Nonindustrial Private Forest Landowners and the Southern Pine Beetle: Factors Affecting Monitoring, Preventing, and Controlling Infestations

Joseph J. Molnar, John Schelhas, and Carrie Holeski

ABSTRACT

The southern pine beetle (SPB; *Dendroctonus frontalis* Zimmermann) has been a major source of timber and income loss to nonindustrial private forest landowners in the southern region of United States. Efforts to promote forest health through prevention and control must identify new ways to reach the sociologically diverse and spatially dispersed nonindustrial private landowners in this region. This study examined the knowledge levels, perceptions, and forest management practices among a sample of 205 southern forest landowners contacted in a mail survey. Results show that respondents with personal value commitments to conservation and wise use of forestland took more monitoring, prevention, and control actions. Membership in forest landowner associations, familiarity with public assistance programs, and use of more sources of forest management advice defined a context for increased awareness, interest, and desire to manage the SPB. Furthermore, two aspects of the landowner situation seemed to enhance the propensity to take SPB prevention and control actions. Recent SPB-caused timber losses in the county and the presence of a written management plan were associated with greater prevention efforts. An established consideration of what treatments and purposes a piece of property was to receive seemed to lead to better responsiveness to forest health risks such as the SPB. Although plans to harvest timber seemed to enhance vigilance about the SPB, involving forest holders in a broader community of landowners seems to be a central means for stimulating the vigilance and commitment necessary to intervene early in the development of forest health problems before larger losses ensue.

Keywords: southern pine beetle, prevention, extension, landowners, education

In August 2002, President Bush proposed a Healthy Forests Initiative (HFI) that would join the USDA Forest Service, the US Department of the Interior, and the White House Council on Environmental Quality in an effort "to restore [forest and rangeland] ecosystems to healthy, natural conditions and assist in executing core components of the National Fire Plan" (White House 2002). This 10-year comprehensive plan was a response to the devastating fires of the summer of 2002, one of the worst fire seasons on record (National Oceanic and Atmospheric Administration [NOAA], White House 2005). Although fire can have an acute and fast-acting impact on forest health (albeit sometimes beneficial), the HFI concluded that greatest long-term threats to the future health of southern forests stem from surges in nonnative and indigenous pests and diseases (NOAA 2005).

The southern pine beetle (SPB; *Dendroctonus frontalis* Zimmermann) is the most serious insect threat to pine forest health in the southern United States (Thatcher and Barry 1982). Once a forest stand is infected, there are few options to immediate elimination and isolation of infected trees (Billings and Pase 1979, Clarke 2001). The mixed oak–pine ecosystems in the southern Appalachians are in decline because of a combination of drought and SPB infestation (Knoepp et al. 2004). Unless insect-infested trees are removed swiftly, infestations can spread to healthy forests. It seems that no single compound is responsible for mediating SPB parasitoid host-tree location and that both oxygenated and hydrocarbon semiochemicals are involved in this process (Sullivan et al. 1997). Thus, the most effective approach to preventing losses from the SPB is through forest management, including thinning and prescribed burning. Nevertheless, many landowners do not undertake these measures (Clarke and Billings 2003).

Pine beetle outbreaks are cyclic, sporadic, and potentially highly devastating (Meeker et al. 1995). Extensive outbreaks not only inflict losses on individual owners forced to sell high-value sawtimber for low-value pulp but also can impose collective damages (e.g., wood pricing) on all forest owners. When extensive cutting of infested stands overruns woodyards with diseased timber, the price of pulpwood often falls to unprofitable levels when supply exceeds demand. In extreme situations, producers suffer dead weight losses when infested trees are simply felled and left in the forest (the most immediate control response to an outbreak).

Clarke and Billings (2003) reviewed infestations of SPBs on forests in Texas during the 1990s. Direct control treatments were applied to two-thirds of the infestations on a managed forest; the average size of treated spots was 1.3 ac, but inactive infestations averaged only 0.25 ac. Cut-and-remove was the preferred treatment and over 97% of infestations required but a single treatment by this method. Cut-and-leave was applied to 27% of infestations requiring treatment, and, again, a single treatment was effective for 90% of

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treated infestations. In stands where SPB suppression was limited due to legal constraints, large infestations developed, killing over 40% of the susceptible trees. In contrast, less than 2% of the susceptible pines were killed in managed areas. Thus, the outbreak prevention tools available to nonindustrial private forestland (NIPF) landowners can be largely effective if implemented.

