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# Capturing Community Context of Human Response to Forest Disturbance by Insects: A Multi-Method Assessment

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**Abstract** The socioeconomic and environmental features of local places (community context) influence the relationship between humans and their physical environment. In times of environmental disturbance, this community context is expected to influence human perceptual and behavioral responses. Residents from nine Colorado communities experiencing a large outbreak of mountain pine beetles (*Dendroctonus ponderosae*) were surveyed in 2007. Multiple analytic methods including ordinary least squares regression and multilevel modeling techniques were used to evaluate a community-context conceptual model of factors influencing individual actions in response to forest disturbance by beetles. Results indicated that community biophysical and socioeconomic characteristics had important impacts on participation in beetle-related actions and influenced the relationships of individual-level variables in the conceptual model with beetle-related activities. Our findings have implications for natural resource management and policy related to forest disturbances, and for developing a methodology appropriate to measure the general community context of human-environment interactions.

**Keywords** Community context · Forest disturbance · Individual actions · Multilevel modeling · Regression techniques

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## Introduction

Human behavior is always situated in specific temporal and spatial contexts in which social interactions, events, and processes take place (Thrift 1983). As the key social unit linking individuals with society, communities provide important context for experiencing various social actions and problems (Wilkinson 1991). Communities also serve as a unique interface between the environment and society (Field and Burch 1988). As Amos H. Hawley wrote, "… [community] is in fact, the least reducible universe within which ecological phenomena may be adequately observed….The community, then, is the basic unit of ecological investigation" (1950: 180). Therefore, communities, especially those centered on utilization of natural resources, form primary backdrops for the study of human-environment interactions.

Communities dependent on forest resources and which are therefore vulnerable to natural risks, tend to be particularly impacted by problems encompassing both environmental and societal processes (Flint and Luloff 2007). In recent decades, forest disturbance by insects has increasingly affected forest communities in North America. Changing biophysical landscapes caused by insect infestations are further complicated by the associated diverse human dimensions of forest disturbances. Local communities often differ in perceived impacts and risks and relationships with land managers (Flint *et al.* 2009). Community residents also respond to insect disturbances and forest management approaches in very different ways involving a wide range of social, cultural, economic, and environmental factors. An ecological approach to the analysis of these perceptions and responses stresses the socioeconomic and biophysical community context for local reactions to insect-induced forest disturbance.

While the importance of social context is commonly recognized in social science research, quantitative methods assessing community context are underutilized (Luke 2005). We here investigate community context of human response to forest disturbance by insects using secondary socioeconomic and biophysical data and mail surveys from nine communities in north central Colorado, where mountain pine beetles (MPB) (*Dendroctonus ponderosae*) have infested over 1.9 million acres (607,028 ha) of trees since 1996 (Leatherman 2008). We build upon a conceptual model of action in response to forest disturbance risks developed by Flint and Luloff (2005, 2007), and evaluate several posited paths through which community context influences beetle-related actions taken by local residents. Multiple analytic methods including constructing contextual variables, ordinary least squares (OLS) regression analysis for the aggregate dataset and for individual communities, and multilevel modeling, were used to explore community contextual effects on beetle-related activeness. Data analysis revealed that community context mattered for participation in local action in response to forest risks associated with the MPB outbreak. This finding has important implications for natural resource management and mitigation strategies for ecological disturbances. Moreover, it is our hope that this study can foster more research interest in measuring the community context of human environmental behavior, and contribute to the development of a methodology for empirically examining community contextual effects in general ecological social science research.

