

recreation

Understanding Public Knowledge and Attitudes toward Controlling Hemlock Woolly Adelgid on Public Forests

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Hemlock woolly adelgid (HWA) (*Adelges tsugae*), an exotic forest pest, has infested millions of acres of eastern hemlock (*Tsuga canadensis*) forest from Georgia to Maine. Hemlock mortality has been linked to a loss in esthetics, declines in trout habitat, and an increase in safety hazards in public forests. Available options to control HWA vary in terms of cost and environmental impact. As infestations occur often on public lands, which are popular recreation destinations, understanding public knowledge of and attitudes toward HWA control options will be important to any successful control program. Household survey results indicate public support for combating HWA, but public awareness of control options and of HWA in general is low. Survey respondents revealed concerns related to increased risk of wildfire, safety, and reduced quality of recreation but were less concerned with property value reduction or loss of trees on private land. Spraying oil and soap on branches and injecting insecticides into tree trunks were preferred to chemical soil treatments or releasing nonnative predatory beetles. Both site- and user group-specific differences in acceptability were observed for alternative control options, suggesting a need for careful selection of control options, depending on site characteristics and user populations.

Keywords: biological control, forest pest, hemlock, insecticide, invasive species, public opinion

Hemlocks are an important component of eastern forest ecosystems, often providing unique habitat for wildlife, moderating temperatures (Yamasaki et al. 2000), and maintaining riparian areas (Ford and Vose 2007). Hemlocks are considered a “foundation species” for their strong influence on the structure and function of the riparian ecosystems (Vose et al. 2013) and are also known for their significant scenic beauty along hiking trails and camping areas, as well as for increasing real estate values in residential landscapes (Hol-

mes et al. 2005). There is also evidence of cultural value, as the eastern hemlock (*Tsuga canadensis*) is Pennsylvania’s state tree. Unfortunately, both Carolina hemlock (*Tsuga caroliniana*) and eastern hemlock, which cover a large portion of the eastern United States, are facing increased mortality due to hemlock woolly adelgid (HWA) (*Adelges tsugae*), an invasive insect native to Asia (Foster 2014). This pest feeds on the sap of hemlock tree shoots and ultimately kills the tree within a few years (McClure et al. 2001). Infestations of HWA have spread

rapidly and pose a significant threat to long-term forest health in the East (Small et al. 2005). Studies have reported that HWA has infested millions of acres of hemlock forest from Georgia to Maine (Ward et al. 2004). Damage is so rampant in the Appalachian region that the dead hemlocks with their pale, skeletonlike appearance are described as “gray ghosts” in “beautiful forests” (Firley 2014) (Figure 1).

Recent advances in combating HWA suggest several possible treatments for the problem, including branch and needle sprays (i.e., spraying horticultural oil and insecticidal soap on infested branches), trunk injections using the insecticide imidacloprid, soil application (i.e., applying the insecticides imidacloprid or dinotefuran to the soil around infested trees), and predatory beetles (i.e., releasing nonnative beetles, *Laricobius nigrinus* and *Sasajiscymnus tsugae*, that feed exclusively on HWA) (Onken 2005). These treatment and containment strategies differ in ease of application, costs, environmental impacts, and duration of control. For example, with the exception of tall trees, spraying insecticide on tree branches is easier and cheaper than other techniques but requires more frequent ap-

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Figure 1. HWA infestation seen from Linville Gorge in Pisgah National Forest, North Carolina. (Photo Credit: Steve Norman, USDA Forest Service. Photo taken June 12, 2011.)

plications. Soil treatment is an easier option but can contaminate adjacent water bodies and kill aquatic species such as fish and other wildlife (Moore et al. 2011). Similarly, injecting insecticide into the trunk of an infested tree is relatively safe but requires skilled workers and is more expensive. Releasing predatory beetles is often argued to be the only viable long-term option (Jacobs 2005), but the field experiments for biological controls are too new to determine a long-term success rate. Further, treatment of infested sites in smaller areas or those in the early stage of infestation is less practical with this option. It is also unclear how local people and visitors to public forests will react to introducing another exotic species into the ecosystem. Hence, an important consideration in choosing the best mitigation strategy, which could be a combination of treatment types, is to know whether, how, and where the general public, as well as the users of the public forests, want the infestation to be treated.

Several studies have explored the human dimensions of invasive species (Holmes and Kramer 1995, Jetter and Paine 2004, Fischer and Charnley 2012). García-Llorente et al. (2008) concluded that stakeholders show a variety of attitudes toward management of invasive species, and a decisionmaking process should consider understanding and incorporating those attitudes. Meitner et al. (2008) studied the public's perception of mountain pine beetle (*Dendroctonus ponderosae*) and found support for increased salvage logging and for replanting of harvested areas with mixed species over monoculture pine, fertilized pine, or natural regeneration. Studies have also shown that

the public is generally willing to pay for controlling invasive forest pests (Miller and Lindsay 1993, Jetter and Paine 2004, Mel-drum et al. 2011) and HWA in particular (Moore et al. 2011). Moore et al. (2011) found that North Carolinians overwhelmingly supported a hemlock protection program, while placing higher importance on controlling HWA at culturally and ecologically important sites.