Prevention efforts require vigilant surveillance for infestations and adherence to planting and management recommendations that discourage SPB outbreaks, although the mechanisms of SPB population dynamics are complex (Hofstetter et al. 2005). Control of outbreaks requires prompt treatment and a comprehensive response of all forest owners to stop the spread of SPBs to neighboring lands (Egan and Jones 1993, Ervin et al. 2001). NIPFs comprise more than two-thirds of the forestland east of the Mississippi (Clawson 1977, Birch 1996). However, many NIPF owners have weak and uneven ties to their properties, and many do not share the sense of urgency that professional foresters often have about SPB prevention and control (Williston et al. 1998).

Rapid population growth and urban/suburban expansion in the South have caused parcelization (division of forest landholdings into increasingly smaller units), resulting in many new NIPF landowners (Birch 1997). With parcelization, there is concern that SPB outbreaks might begin on any landholding that is not subject to active management (Ervin et al. 2001). Previous studies have found that NIPF landowners constitute a diverse group, with great variance in landowning objectives, use of professional forestry assistance, and forest management strategies (Bliss and Martin 1989, Jones et al. 1995, Dedrick et al. 1998, Measells et al. 2005).

There are a number of possible reasons why NIPF landowners might not engage in practices known to be effective in preventing SPB infestations. First, landowners may be unaware of SPB, its impact, and practices for controlling it. Second, landowners may not be generally involved in active forest management, with reasons ranging from lack of knowledge, different landownership objectives, and perceived conflict of forest management with other values. Third, landowners may be aware of SPB prevention measures but not take appropriate steps because of cost, lack of access to control measures, limited resources, or other conditions (Price et al. 1992). These potential reasons fit well into the Awareness, Interest, Desire, Action (AIDA) model (Witzel 2002), which portrays the reasoned steps landholders pass through as they consider compliance with SPB management practices.

Landowner Decision Processes

A number of models in the social sciences purport to show how individuals become committed to a course of action. In 1898, St. Elmo Lewis presented a model that attempted to explain how personal selling works. The AIDA framework suggests that when considering making purchases, human thought processes go through four stages (Witzel 2002). It specifies the stairstep conditions that a salesperson must lead a potential customer through to achieve a sale. We maintain that this linear hierarchy of cognitive states is useful for understanding the context of public agency efforts to promote forest health (Barry 1987).

Forest health, specifically SPB prevention and control, often is an unrecognized need on the part of NIPF owners. That is, landowners may not know about the potential for damage from the insect, may discount its likelihood of occurrence on their lands, or may be unwilling to undertake measures necessary to monitor and respond to outbreaks (Belanger et al. 1993). Simply put, to be motivated to actually make a forest management choice that promotes forest health (i.e., to control pine beetles), landowners must process through three states before acting. The landowner must (1) be aware of an SPB threat and the existence of a management strategy, (2) be interested enough to pay attention to the strategy's features and benefits, and (3) have a desire to benefit from the outcome of the strategy for their own trees and those of their neighbors.

The fourth stage, action, is conceptualized as a natural result of movement through the first three stages; i.e., desire leads to action (Barry 1987). The model is commonly used in designing advertising and promotions, and advertisers try to develop material that stimulates as many stages as possible in response to a single communication. Rogers (1995) adapted this perspective to describe and understand the diffusion of innovations. Others have used similar frameworks to understand conservation behavior and other resource-owner decisions that involve a private benefit and a public good (Pattanayak et al. 2003, Trumbo and O'Keefe 2005).

The AIDA model is straightforward, which partly explains its longevity and widespread use. To begin with, before they will make a utilization decision, landowners need to be aware that they have a problem and that a solution or management strategy exists to resolve the situation. Perhaps landowners also need to know where and when the components of the solution are available and what advice they can obtain (van den Ban and Hawkins 1996).

Next, landowners need to be stimulated to take some interest in the solution or management strategy. What special features does the approach have? What benefits does it offer to the landowner? How might it satisfy any one of a variety of management objectives that the landowner might have? During this stage the landowner develops a reaction to the management strategy, usually either favorable or unfavorable (van den Ban and Hawkins 1996).