## Community Context of Environmental Behavior

From an interactional perspective, community is an emergent process among people who live in a common territory and regularly interact with one another (Wilkinson 1991). Community context refers to the socioeconomic and biophysical situations of the local place in which human behavior and social interaction are embedded. Environmental-related behavior is shaped by economic, sociocultural, institutional, and environmental conditions of the actor's community (Altman *et al.* 1984). Typically, the community context of human environmental behavior is depicted with detailed qualitative descriptions (e.g., Fitchen *et al.* 1987; Flint and Haynes 2006; Huntington *et al.* 2006; Salomon 1992). Only a few studies have statistically analyzed the extent to which socioeconomic and ecological contexts of the community affect human actions on environmental issues. Guerin *et al.* (2001) examined the role of contextual factors in participation in recycling programs with a multilevel modeling approach. Although this research used national level contextual variables in the analysis, its findings suggest that conservation behavior is substantially influenced by the context of environmental activism and ecological conditions in which it occurs. In a similar vein, Dolisca *et al.* (2009) conducted a multilevel analysis of the determinants of participation in forest conservation activities among farmers in southeastern Haiti. The results also showed that the organizational, structural, and ecological village contexts greatly affected forest conservation behavior.

Contexts shaping and constraining human behavior toward environmental problems can also be operationalized as variables other than socioeconomic and environmental characteristics of the community. Olli *et al.* (2001) measured the social context of environmental behaviors through participation, frequency of volunteering, and face-to-face interaction with other members in environmental organizations. In a study on the influencing factors of households' use of non-wood alternative fuels in rural south-central Nepal, Macht *et al.* (2007) estimated the community context of household energy consumption as access to major nonfamily organizations and services (such as markets, schools, banks, and clinics) in local neighborhoods. In both of these studies, the contextual measure was found to be highly significant in its impact on relevant environmental behaviors.

Although many social ecology scientists value contextualization, the number of empirical analyses of the community context of environmental behavior using appropriate quantitative tools remains limited. There is an increasing need for greater statistical rigor in assessing community context in human ecological science. Our study contributes to this literature by employing multiple statistical methods to examine the community context of human actions in response to forest disturbance by beetles in north central Colorado.

## A Community-context Model of Human Response to Forest Disturbance

The literature on natural resource-based communities, disaster, and risk has identified a wide array of factors influencing human and community response to forest ecosystem disturbances (Flint and Luloff 2005). Figure 1 shows a community-context conceptual model that outlines factors influencing local action in response to ecological disturbances of forests by insects. The community risk context is a combination of social, economic, and biophysical settings in which forest-based communities are embedded. This community context encompasses structural characteristics based on socioeconomic and demographic data as well as environmental characteristics that place a community at risk from forest disturbances (Flint and Luloff 2007). Beyond the community risk context, five individual-level factors are seen to act as primary influences

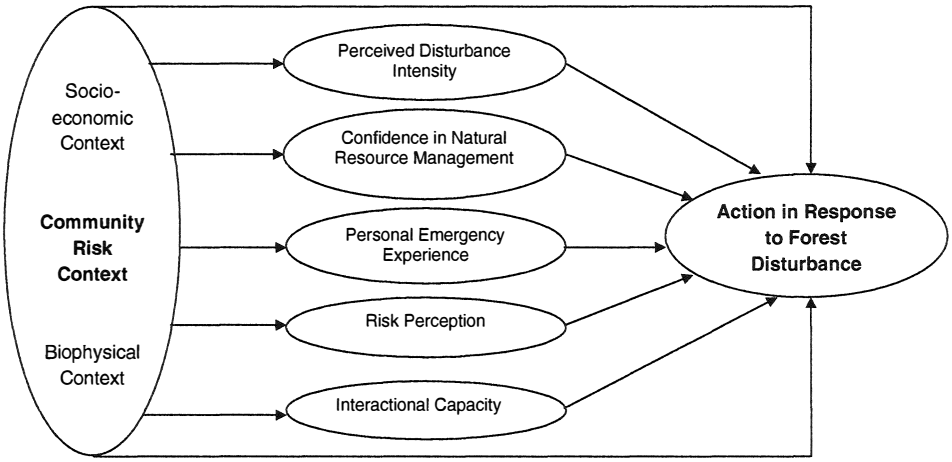


**Fig. 1** A community context model of action in response to forest disturbance by insects, adapted from conceptual framework by Flint and Luloff (2005, 2007)

on action in response to forest risks: (1) perceived forest disturbance intensity (Savage 1993; Sorokin 1928); (2) satisfaction or confidence in natural resource management (Peters *et al.* 1997; Wynne 1996); (3) personal experience with environmental disturbances or crises (Hannigan 1995; Zekeri *et al.* 1994); (4) interpretations of risk (Fitchen *et al.* 1987; Hannigan 1995); and (5) ability of community residents to work together in collective response to problems (Luloff 1990; Luloff and Swanson 1995; Luloff and Wilkinson 1979). The first four factors are important in molding perceptions of environmental problems and promoting local participation in associated actions. In addition, residents with higher participation levels in general community interactional activities are more likely to take actions in response to specific threats or risks (Flint and Luloff 2005, 2007).