Because national forests and state parks are publicly owned, taxpayers' perceptions of the impact of an invasive species like HWA and input on which, if any, control measures to implement become key aspects of program design. Programs to control HWA without considering

public opinion could result in value conflicts, possible loss of public support, and declining trust for management agencies (Bowker et al. 2008). In addition, perceptions may depend on where the hemlocks are located within the public forests and how visitors interact with those sites. Knowing whether the public prefers alternative treatment methods in different locations and whether certain types of treatments are opposed by specific user groups (e.g., hikers, campers, and anglers) could be very helpful to those managing for ecosystem health as well as visitor benefits. With the exception of Moore et al. (2011) in North Carolina, no study has investigated such questions with forest invasives. Our study diverges from that of Moore et al. (2011) by sampling at the regional level, i.e., all counties within the hemlock range where HWA infestations have already been identified, and by incorporating a wider array of human dimension questions in the survey.

The overall goals of our study are to assess public knowledge and concern regarding hemlocks and HWA and to evaluate attitudes associated with alternative strategies for managing HWA on public forests. In addition to identifying general opinions, we investigate differences across subgroups of the regional population. This comparison is meaningful because the literature on the human dimensions of forest health indicates that residents living closer to public forests may have greater

Management and Policy Implications

Combating invasive species such as hemlock woolly adelgid (HWA) on public forests requires public support. It will be key for land managers to understand what aspects of HWA infestations concern the public and where, when, and, more importantly, how people want HWA controlled. This information is particularly important at a time when land management budgets are relatively static, if not shrinking. A primary implication of our study is that public awareness of HWA infestation is rather low, and there is a need for outreach programs to inform and educate people on HWA and available control methods. This could be done through mailing informative flyers, sponsorship of public messages in extension publications and newsletters targeted to landowners, kiosk or bulletin board materials on site targeted to public forest visitors, and other popular means of communication targeted to the broader public in the hemlock region. Another implication is that the public wants control programs to be prioritized in ecologically and culturally important sites. Although our sample generally supports controlling HWA, implementing some control methods at certain sites may induce potential conflict, especially from primary recreation users of those sites such as anglers, hikers. Hence, forest managers will have to select from a range of alternative control options, considering the potential impact of these activities on visitor attitudes and behavior, as well as the direct impacts on the condition and quality of natural resources at the site. Forest managers may develop socially acceptable pest management programs by incorporating input from the sites' relevant recreation user groups.

self-interest than their nonlocal counterparts (McFarlane et al. 2006, Anderson et al. 2008). Studies have also found similar results with tourists' attitudes toward pest programs on national parks (Muller and Job 2009). In this study, we focus on four specific objectives:

- To assess public awareness and attitudes toward HWA and relevant control options;
- To identify public concern over the impacts of HWA damage;
- To examine preferences toward alternative HWA treatment and containment strategies at various sites within public forests; and,
- To compare attitudes and preferences for alternative HWA control options among population segments in the geographic region and by recreation user groups.

Results from our study could be of immediate use to forest managers who are currently developing management strategies and public outreach and education campaigns related to HWA.

Methodology

Study Area

Our sample was collected in the eastern United States, in counties where HWA was present. Using the US Department of Agriculture (USDA) Forest Service 2011 HWA Distribution Map,¹ we identified all counties with established HWA infestations that were confirmed and reported by state forest health officials. Given the variation in population density, we separated these counties into three sample strata: counties within a 50-mile buffer of Great Smoky Mountain (GSM) National Park or a 20-mile buffer² of Delaware Water Gap (DWG) National Recreation area (park buffer); other counties in major metropolitan areas (metro); and other counties not located in major metropolitan areas (nonmetro). The first stratum, park buffers, includes counties near two popular public forest recreation areas that have been significantly impacted by HWA (Abella 2014). Residents in these areas were expected to be more familiar with hemlock and HWA, but the regions are relatively rural and without oversampling these regions, this stratum would have insufficient observations for any testing across strata. The park buffer sizes accounted for the difference in population density surroundings each park. Similarly, we wanted to ensure a sufficient number of responses from other rural

counties. Using the 2003 Rural-Urban Continuum Codes (RUC) developed by USDA Economic Research Service, we defined metro areas outside of the park buffers as those counties with an RUC of 1 or 2 and nonmetro as those counties with an RUC greater than 2.

Survey

During fall 2012, we conducted a mail survey of the general adult population residing in the study area. After an initial pretest of 100 surveys, we sent a final version of the survey to 3,300 residents from the sample population (1,100 to each stratum). Names and addresses were purchased from a third-party contact list vendor (SSI Market Research). We used a three-contact procedure for the mailing, including the initial survey mailing, a follow-up postcard, and a second survey sent to all nonrespondents. To increase response rates, all respondents were entered into a drawing for 1 of 10 gift cards from a popular retailer. The survey instrument³ included 5-point Likert scale questions that allowed respondents to indicate their level of agreement with statements regarding knowledge of HWA, concerns over the risk of HWA damage, attitudes toward treatment methods, and attitudes toward treating HWA at various sites within public forests. Questions used previously in similar studies (e.g., Moore et al. 2011) provided a starting point to develop the survey instrument, which also included dichotomous responses to indicate acceptability of alternative treatment methods at various site types within public forests. A separate section of the survey elicited demographic information. Because the intended audience was the general public, we included a brief description of facts about hemlock trees, HWA, and available control options.