If the response is favorable and the communication is successful in awakening interest, the model suggests that the next step is to attempt to create in the landowner's mind a desire to implement the management strategy. This might be done by connecting the solution's benefits with the landowner's needs and wants. Often, this is the most difficult aspect of program design. It is relatively easy to portray a forest management solution in an attractive manner that stimulates landowner interest but it is often difficult to persuade them that they actually need to implement it. Many landowners might admire the Biltmore Estate near Asheville, North Carolina (or its equivalent level of land management) as attractive, well-engineered lands. However, rather few actively desire to own such a holding (if only because of its high cost). Therefore, the desire phase of communication has to show landowners that there are prevention strategies that fit their situation and show them how they can act to protect and improve their forest. This leads to the final stage, action, where landowners actually seek the forest management solution and implement the strategy on their lands.

Understanding factors that shape landowner perceptions of SPB problems can help structure efforts to promote forest management for SPB prevention and control. Such approaches should be formulated in ways that reflect barriers actually perceived by landowners. They also should enhance the benefit streams that NIPF landowners seek to obtain from their holdings.

Methods

Sample and Data Collection

A sample of 1,292 nonindustrial private landowners was obtained from a commercial sampling firm that maintains a list of

Table 1. Descriptive statistics for selected background and experience variables and SPB AIDA measures for Southern US landowners (n = 205), 2002.

Variables (response code)	n	Minimum	Maximum	Mean	Standard deviation
Dependent					
Awareness of SPB as problem (1 = not aware; 4 = very aware)	202	1	4	2.8	1.1
Interest level in SPB (1 = not interested; 4 = very interested)	201	1	4	3.0	0.9
Desire to take action (1 = no desire; 4 = great desire)	198	1	4	2.9	1.0
Number of monitoring actions taken	204	0	5	0.9	0.8
Number of prevention actions taken	205	0	3	0.4	0.6
Number of control responses to SPB damage	204	0	3	0.5	0.7
Independent					
Conservation of forestland important (1 = not; 4 = very)	199	1	4	2.8	1.1
Familiar with public forest assistance programs (1 = not; 4 = very)	200	1	4	1.7	1.0
Member state forest landowner association (0 = no; 1 = yes)	198	0	1	0.1	0.3
Number of sources of forest management advice	204	0	8	1.6	1.8
Plans to cut trees for sale (1 = none; 3 = yes, definitely)	201	1	3	1.9	0.7
Timber loss in county (1 = none; 4 = great losses)	201	1	4	2.3	1.2
USDA NRCS an important information source (1 = low; 3 = high)	145	1	3	1.5	0.7
Wise use forest management approach (1 = not at all; 4 = great extent)	194	1	4	2.4	1.2

NRCS, Natural Resource Conservation Service.

NIPF owners in the US South. The sampling frame was stratified to target counties with substantial areas of pine forest and to include landowners with 8 ac of forestland or more. Data were obtained from mail questionnaires completed by 205 nonindustrial private landowners in 13 southern US states that included Kentucky, Virginia, North Carolina, South Carolina, Georgia, Florida, Alabama, Tennessee, Mississippi, Louisiana, Texas, Arkansas, and Oklahoma.

The authors developed a 10-page draft instrument examining SPB management practices and circulated drafts for comment among forestry-knowledgeable extension and research personnel in the region. The instrument was pretested in a congregate setting and responses were used to revise the instrument. Following procedures outlined by Dillman (2000), a precontact letter was sent on Feb. 7, 2002—day 1. On day 10, the survey instrument and first cover letter were mailed. On day 17, a reminder postcard was sent. On day 24, the questionnaire and second cover letter were sent to the remaining nonrespondents. Three weeks later (day 45), the questionnaire and third cover letter were sent to the remaining nonrespondents.