This conceptual framework shapes our analytic approaches to assess the community context of human response to forest disturbance by insects. There are several hypothesized mechanisms through which community context influences local activeness with respect to the MPB outbreak. First, socioeconomic and biophysical community characteristics can directly affect beetle-related action in the case of forest risks. Residents from communities characterized by higher level of socioeconomic development and/or greater biophysical vulnerability may be more likely to engage in actions in response to the beetle impacts. Second, the effects of community context on local beetle-related action can be mediated through the individual-level constructs described in the model (Fig. 1). For example, higher biophysical vulnerability may increase perceived intensity of forest disturbance, which in turn leads to more actions by residents. If individual-level factors and community characteristics are highly associated, the relationships between these factors and beetle-related action may be confounded by community contextual variables. Finally, community context can modify or condition the impacts of individual-level factors on action in response to risks stemming from the beetles. For example, the expected positive effects of risk perception on beetle-related activities may be more acute in communities with high biophysical vulnerability than in those with low biophysical vulnerability. In assessing factors influencing local action in response to the spruce bark beetle outbreak in the Kenai Peninsula, Alaska, Flint and Luloff (2007) found community-level biophysical and socioeconomic contextual variables to significantly affect beetle-related action, but they did not examine in depth other possible pathways of community contextual influences. In this study, we build on prior work in this area and explicitly test the above three types of community contextual effects on human response to forest disturbance in the setting of the MPB outbreak in north central Colorado. The emphasis here is on employing different quantitative analytic methods to assess the efficacy of the community-context conceptual model. Detailed interpretations of qualitative findings from the study communities are discussed elsewhere (Flint *et al.* 2010).

## Study Area

A massive MPB outbreak has swept over 1.9 million acres in north central Colorado since 1996, killing millions of lodgepole pine (*Pinus contorta*) and ponderosa pine (*Pinus ponderosa*) which dominate forests in this high elevation region (Leatherman 2008). The study communities—Breckenridge, Dillon, Frisco, Granby, Kremmling, Silverthorne, Steamboat Springs, Vail, and Walden were purposively selected to broadly represent the array of local experiences with the MPB disturbance and socioeconomic conditions in the study area (see Fig. 2). The study communities range from luxury resort towns (such as Breckenridge and Vail) to rural communities transitioning from extractive industries such as ranching and logging to more of a natural amenity orientation (such as Granby, Kremmling, and Walden). The nine communities also