Data Analysis

We tabulated descriptive statistics of item responses for the whole sample and various subgroups. To test for significant differences among sample groups, we used Kruskal-Wallis and Pearson χ^2 tests because these tests are more appropriate for nonparametric tests on categorical data (Walpole et al. 2002). Because of differences in response rates, we used a poststratification weighting scheme to account for underrepresented groups in the population. Population-based

weights were used to deflate the influence of the oversampled strata.

Results

After all contacts, 303 surveys were undeliverable, and 438⁴ responded, yielding an overall response rate of 15%. Response rates for the park buffer, metro, and nonmetro strata were 18, 10, and 17%, respectively. Although less than ideal, this response rate is comparable to response rates reported in recently published human dimensions survey research about forestry issues (e.g., 12% reported by Thompson and Hansen 2012, 10% reported by Moore et al. 2011, and 11% reported by Rothlisberger et al. 2010). We suspect that our low response rate relates to the fact that the intended audience was the general public and that HWA is simply not a major issue for them, particularly those living in metro areas. In addition, while we sampled households from counties reported to have HWA infestations, it is possible that HWA may be present in only a portion of the county, and few county residents are aware of, or interested in, the issue. For example, only 30% in our sample had hemlocks on their own property, whereas more than 78% were familiar with the tree.

Respondent average age was 55 years with 22% older than 65 years, 59% were male, and 90% were white. About 24% had a high school or less education, whereas 46% had a college degree. In terms of annual income, 23% reported annual income of more than \$75,000 and 20% reported less than \$30,000. Despite the low response rate, we found reasonable similarities between our sample and the general population of our study area in several key demographic characteristics and participation in outdoor recreation activities. For example, according to the 2010 US Census, the percentage of white population in study area counties was 85%, 32% had completed a college degree and 15% were older than 65 years. Similarly, 56% in our sample had full-time employment with a professional job, whereas the population of study area counties had 58% with a similar job.

Regarding participation in outdoor recreation, 33% in our sample participated in camping and 73% participated in hiking or walking for pleasure, whereas two reports based on National Survey on Recreation and Environment (NSRE) data reported that 38% of the Americans

participate in camping (Bowker et al. 2012) and that 85% participate in walking for pleasure and/or hiking (Cordell 2012). Similarly, the rates of participation in fishing (38%), hunting (20%), and bird watching (29%) from our sample are similar to the participation rate reported in 2011 National Survey of Fish and Wildlife-related Recreation for fishing (37%), hunting (15%), and bird watching (33%) (US Fish and Wildlife Service 2011). A recent report based on NSRE data also estimated the participation rates for fishing and hunting to be 31% and 12%, respectively (Bowker et al. 2012). These com-

parisons indicate that our sample appears representative of the broader population of outdoor recreationists in the area. A demographic breakdown of study sample by sampling strata is also presented in Table 1.

Awareness and Attitude toward HWA and Its Control Options

Approximately 22% in the sample did not know about hemlocks or HWA; 40% knew of hemlocks, but not about HWA; and 38% knew of hemlocks, HWA, and one of the control methods. A previous survey of landowners in New York similarly found a

low level of awareness of HWA, with more than 58% of those sampled indicating that they had never heard of HWA (Connelly et al. 2007). As for control options, 32% of the sample claimed to have heard of branch treatment, 17% trunk treatment, 14% soil treatment, and 21% predatory beetle (Table 2). Prior knowledge of each of the control options also varied among strata; a significantly higher portion in the park buffer stratum claimed to have previously heard of control options. Respondents' knowledge of HWA and control methods seemed related to their familiarity with hemlocks, as a significantly higher percentage of those owning property with hemlocks indicated that they had known of both HWA and control methods ($P < 0.01$) than others. Similar results were noted with more-frequent visitors (>5 trips/year) to national forests and national parks than less-frequent visitors ($P < 0.05$).

Among the respondents who knew about HWA and control options before reading the survey, sources of information varied. About 65% claimed to have gotten HWA information from direct contact with experts (e.g., foresters and extension workers), 27% from popular media, 22% from the Internet, 16% from outdoor recreation clubs/groups, and 16% from brochures.

When presented with the statement that "HWA should not be controlled," 85% of the whole sample either disagreed or strongly disagreed (Figure 2). Asked about when HWA should be controlled, respondents expressed different opinions in different scenarios. About 78% disagreed or strongly disagreed with the statement that "HWA should be controlled only if it causes economic damage," whereas 61% either dis-

Table 1. Demographic characteristics of the respondents in sample and strata.

Variable	Sample (438)	Strata		
		Park buffer (40%)	Metro (22%)	Nonmetro (38%)
Age (years)	55	55	52	56
Gender (% male)	59	54	52	65
Race (% white)	90	88	88	94
Education (% college degree)	46	49	60	34
Annual income (% <\$30K)	20	21	18	21
Annual Income (% >\$75k)	23	22	25	22
Hiker (%)	73	71	81	72
Angler (%)	38	44	26	38
Camper (%)	33	33	25	38

Table 2. Percentage of respondents who had previously heard of HWA control options.

Control option	Sample	Strata			Pearson χ^2
		Park buffer	Metro	Nonmetro	
		(%).....			
Branch treatment	32	38	31	26	10.76*
Trunk treatment	17	23	12	14	12.69*
Soil treatment	14	18	11	13	10.78*
Predatory beetle	21	32	13	13	18.48*

*Statistic is significant at the 1% level to reject the null hypothesis that the strata percentages are equal.