Measures

This study examined six measures of SPB monitoring, prevention, and control. We measured awareness, interest, and desire to address SPB problems with single-item self-ratings.[1] Measures of monitoring, prevention, and control actions were developed by counting ticked responses to a series of possible management practices. Three aspects of action were measured—monitoring, prevention, and control. One indicator counted the number of monitoring behaviors.[2] Another counted the number of prevention steps ticked by respondents to measure aspects of the action phase of the decision process.[3] Similarly, a third indicator counted control measures used by respondents to limit SPB infestations when they occurred.[4]

Results

Accounting for undeliverable addresses and deceased respondents, the 205 respondents in the sample represented a 29% completion rate. Table 1 shows the means, standard deviations, and ranges for study variables. On average, respondents reported high levels of AIDA with respect to the SPBs. Variables that measured the number of actions taken portray a generally a low level of activation among NIPF landowners with respect to SPB monitoring, prevention, and control. Respondents took, on average, less than one monitoring step out of five possible. They reported taking less than one out of five possible previous actions and less than one out of five possible responses to infestations.

Table 2 reported the extent respondents had taken on any of each of three types of action—monitoring, prevention, and control—tabulated by the awareness, interest, and desire variables, controlling forest holding size. Only the proportion of each landowner category that took actions was shown. Chi-square tests indicated the association between each AIDA variable and actions taken within subsets of respondents holding less than 30 ac of timberland and those with 30 ac or more.

Data suggested that the percent of landowners reporting monitoring, prevention, and control actions was nearly monotonically related to self-rated awareness of the SPB problem. The relationship was stronger for those with 30 ac or more of forestland but holds for smaller landowners as well. Chi-square tests were significant for most monitoring, prevention, and control subtables, although the differences were slightly greater for respondents with more than 30 ac. Awareness of the SPB problem clearly was related to monitoring, prevention, and control actions regardless of holding size.

Landowner interest in limiting the SPBs as a source of timber losses was associated with monitoring, prevention, and control actions only among the larger landholders. Interest was not correlated with actions taken for those with less than 30 ac of timber. Desire to

Table 2. Percent of sample taking any SPB monitoring, prevention, or control actions tabulated by awareness, interest, and desire, controlling holding size for southern US landowners (n = 205), 2002.

Item	Monitoring actions taken		Prevention actions taken		Control actions taken	
	<30 ac	≥30 ac	<30 ac	≥30 ac	<30 ac	≥30 ac
	Percent "yes"*		Percent "yes"		Percent "yes"*	
Awareness of the SPB as a source of timber losses from forest land						
Not aware	32	60	12	0	16	0
Slightly aware	55	40	7	36	21	57
Somewhat	68	100	24	19	52	30
Very aware	100	85	18	65	35	73
Interest in limiting the SPB as a source of timber losses from forestland						
Not interested	50	33	13	0	13	0
Slight interested	56	100	10	38	23	63
Interested	64	91	21	35	42	38
Very interested	73	94	13	54	33	67
Desire to take action to limit damage from the spread of the SPB on your lands						
No desire	50	20	10	20	30	20
Slight	49	100	13	30	23	50
Somewhat	67	93	19	29	37	43
Great desire	78	96	17	57	39	64

* Because only "yes" responses are shown, percents do not sum to 100.

Table 3. Logistic ordinal regression of SPB AIDA measures on selected background and experience variables for southern US landowners, 2002.

Variable	Logistic ordinal regression					
	AID indicators			Actions taken by landowners		
	Awareness of problem	Interest level	Desire to take action	Monitor	Prevent	Control
Number of sources of forest management advice	−0.141	−0.090	0.049	*1.561*	**0.267**	*0.413*
Conservation of forestland important	−0.052	*0.700*	*0.784*	−0.635	0.166	0.190
Wise use forest management approach	0.194	0.184	0.208	**1.067**	**0.580**	**0.508**
Familiarity with public forest assistance programs	**0.504**	0.164	0.426	0.211	−0.199	−0.278
USDA NRCS an important information source	0.407	*0.736*	*0.791*	−0.076	−0.152	−0.261
Level of SPB loss in county	*0.934*	*0.431*	0.240	0.520	**0.352**	*0.408*
Member of state forest landowner association	1.607	0.751	0.441	1.204	0.203	0.500
Plan to cut trees for personal use	0.151	*0.828*	0.378	*1.357*	0.144	−0.056
Plans to cut trees for sale	0.482	**0.792**	0.338	*1.751*	−0.158	−0.063
Have a written management plan	0.828	0.669	0.463	2.182	**1.008**	0.054
Model X^2 (10,140 df)	*91.3*	*107.5*	*92.9*	*79.2*	*55.3*	*60.6*
Pseudo-R^2						
Nagelkerke	0.514	0.581	0.528	0.506	0.404	0.407
McFadden	0.243	0.300	0.261	0.295	0.240	0.218
Cox and Snell	0.479	0.536	0.488	0.432	0.326	0.351
Link function	Logit	Logit	Logit	Negative log-log	Cauchit	Negative log-log