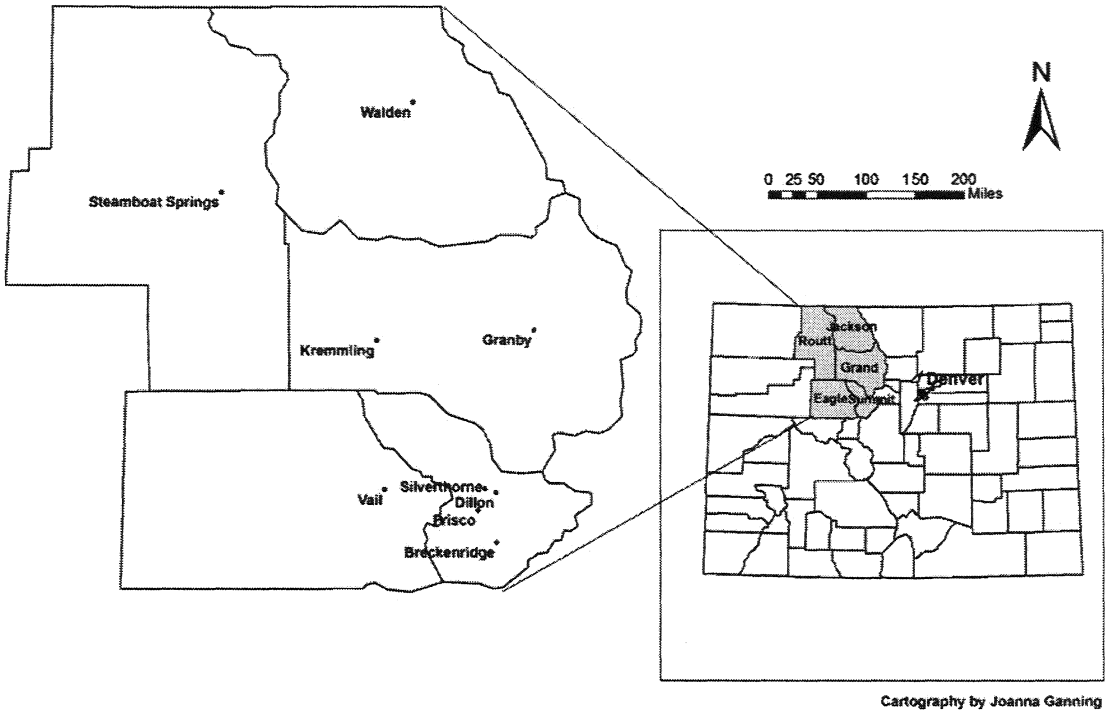


**Fig. 2** Map of north central Colorado and study communities

differed in their proximity to forests infested with beetles and intensity of disturbance. Breckenridge, Dillon, Frisco, Silverthorne, Steamboat Springs, and Vail are situated closer to national forests and the community landscape is more heavily forested. Forests around these communities also have a somewhat greater mix of tree species which may mitigate the impacts of beetles. By contrast, Granby, Kremmling and Walden are located further from forests in open park-like valleys, but the forests around them were more heavily affected by bark beetle activity.

## Mixed Methodology

This study used a mixed methods approach to collect and analyze data (Tashakkori and Teddlie 1998). Secondary socioeconomic and biophysical data from the US Census, the US Forest Service, and the National Land Cover Database (NLCD) 2001 were used to provide information on the structural and environmental characteristics of the study communities. Interviews with 165 key informants were conducted early in the study to provide rich narratives of community experience and to explore the range of variation in the key constructs in the conceptual framework. These interviews were analyzed thematically (Dunn 2000) and then used to inform the construction of a mail survey which was send to a sample of 4027 randomly selected households from the nine study communities. A modified tailored design method was used to administer the survey and increase response rates (Dillman *et al.* 2009). Prior to the survey mailing, advertisements were placed in local newspapers to increase local residents' attention to the survey. Each survey included the booklet-style questionnaire, a cover letter signed by the principal investigator, and a postage-paid and pre-addressed return envelope. The first wave of survey was followed after ten days by a thank you/reminder postcard to all households. Two weeks later, a second modified letter underscoring the importance of the survey and a replacement questionnaire were sent to non-respondents. The final contact was made after an additional two weeks by a third modified letter and survey accompanied with reminder phone calls to non-respondents. All unreturned surveys were considered non-responses following these efforts over ten weeks. Overall, 1346 of the mailed surveys were completed and returned, yielding a response rate of 39% after accounting for 569 undeliverable surveys.[1] Response rates varied across study communities,

[1] Survey data on respondent sociodemographic characteristics (age, gender, ethnicity, household income, and educational attainment) were compared to available census data for the study area, revealing no substantial non-response bias. This was further confirmed by comparing respondents answering the first, second, and third mailings of the survey on sociodemographic characteristics and responses to major questions. No significant differences in these variables were found among respondent groups thereby reducing concerns about survey representativeness.

but the resulting community sample sizes (ranged from 102 to 195) were generally balanced and sufficient for the analysis of survey data at the community level. The total cost of the mail survey effort was approximately $20,350, including printing, postage, and labor for assembly and data entry.