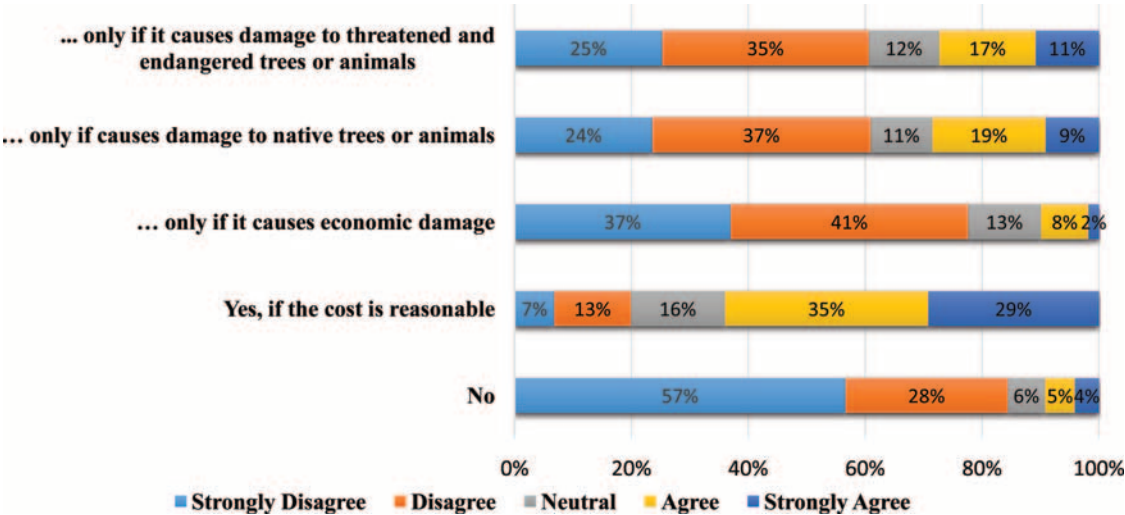


Figure 2. Respondents' agreement or disagreement regarding when HWA should be controlled.

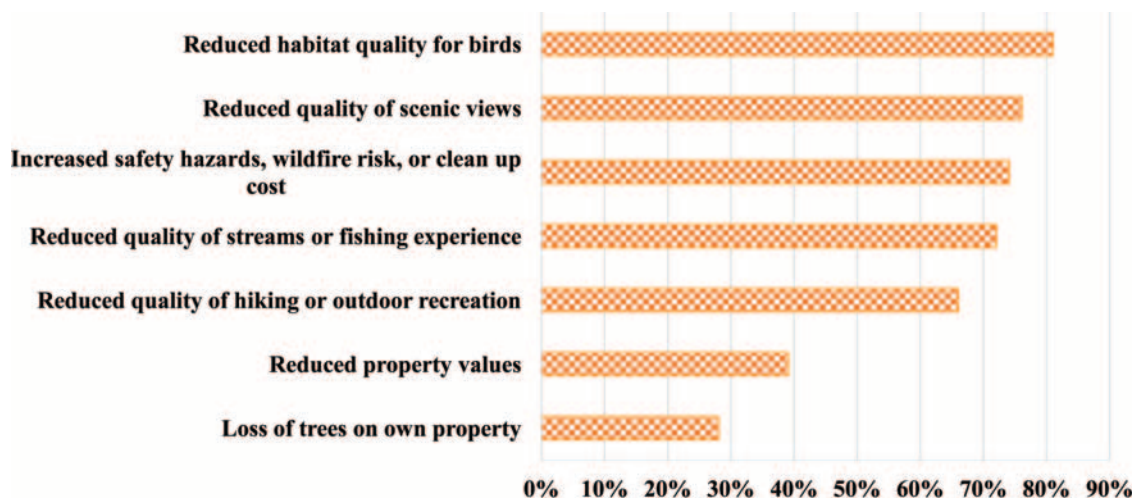


Figure 3. Percentage of respondents that were concerned about the possible impact of HWA damage.

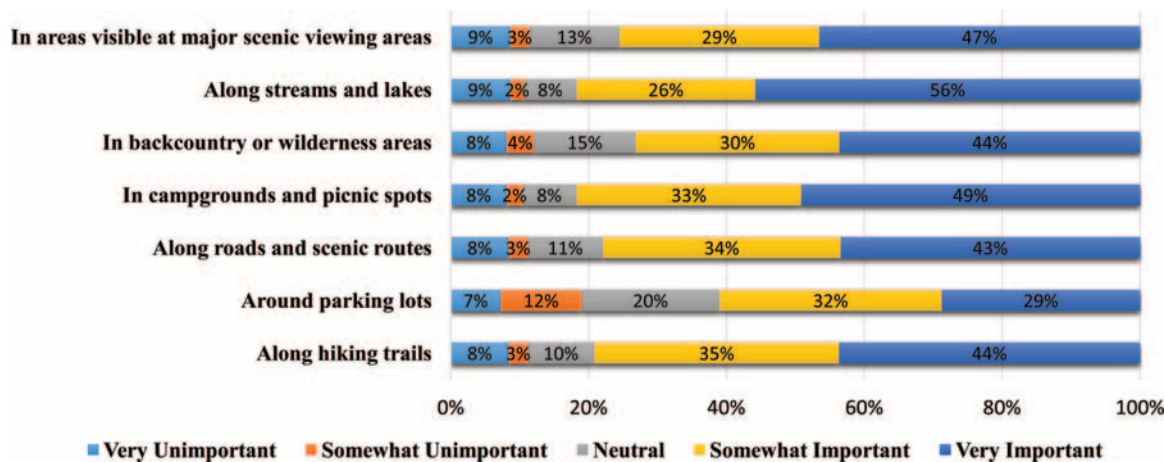


Figure 4. Importance of controlling HWA at various sites within public forests.