Coefficients in boldface have Wald statistics ($[B/SE^2]$) $P < 0.05$; boldface italic signifies $P < 0.01$.

take action to limit damage from the spread of SPB was associated strongly with monitoring actions for both small and larger landowners. Prevention actions were followed by an increasing desire to control the SPB among those with 30 ac or more of land. Desire to take action was not associated with actual control actions taken for either size category. Thus, an association between desire and prevention actions was manifested only for larger landholders.

A series of logistic ordinal regression equations summarized the best predictors of SPB AIDA in the sample of NIPF landowners[5] (Table 3). All equations had statistically significant model chi-square statistics ($P < 0.01$; $n = 140$), meaning that at least one of the coefficients is not zero (analogous to the F test in ordinary least squares [OLS] regression). The equations accounted for as much as one-half of the variation in each of the dependent variables as reflected in the various synthetic indicators of explained variation.[6] As listed for each equation, different link functions were used to estimate coefficients depending on the shape of the distribution of each dependent variable (Norušis 2006). The maximum likelihood technique yields B coefficients analogous to least squares regression coefficients for dependent variables measured at the ordinal level. As in OLS regression, B is the change in the dependent variable logit(Y) given a 1-unit change in the independent variable (Menard 2002, p. 50). A positive B coefficient means that as values of the ordinal- or interval-independent variables increase, the likelihood of larger scores on the dependent variable increases (Norušis 2006).

The extent of timber losses in the landowner's county was a predictor of self-rated awareness of the SPB problems ($B = 0.934$). Those who were more familiar with public assistance programs for forest landowners also were more aware of the SPB issue ($B = 0.504$). Respondents who indicated that conservation of forestland was a central part of their forest management strategy rated themselves as more interested in the SPB problem ($B = 0.700$). Planning to cut timber for sale in the near future was related to SPB interest ($B = 0.792$). A recent timber loss in the respondent's county was positively related to SPB interest ($B = 0.431$). Commitment to

conservation of forestland was positively related to desire to take SPB control and prevention actions ($B = 0.784$). Landowners with connections to USDA Natural Resources Conservation Service technical assistance had more desire to take action ($B = 0.791$).

Three aspects of action about the SPB problem were examined. We counted a series of possible steps that landowners could take to monitor their forest for SPBs as one aspect of action in the AIDA model. Several variables were related to the number of monitoring steps taken. Those who reported using a greater number of sources of forest management advice took more monitoring steps ($B = 1.561$). Those with plans to harvest trees endeavored to prevent SPBs more than other landowners ($B = 1.751$), as were those who endorsed wise use of forestland as an important value ($B = 1.067$).

Some aspects of the landowner's situation seemed to enhance SPB prevention efforts. Recent SPB timber losses in the county seemed to motivate more prevention efforts ($B = 0.352$). Those who had a written management plan were likely to take prevention measures ($B = 1.008$), as were those who had more sources of forest management advice ($B = .0267$). An established outline of what purpose was to be served and what treatment a piece of property was to receive seems to lead to better responsiveness to forest health risks such as the SPB.[7]

When SPB outbreaks actually occur, the landowner can take a number of responses to control infestations. We counted the number of control actions that landowners indicated they implemented in response to SPB outbreaks. The number of sources of forest management advice was a predictor of control actions taken ($B = 0.209$). Members of state forest landowner associations took more steps ($B = 0.500$), as did those whose management strategies emphasized wise use of forestland ($B = 0.508$).

Discussion

This study examined antecedents of SPB prevention and control behaviors as a function of intervening levels of awareness, interest, and desire to prevent and control infestations of a destructive insect. Salom et al. (2001) described a website designed to increase communication among researchers and professionals to help advance SPB management. Thus, the supply of technical information is available and growing; but questions remain on how to stimulate demand for information on the part of NIPF landowners.