## Measurement of Variables

*Dependent Variable: Participation in Beetle-Related Actions* Local actions in response to forest disturbance included informal or formal activities taken by community residents to reduce the risks from the MPB outbreak or forest management strategies. Resident participation in these beetle-related actions was used as the dependent variable in the analysis. Respondents were asked whether they had (1) removed beetle killed trees from personal property; (2) participated in a neighborhood or community effort to clear trees; (3) contributed money to Homeowner Association efforts to clear trees; (4) actively watered trees to prevent beetles from killing trees; (5) sprayed trees on personal property with chemicals or insecticides; (6) cleared vegetation near structures for defensible space against wildfire; (7) used fire resistant building materials for structures; (8) planted or transplanted trees; (9) attended a public informational meeting; (10) helped with clearing or maintaining public trails; (11) consulted with public officials or foresters; (12) attended a beetle task force meeting; (13) participated in group efforts to preserve natural forests; and (14) participated in group efforts to promote resource utilization. Responses were coded into dichotomous values: "0" for no participation and "1" for participation. A composite dependent variable was created by summing responses across these 14 actions (alpha reliability coefficient = 0.75).

*Community Contextual Variables* Two community contextual variables were constructed using secondary biophysical and socioeconomic data. Geographical information system (GIS) is one of the most useful techniques for assessing community context (Luke 2005). The first contextual variable was an indicator of biophysical vulnerability built with ArcGIS using forest mortality data originated from aerial insect surveys undertaken by the Rocky Mountain Region of the US Forest Service and forest spatial data obtained from the NLCD 2001. It measured the percentage of tree mortality within a 15-mile radius around the census designated place boundary of each study community. The second contextual variable was a community-level amenity index created based on demographics, employment, and housing data from the US Census and forest cover and recreational data from the NLCD 2001 and the US Forest Service (Ganning and Flint 2010). This composite indictor provides an integrative measure of general community socioeconomic and environmental characteristics. The community amenity index centers on zero due to standardization and has positive or negative values.

*Independent Variables* Perceived intensity of the MPB disturbance was measured by two variables. One question asked respondents to describe tree mortality in and around their community (possible responses ranged from "1" no pines are dead to "5" all pines are dead). The other addressed the perceived amount of natural re-growth of new trees in and around respondents' community (possible responses ranged from "1" no natural re-growth to "5" much natural re-growth; recoded in reverse for the analysis).

Levels of confidence in natural resource management were measured by respondents' attitudes about a series of statements on forests in Colorado and forest management in and around their community (possible responses ranged from "1" strongly disagree to "5" strongly agree). Exploratory factor analysis of responses to these questions revealed two factors: faith in forest industry and trust in forest management. A composite measure of the faith in forest industry factor (alpha reliability coefficient = 0.79) was created based on the following seven statements: (1) forests should be managed to meet as many human needs as possible; (2) forests should have the right to exist for their own sake, regardless of human concerns and uses (reverse-coded); (3) forests should be left to grow, develop, and succumb to natural forces without being managed by humans (reverse-coded); (4) forests that are not used for the benefits of humans are a waste of our natural resources; (5) the present rate of logging is too great to sustain our forest in the future (reverse-coded); (6) the economic benefits from logging usually outweigh any negative consequences; and (7) forestry practices generally produce few long-term negative effects on the environment. Another six statements were included in a composite measure of trust in forest management (alpha reliability coefficient = 0.88): (1) forests are being managed successfully for a wide range of uses and values, not just timber; (2) forest management does a good job of including environmental concerns; (3) citizens in Colorado communities have enough say in forest management; (4) forests are being managed successfully for the benefit of future generations; (5) I have confidence in the US Forest Service to mange forest in Colorado; and (6) the US Forest Service shares my values about how Colorado forests should be managed.

Information obtained through analysis of interview data was used to construct mail survey questions about past experience with crises or disturbances and perceived risks. Experience with emergencies was measured by asking respondents to indicate their personal experience with the following emergencies (responses coded as "0" for no

experience and "1" for experience): nearby wildland fire, avalanche or landslide, flooding, and toxic contamination (e.g., gas spill, chemical exposure). A composite variable was created by summing responses to questions of experience with these emergencies (alpha reliability coefficient = 0.64).