agreed or strongly disagreed with both of the statements “HWA should be controlled only if it causes damage to native trees or animals” and “HWA should be controlled only if it causes damage to threatened and endangered trees or animals.” Thus, respondents seemed to suggest overwhelming support for HWA control, but in doing so they also suggested that economic damage was not the sole driving factor. Moreover, respondent support for control was internally consistent as only 20% either disagreed or strongly disagreed with the statement “HWA should be controlled if the cost is reasonable.”

Concerns over the Impacts

Figure 3 presents respondents’ binary responses toward concern over various impacts associated with potential damage from HWA. The areas of highest concern were reduced habitat for birds (81%), reduced quality of scenic views along roadways (76%), increased safety hazard (74%), wild-

life risk (74%), cleanup cost (74%), and reduced quality of streams or fishing experience (72%). Similarly, Moore et al. (2011) showed a large proportion of North Carolina residents (70%) indicating “extremely important” to protect hemlock for wildlife habitat. A majority of respondents in this study also expressed concern over reduced quality for their hiking or outdoor recreation experiences (66%). Alternatively, of less concern were the loss of trees on one’s own property (39%) and reduced property values in general (28%). However, only 30% of the sample had hemlock trees on their property, of whom 95% had noticed damage from HWA on their own property.

When asked generally where in public forests they thought it was important to control for HWA, respondents indicated a relatively high level of importance for controlling HWA at all sites (Figure 4). Most respondents indicated that it was somewhat or very important to control HWA along

streams and lakes (82%), in campgrounds and picnic spots (82%), along hiking trails (79%), and in backcountry or wilderness areas (74%). Fewer indicated that it was important to control HWA in areas around parking lots (60%), suggesting that people do not consider such areas particularly valuable to either their recreation experiences or esthetics. A Kruskal-Wallis test of differences in importance among sites confirmed that there is a statistically significant difference in importance ($P < 0.01$). This corroborates the findings of Moore et al. (2011) that the public places higher importance on controlling HWA in areas of cultural and ecological significance than in areas of less cultural and ecological significance.

Preference for Control Options in Public Forests

Figure 5 shows the percentage of respondents who objected to selected treatment options at various sites within public forests. Generally, a higher percentage of re-

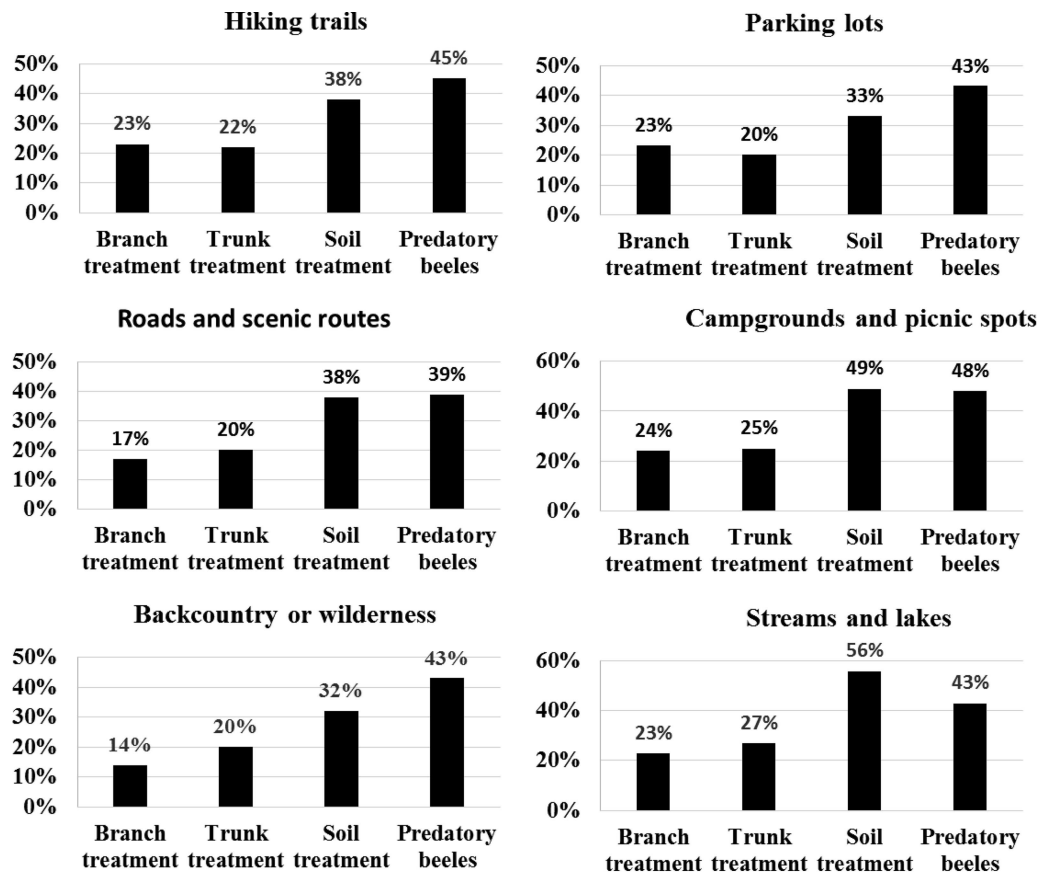


Figure 5. Percentage of respondents who objected to control options at various sites.

