.
Sharp, R., Larson, L., & Green, G. (2011). Factors influencing public preferences for invasive alien species management. *Biological Conservation, 144*(8), 2097–2104.
Southern Indiana Cooperative Invasives Management (SICIM). (2018). Indiana CISMAS. Available from: http://www.sicim.info/cismas/.
Silver, E., Leahy, J., Weiskittel, A., Noblet, C., & Kittredge, D. (2015). An evidence-based review of timber harvesting behavior among private woodland owners. *Journal of Forestry, 113*(5), 490–499.
Simberloff, D. (2013). *Invasive species: What everyone needs to know*. New York, NY: Oxford University Press.
Snyder, S. A., & Butler, B. J. (2012). A national assessment of public recreational access on family forestlands in the United States. *Journal of Forestry, 110*(6), 318–327.
Steele, J., Chandran, R. S., Grafton, W. N., Huebner, C. D., & McGill, D. W. (2006). Awareness and management of invasive plants among West Virginia woodland owners. *Journal of Forestry, 104*(5), 248–253.
Steele, J., McGill, D., Chandran, R., Grafton, W., & Huebner, C. (2008). Landowner characteristics associated with receiving information about invasive plants and implications for outreach providers. *Journal of Extension, 46*(6), 1–7.
Sullivan, A., York, A. M., An, L., Yabiku, S. T., & Hall, S. J. (2017). How does perception at multiple levels influence collective action in the commons? The case of *Mikania micrantha* in Chitwan, Nepal. *Forest Policy and Economics, 80*, 1–10.
Sullivan, A., York, A. M., White, D. D., Hall, S. J., & Yabiku, S. T. (2017). De jure versus de facto institutions: Trust, information, and collective efforts to manage the invasive mile-a-minute weed (*Mikania micrantha*). *International Journal of the Commons, 11*(1), 171–199.
Thomas, H. S., White, S., Kittredge, D. B., & Dennis, D. (2002). Factors affecting NIPF landowner participation in management programs: A Massachusetts case study. *Journal of Forest Economics, 8*(3), 169–184.
Yung, L., Chandler, J., & Haverhals, H. (2015). Effective weed management, collective action and landownership change in Western Montana. *Invasive Plant Science and Management, 8*(2), 193–202.