Risk perception following the MPB outbreak in north central Colorado was measured by asking how concerned respondents were about a series of forest risks for their community (possible responses ranged from "1" not concerned to "5" extremely concerned): forest fire, falling trees, decline in wildlife habitat, impact on livestock grazing, increased erosion and runoff, and invasive plant specifies, loss of forests as an economic resource, loss of scenic/aesthetic quality, loss of tourism and recreation opportunities, loss of community identity tied to the forest, and impact on property values. Responses to these questions were summed and divided by the number of questions answered, yielding a composite measure for general risk perception (alpha reliability coefficient = 0.89).

Two independent variables were used in this study to measure interactional capacity. The first is a composite variable indicating a respondent's level of participation in the following community activities in the previous 12 months: (1) attending a local community event; (2) contacting a public official about some local issue of concern; (3) working with others in the community to try and deal with a community issue or problem; (4) attending any public meeting in the community; (5) serving as an officer in a community organization; (6) voting in an election; and (7) serving on a local government or advisory commission, committee, or board. Dichotomous responses ("0" no and "1" yes) were summed as an index of community participation (alpha reliability coefficient = 0.74). The second measure of interactional capacity was a variable representing a respondent's level of communication about forest issues and risks. Respondents were asked to identify whether or not they relied on any of the 15 sources of information listed in the survey, such as newspaper, radio, local fire department, city government, county beetle task force, and Colorado State/US Forest Service.[2] A composite variable measuring the total number of information sources was created based on the sum of responses to these questions (alpha reliability coefficient = 0.67).

*Sociodemographic Controls* Five sociodemographic variables were included in the study to control for the influences of respondents' selected characteristics on participation in local actions in response to forest disturbance by beetles. The sociodemographic controls included in the analysis were age, gender, years lived in community, annual household income, and education. Possible responses for annual household income included eight levels from "less than $15,000" to "$150,000 or more." Educational attainment was measured by six categories ranging from "less than a high school degree" to "advanced degree" (i.e., Masters, JD, MD, Ph.D.).[3]

## Analytic Procedures and Methods

The statistical analysis of community contextual effects on participation in beetle-related actions was conducted in four phases using the secondary and mail survey data. First, bivariate correlations among major variables were examined to explore the associations among community characteristics, individual-level predictors, and the dependent variable. Next, both OLS regression and multilevel modeling were used to assess the impacts of community contextual variables and independent variables on beetle-related action. Because respondents were nested within study communities in the survey data, multilevel modeling was more appropriate than traditional single-level regression for the analysis. The comparison of the two types of models also sheds light on the effects of community context. Third, multilevel modeling was also used to test whether community contextual variables modify the effects of independent variables on beetle-related action. Finally, an OLS regression model was constructed for each study community to provide more detailed information about community contextual influences. All the data analysis was conducted with the SPSS software (Version 16.0 released in 2007). Restricted maximum likelihood (REML) was used as the estimation method for multilevel regression models because the number of higher-level units is small.[4]

## Results

### Bivariate Analysis

Bivariate correlation analyses were used to examine the relationships among community contextual variables, inde-

[2] Other sources of information included word of mouth, own observations, local loggers, the Bureau of Land Management, county extension office, environmental organizations, public meetings, and county government.

[3] The eight household income levels were: (1) less than $15,000; (2) $15,000 to $24,999; (3) $25,000 to $34,999; (4) $35,000 to $49,999; (5) $50,000 to $74,999; (6) $75,000 to $99,999; (7) $100,000 to $149,999; and (8) $150,000 or more. The six educational levels were: (1) less than a high school degree; (2) high school degree or GED; (3) some college or post high school training; (4) two year technical or associate degree; (5) four year college degree (BA/BS); and (6) advanced degree (i.e., Master's, JD, MD, Ph.D.).