spondents objected to either releasing predatory beetles or applying chemical insecticides to the soil around infested trees than to injecting insecticide into the trunks of or spraying oil and soap on the branches of infested trees. A majority (56%) objected to applying soil insecticides in the vicinity of streams and lakes. Almost half (49%) of respondents objected to soil treatments in campgrounds and picnic areas, whereas 48% objected to predatory beetles in the same areas. In North Carolina, Moore et al. (2011) found that the proportion of respondents who objected to adopting chemical control or predatory beetle methods to control HWA in three public forests ranged from 31 to 59%. Compared to 43% in our sample, a somewhat lower proportion (31%) in the Moore et al. (2011) sample objected to releasing predatory beetles in wilderness and backcountry areas. However, the difference could be attributable to various factors including a higher proportion of college graduates and a lower proportion of public forest visitors in the Moore et al. (2011) sample. Also, the Moore et al. (2011) study asked about releasing beetles in congressionally designated wilderness and back-

country areas in three specific national forests and national parks, whereas our study asked about all backcountry areas across the state regardless of congressional designation. It should also be noted that the Moore et al. (2011) sample was heavily drawn from counties in western North Carolina that contain or border parts of three national forests and GSM National Park. This part of the state is arguably comparable to the “park buffer” stratum of our sample, which had only 39% of respondents who objected to predatory beetle releases in wilderness areas. Overall, our results show that the objection to soil treatment was comparatively low in areas of less recreational importance such as parking lots or sites of limited use or access (i.e., scenic viewing areas and wilderness areas) than in areas where human contact was more likely.

Comparisons among Sample Segments

The sample was stratified geographically (i.e., park buffer, metro, and nonmetro). A Pearson χ^2 test showed that significantly higher proportions in metro (45%) and nonmetro (47%) areas indicated

that they did not know about HWA than in park buffer areas (29%) ($P < 0.01$). However, no significant differences were observed among these strata in terms of the importance of controlling HWA at various sites and the level of concern with various risks associated with HWA damage or with objections to alternative treatment methods at various sites on public forests. When asked whether they agreed with controlling HWA if the cost was reasonable (in a 5-point Likert scale), statistical differences were insignificant among nonmetro (3.75), park buffer (3.64), and metro (3.56) strata. Thus, across control options, we observed less difference across strata than for previous knowledge of HWA. Pearson χ^2 tests (Table 2) show that a significantly higher proportion of the park buffer group had heard of the various control options, suggesting some spatial disparity in HWA knowledge.

An alternative sample partitioning was made across general recreation user groups—visitors and nonvisitors to public forests (national or state forest, park, or recreation area). A Pearson χ^2 test showed that a significantly higher proportion of public forest visitors (20%) indicated knowing

Table 3. Percentage of respondents in user groups that object to alternative control options at specific sites.

Site in public forests	User groups	Control options			
		Branch treatment	Trunk treatment	Soil treatment	Predatory beetle
.....(%).....					
Around parking lot	Public forest visitors	15*†	22‡§	43*§	50
Along hiking trails	Hikers	18	24	42	51*§
Along road and scenic routes	Sight seers	14	20	32	42
In campgrounds and picnic areas	Campers and picnickers	20	30‡§	49	50
In backcountry or wilderness areas	Backpackers	17	38	45	71*§
Along streams and lakes	Anglers	27	19 †	52	50

* Significant at the 1% level as to whether the percentages are equal.

† Percentage objecting in a user group (e.g., anglers) is smaller than its counterpart (e.g., nonanglers).

‡ Significant at the 5% level as to whether the percentages are equal.

§ Percentage objecting in a user group (e.g., anglers) is larger than its counterpart (e.g., nonanglers).

|| Significant at the 10% level as to whether the percentages are equal.

about HWA and control methods than nonvisitors (1%) ($P < 0.01$). However, we found no significant difference between visitors and nonvisitors in terms of their concerns over the impacts of HWA damage or about their support for controlling HWA at various locations on public forests. However, a significantly higher proportion of public forest visitors (69%) indicated concern for reduced quality of scenic views and reduced quality of hiking or outdoor recreation than nonvisitors (51%) ($P < 0.01$). One might infer from this result that both visitors and nonvisitors are concerned about the existence values of healthy forests, but visitors might be more concerned with the damage as their use values of forests could be at stake. One might also posit that existence values probably dominate use values when it comes to making policies to maintain forest health while preserving the public interests.