We used the AIDA model of response to communications designed to alter choices and behavior to understand SPB responses. The data suggested that awareness was a central mediator of this process, because it was reflected in strong and reasonably consistent relationships to the measures of SPB prevention and control that we examined. Public agencies might emphasize creating awareness of the SPB as a basic condition necessary to engender greater levels of monitoring, prevention, and control among NIPF landowners.

We expected that holding size would moderate relationships between awareness, interest, and desire indicators and measures of monitoring, prevention, and control actions. We observed strong and consistent relationships between awareness and action variables, but desire and interest were less systematically associated with prevention and control actions when holding size was controlled. Interest was associated with prevention and control actions for larger holders, but desire led to prevention actions only for respondents with more than 30 ac of timber.

These results pointed to the diverse set of motivations and circumstances that govern landowner views toward SPB prevention and control. One empirical generalization that emerges from the findings was that with larger landowner holdings, the more salient the direct interest in timber harvest and management. Ordinal linear regression analysis suggested a number of consistent and strong factors associated with SPB prevention and control. The number of sources of forest management advice used by a landowner was consistently related to all the action variables, a key finding for those endeavoring to inform and motivate NIPF landowners. Similarly, commitment to wise use of forest resources was related consistently to actions taken to monitor, prevent, and control SPB infestations.

The results also pointed to a set of characteristics of the respondent's context that shape SPB attitudes and behaviors. Clearly, timber losses in a locale raise concerns and motivate actions about SPBs. Social networks activated by reports of neighbor losses and experiences stimulate awareness and augment knowledge of the problem. Respondents with personal value commitments to conservation and wise use of forestland had more positive attitudes and took more monitoring, prevention, and control actions. Connections to forest landowner associations, familiarity with public assistance programs, and use of more sources of forest management advice were central contours of the context for more active management of SPBs.

Conclusion

SPB monitoring, prevention, and control is part of a larger effort to maintain forest health. It is the interest of forest landowners to protect their own holdings, but there also were common property interests at stake in containing insect threats before they cause widespread damage. Involving forest landowners in a broader community of landowners seems to be a central means for stimulating the vigilance and commitment necessary to intervene early in the development of forest health problems before larger losses take place.

Extension and technical assistance programs may emphasize themes that relate SPB prevention and control to a broader program of sustainable management. Fire protection, insect management, and other forest health issues can be mutually reinforcing topics for communication with NIPF landowners. Motivating and supporting pine beetle prevention and control will be an enduring challenge in the face of periodic surges in insect populations and a heterogeneous target audience of decisionmakers with diverse connections to their property and their trees.

Endnotes

[1] The questions and response frameworks are given in Table 2.

[2] Respondents were asked, How do you look for SPB damage on your land? The following were counted responses: look for damage when I visit the land; instruct employees to look for damage; rely on the state forestry agency to look for damage; pay consultants to watch for damage; ask hunting leaseholders to report damage if they see it; and other actions.

[3] Respondents were asked, What actions have you taken to limit or prevent SPB problems? The following were counted responses: thin stands to avoid infestations; plant fewer trees per acre; plant other tree species; and other actions.

[4] Respondents were asked, What happens when you have SPB damage on your forestlands? The following were counted responses: cut and remove infested trees (sell or give away timber); cut, pile, and burn infested trees; cut and leave infested trees; spray infested trees with insecticides; and other actions.

[5] As a data reduction strategy, a large set of bivariate associations among study variables were focused to a subset with consistent relationships to the dependent variables for subsequent analysis. The complete set of associations is available from the authors on request.

[6] The SPSS Ordinal Regression procedure, or PLUM (Polytomous Universal Model), is an extension of the general linear model to ordinal categorical data (Norušis 2006). The ordinal regression model is called the cumulative logit model because the maximum likelihood model is built based on the cumulative response probabilities $g_j(X)$ of being in category (j) or lower given the known explanatory variable.

[7] One intermediate diagnostic step for conducting ordinal logistic regression is the test of parallel lines. The null hypothesis that the lines are parallel was accepted for all the dependent variables except prevention ($X^2 = 45.6$; $P < 0.05$). This result suggests that the prevention equation should be cautiously interpreted because the relationship between the independent variables may not be the same for all logits (Norušis 2006, 74).

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