[4] For a detailed discussion on procedures of estimating multilevel regression models using SPSS, see Hayes (2006).

pendent variables, and participation in local action in response to forest disturbance by beetles. Pearson's correlations for the aggregate dataset are shown in Table 1. Neither of the two community contextual indicators was statistically significant in its bivariate correlation with beetle-related action. However, both of them had significant association with at least one independent variable measuring each construct in the conceptual model with the exception of personal experience with emergencies. Moreover, all the independent variables except for perceived amount of tree re-growth were statistically significant in bivariate relationship with beetle-related activeness. Community variations in independent and dependent variables were also assessed with a one-way analysis of variance (ANOVA). Significant differences across the nine study communities existed for all these variables (though only marginally significant for personal experience with emergencies).

## OLS Regression Modeling

In the multivariate analysis stage, OLS regression was first used to analyze the direct effects of community-level indicators on participation in beetle-related actions and their influences on the relationships between independent variables and beetle-related action. Results of a two block regression modeling process are shown in Table 2. The first OLS regression model (OLS Model 1) included all the individual sociodemographic controls and independent variables. Age and household income were positively and highly significantly related with beetle-related action, while at least one independent variable from each construct in the conceptual framework had a significant influence on beetle-related action. Those who were older, earned higher income, perceived a higher degree of forest disturbance and associated risks, held lower trust in forest management, had more experience with local emergencies, indicated higher levels of community participation, and consulted more information sources concerning forest issues were more likely to engage in action in response to the beetle outbreak.

OLS Model 2 added the two community contextual variables to the analysis. All significant variables in the previous model remained significant. Education was marginally significant in OLS Model 1, but its impact decreased with the inclusion of the community-level characteristics. In addition, the biophysical vulnerability indicator and the community amenity index were significant in their relationships to beetle-related action. Respondents from communities with larger proportions of forests impacted by beetles or higher amenity indices were more likely to take actions in response to forest disturbance by beetles. A comparison of these two models showed that the relationships between individual predictors and beetle-related action were not confounded by the inclusion of community characteristics in the regression analysis, suggesting that the influences of these two sets of variables on beetle-related action were relatively independent.

## Multilevel Regression Modeling

Since respondents are clustered within communities in the survey data, multilevel linear modeling (MLM) was also used in the multivariate regression analysis. Multilevel modeling relaxes the basic independence assumption of OLS models and allows for potential correlated errors of observations (Luke 2004). Multilevel model fitting normally includes multiple stages. Following the process described

**Table 1** Bavariate correlations among variables in the conceptual framework ($N$=1346)

| Variables | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Participation in beetle-related actions | | | | | | | | | | | |
| 2. Biophysical vulnerability | 0.00 | | | | | | | | | | |
| 3. Community amenity index | 0.04 | −0.93*** | | | | | | | | | |
| 4. Describe loss of trees | 0.11*** | 0.29*** | −0.30*** | | | | | | | | |
| 5. Describe lack of re-growth | 0.02 | −0.00 | 0.02 | 0.13*** | | | | | | | |
| 6. Risk perception | 0.14*** | 0.19*** | −0.16*** | 0.19*** | 0.11*** | | | | | | |
| 7. Faith in forest industry | 0.08** | 0.47*** | −0.46*** | 0.22*** | 0.08** | 0.16*** | | | | | |
| 8. Trust in forest management | −0.15*** | −0.31*** | 0.28*** | −0.24*** | −0.09** | −0.22*** | −0.14*** | | | | |
| 9. Personal experience with emergencies | 0.17*** | −0.01 | 0.01 | 0.08** | 0.00 | 0.05 | 0.04 | −0.09** | | | |
| 10. Community participation | 0.38*** | 0.09** | −0.07** | 0.02 | 0.00 | 0.02 | 0.07* | −0.17*** | 0.16*** | | |
| 11. Number of information sources | 0.37*** | 0.04 | −0.01 | 0.00 | 0.01 | 0.11*** | −0.01 | −0.00 | 0.11*** | 0.28*** | |
| Mean | 3.87 | 0.37 | −0.06 | 3.08 | 3.79 | 3.70 | 2.78 | 2.56 | 1.21 | 4.23 | 5.85 |
| SD | 2.92 | 0.22 | 0.77 | 0.89 | 0.88 | 0.78 | 0.84 | 0.88 | 1.20 | 1.84 | 2.80 |