We also compared the acceptability of specific control options among specific user groups (e.g., hikers, campers, picnickers, and anglers), whose typical recreation sites could be directly influenced by treatment. For the most likely user groups of each site or setting, the percentage of respondents who objected to a given treatment is presented in Table 3. Consistent with Figure 5 (shown for the sample), soil treatments and predatory beetles were found to be more objectionable than branch and trunk treatments, across all user groups and sites. It is important to note that some user groups showed strong objections to certain methods in their likely recreation areas. For example, 50% of the public forest visitors objected to releasing predatory beetles around parking lots. We chose general visitors as the most relevant user group for parking lots as almost all

visitors are expected to use them. This result is consistent with the report of Muller and Job (2009) who found that tourists at national parks had a neutral attitude toward beetles and were against controlling the insect in the park. Similarly, 51% of hikers objected to releasing beetles along hiking trails. Half of the campers and picnickers objected to soil treatments and predatory beetle releases in campgrounds and picnic areas. Up to 71% of the backpackers objected to releasing predatory beetles in backcountry or wilderness areas. Moreover, treating soil with insecticides and releasing predatory beetles to control HWA along streams and lakes brought objections from at least 50% of the anglers. As Pearson χ^2 tests suggested, some of these specific user groups showed significantly different objection levels than their counterparts. A significantly higher percentage of public forest visitors objected to trunk injection and soil treatment to control HWA around parking lots than nonvisitors. These results are consistent with the “Not in My Backyard” syndrome observed in other attitudinal surveys related to natural resources or other public policy issues (Dear 1992). Among nonvisitors, 8% objected to trunk injection methods ($P < 0.05$) and only 13% objected to soil treatment methods ($P < 0.01$) around parking lots. Moreover, a significantly smaller proportion of park visitors than nonvisitors (15% versus 47%; $P < 0.01$) objected to spraying soap and oil.

A higher proportion of hikers than nonhikers (51% versus 22%; $P < 0.01$) objected to releasing predatory beetles along hiking trails. In addition, a significantly higher proportion of campers and picnickers (30%) objected to trunk treatment in camping ar-

eas and picnic spots than their counterparts (15%). Moreover, the proportion of backpackers who objected to releasing predatory beetles in wilderness was significantly higher than that of nonbackpackers ($P < 0.03$). However, it is not clear if the self-identified backpackers in the survey were visiting or camping in wilderness areas only. No significant difference was observed between sightseers and others in terms of their preferences for any type of controls applied along roads and scenic routes, nor did we find a significant difference between campers and noncampers regarding their preferences for any methods in wilderness areas even though as high as 50% of the campers were against releasing predatory beetles at all. Compared with other methods, releasing beetles was objected to by a relatively higher percentage in all recreation groups except sightseers.

Nonanglers (35%) objected at a greater rate than anglers (19%) ($P < 0.07$) to trunk injection along streams and lakes. However, it is important to note that for all other treatments along streams and lakes, anglers objected more than nonanglers. The higher support for trunk injection among anglers may be attributable to their perception of the relative benefit of this method compared with the potential environmental costs, as this method could be perceived to be environmentally sensitive and effective (Doccola et al. 2007) and thus may yield the lowest chance of fish habitat contamination. It may also relate to the idea that once injected, the chemicals remain within the tree.

Discussion and Implications

Although public forest managers face increasing challenges for controlling invasive forest pests, a growing body of literature on the human dimensions of forest health has emphasized the need to understand stakeholders’ attitudes and preferences pertaining to control programs. The environmental and cultural benefits of saving hemlocks are significant to society regardless of the control option used as are the social costs of HWA infestation, considering its impact on the outdoor recreation industry and property values (Holmes et al. 2005, Li et al. 2014).⁵ However, the prevalence of this species in riparian areas, along with outcome uncertainty and the environmental consequences of alternative controls, warrants care in the ultimate selection of methods, paying attention to cost-effectiveness and social acceptability.

Findings from our survey-based study

provide a number of human dimensions insights about HWA and associated control programs for public forests. Although the low response rate for our household survey is on par with those of many recent surveys, potential self-selection bias could be a concern and may have influenced the results. Furthermore, although the direction of any bias is unknown, it has been shown that people affected by or familiar with a topic of survey are more likely to respond (Dillman et al. 2009). Moreover, given the demands on people's time and the constant barrage of telemarketing and political surveys, people are just as likely to simply be survey weary (Pelham and Blanton 2012), with those responding providing unbiased results. Despite the response rate, this study is the first to take a comprehensive look at public opinion on HWA, and the results are seemingly consistent with those for other human dimensions literature for invasive species. Considering the similarity of our sample with the population of the study area in key demographics, we believe that the results are reasonably representative and can inform management and policy initiatives.

One implication of our results is that public knowledge of both the HWA and control options is quite limited, even in areas where established populations of HWA are documented. We think this fact is even more pronounced, given the low, but typical, response rate. Therefore, it would appear fair to conclude that, even in an area known to be infested with HWA, the public might be generally unaware of the issue, which is far more important to biologists, environmentalists, and land managers. Further, there is some geographical disparity in knowledge, despite the fact that the sample was drawn from counties known to be infested with HWA. The limited perception of the problem and limited knowledge of control options could imply low levels of support for state-run programs to control HWA on public forests. Of course, that could also mean that the public does not become "interested" until such environmental problems become much larger and, thus, more difficult and expensive to control.

Studies of invasive species have shown that landowners who perceive the threat of invasive species are likely to be motivated to control invasive species (Fischer and Charnley 2012). In fact, our results indicated a higher awareness of the problem and control

methods among those who owned property with hemlocks, which confirms this assumption. However, an objective of this study was to assess whether and how much the general public, not just landowners, knows about this issue. The fact that most respondents demonstrated limited knowledge about HWA calls for more outreach and education, particularly if professionals recognize the magnitude of the problem. Specifically, additional educational and informational campaigns to educate citizens about the issue of HWA and control options may generate support for government-sponsored control programs on public lands. This could be done through informing visitors on-site through bulletin board or kiosk materials and fact sheets. Moreover, where only 20% of our sample disagreed with controlling HWA if the costs were reasonable, including information on program costs (e.g., per acre) in fact sheets could be useful. Communicating with the general public in hemlock region through mailing out of informative flyers and sponsorship of public messages in local media may also prove effective.

Second, public concern about the impact of HWA damage was motivated more by environmental (bird and fish habitat) and cultural reasons (quality of outdoor recreation and scenic views) than economic or commercial ones (loss of private property value or private trees). Our results confirmed that controlling HWA in areas of high recreation use and ecological significance on public land is more important to respondents and, by inference, the public, than in other areas. This could be helpful in designing and implementing control programs in priority areas that preserve forests of higher public value. For example, control programs could be targeted to treat HWA along popular fishing streams, in campgrounds, and in areas where trees provide critical nesting sites for birds, before taking them to parking lots, areas adjacent to human settlements, and vacation homes. It is also important to note that high levels of concern exist over some other issues, including increased safety hazards and fire risk in infested areas. Public land managers facing financial challenges in combating HWA may highlight these safety and liability concerns during budget negotiations with agencies and legislators.

Third, despite respondent support for HWA control, we found a great deal of vari-

ation in acceptability of control methods among various sites within the public forests. In general, direct trunk injection of insecticides and application of soap and oil on infested branches were more acceptable than application of insecticidal chemicals to the soil or releasing nonnative predatory beetles. Despite being made aware (with the informative material included in the survey) of the advantages in cost and ease of application for the soil treatment method and the longer duration of control using predatory beetles, a higher proportion of respondents preferred branch and trunk treatment options. This indicates that the acceptability of control options that are perceived to be more environmentally friendly, and with known consequences, could be higher than that of the options with potentially harmful or unknown environmental consequences. As evident in our analysis, soil treatments and predatory beetles are likely to draw some public resistance if they are openly applied in environmentally and culturally sensitive areas such as along streams and lake shores, in campgrounds, and in picnic spots. If the scientific evidence shows that biological control is the best option available to deal with HWA, efforts should be taken to educate visitors on the facts and myths about the predatory beetles so that people feel comfortable in coexistence and support control programs.

Fourth, not all public forest stakeholders are alike in supporting HWA control programs. In terms of recreation use, more hikers than nonhikers rejected releasing predatory beetles along hiking trails, whereas more anglers than nonanglers supported trunk injection as opposed to other methods around streams and lakes. These contrasting preferences cast doubt on a "one size fits all" approach for HWA. Public land managers may consider input from relevant recreation user groups in developing their pest management strategies so that socially acceptable methods are applied to preserve the forest ecosystem function and enhance the cultural value of forest sites. A previous proposal by the US National Park Service to contain HWA in GSM National Park recommended a combination of chemical control and biological control as an integrated alternative, which received overwhelmingly supportive comments from the public during the environmental assessment (Soehn et al. 2005). Although the recommendation was not specific in sites to be treated, the inte-

grated approach included chemically treating infested hemlocks in accessible and high-use developed areas (campgrounds, picnic areas, and visitor centers) with soap and horticultural oil, treating soil or injecting imidacloprid into trunks, and releasing predatory beetles at inaccessible sites (old-growth and backcountry forests). The proximity of the site to water was also emphasized in selecting between soil treatment and trunk injection. Whereas the park has successfully treated more than 200,000 trees with chemical methods, the overall effectiveness of more than one-half million beetles released since 2002 is yet to be determined (US National Park Service 2015). In the DWG National Recreation area, infested trees within 75 ft of water along high-use areas have also been treated with chemical injection into tree trunks, whereas those located farther away are treated with soil injection (Evans 2009). Remote forests of infested hemlocks have been treated with predatory beetle although with limited success. Reviews of the ongoing efforts at DWG National Recreation Area and GSM National Park indicate much congruence between what managers are doing to control HWA and how the broader public wants it to be managed, which is a judicious use of a variety of methods. However, rather slow progress of the existing methods in containing HWA suggests that future research should focus on new methods such as silvicultural treatment to increase host resistance or diversification of hemlock stand structure for their techno-economic feasibility and social acceptability.

Endnotes

1. For more information, see na.fs.fed.us/fhp/hwa/maps/distribution.shtm.
2. We used buffers of different sizes to account for the size of the park itself and population density in the surroundings. The GSM National Park is bigger than the DWG National Recreation Area, and the communities surrounding it have relatively sparse population.
3. A copy of the survey is available from the authors on request.
4. According to the sample size formulas suggested by Dillman et al. (2009), a sample size of 384 would be sufficient for the population of study area counties (with 95% confidence interval, and $\pm 5\%$ sampling error).
5. Approximately \$25 million in the loss of property value of was estimated for the Southern New England only.

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