*$p$<.05, **$p$<.01, ***$p$<.001

**Table 2** Comparison of OLS and multilevel models of participation in beetle-related actions for aggregate data

| | OLS Regression[a] | | | Multilevel Linear Modeling (MLM)[b] | | | |
|---|---|---|---|---|---|---|---|
| | Model 1 | Model 2 | | Model 1 | Model 2 | Model 3 | Model 4 |
| Intercept | | | | 3.847*** | −4.094*** | −4.767*** | −5.674*** |
| Sociodemographic controls | | | | | | | |
| Age | 0.159*** | 0.158*** | | | 0.031*** | 0.031*** | 0.030*** |
| Gender | −0.015 | −0.009 | | | 0.034 | 0.044 | 0.041 |
| Years lived in community | −0.045 | −0.035 | | | −0.004 | −0.004 | −0.003 |
| Household income | 0.136*** | 0.120*** | | | 0.072 | 0.059 | 0.059 |
| Educational attainment | 0.051(*) | 0.031 | | | 0.240*** | 0.230*** | 0.230*** |
| Perceived disturbance intensity | | | | | | | |
| Describe loss of trees | 0.095*** | 0.111*** | | | 0.285** | 0.311** | 0.290** |
| Describe lack of re-growth | −0.028 | −0.037 | | | −0.092 | −0.096 | −0.092 |
| Risk perception | 0.073*** | 0.071*** | | | 0.275* | 0.267* | 0.267* |
| Confidence in resource management | | | | | | | |
| Faith in forest industry | 0.008 | 0.041 | | | 0.230* | 0.269* | 1.339** |
| Trust in forest management | −0.089*** | −0.099*** | | | −0.317** | −0.334*** | −0.388*** |
| Personal experience with emergencies | 0.115*** | 0.109*** | | | 0.333*** | 0.322*** | 0.322*** |
| Interactional capacity | | | | | | | |
| Community participation | 0.227*** | 0.236*** | | | 0.375*** | 0.380*** | −0.074 |
| Number of information sources | 0.264*** | 0.263*** | | | 0.249*** | 0.250*** | 0.253*** |
| Community contextual variables | | | | | | | |
| Biophysical vulnerability indicator | | 0.153* | | | | 1.908 | 5.129 |
| Community amenity index | | 0.253*** | | | | 0.901(*) | 0.987 |
| Cross-level interactions | | | | | | | |
| Biophysical indicator * Faith in forest industry | | | | | | | −2.989* |
| Biophysical indicator * Community participation | | | | | | | 1.307* |
| Amenity index * Faith in forest industry | | | | | | | −0.600(*) |
| Amenity index * Community participation | | | | | | | 0.376* |
| $R^2$ adjusted | 0.297*** | 0.309*** | Deviance | 6627.428 | 4857.862 | 4850.830 | 4839.897 |
| F value | 34.874*** | 31.934*** | Residual | 8.356*** | 5.932*** | 5.932*** | 5.882*** |
| Cases | 1088 | 1088 | Intercept[c] | 0.213*** | 0.171*** | 0.084 (*) | 0.055 |

[a] Given as standardized coefficients

[b] Given as estimates of fixed effects

[c] Statistical significance assessed with the likelihood ratio test

(*) = $p<.10$; * = $p<.05$; ** = $p<.01$; *** = $p<.001$

in Luke (2004), we built multilevel models through four steps to examine the community contextual effects on action in response to beetle disturbance in forests. The first step was to estimate a null model (also known as random intercept-only model) with no individual-level (level-1) and community-level (level-2) variables (MLM Model 1 in Table 2). Our interest here was in assessing whether participation in beetle-related actions varied significantly across study communities. This unconstrained model is equivalent to a one-way ANOVA model with the level-2 factor (community in this case) set as a random effect.

The null model indicated that, on average, respondents across all communities took nearly four out of 14 possible beetle-related actions. The estimated variance of the random components of the intercept was not significantly different from zero according to the Wald test ($Z$=0.213, $p$=0.120). However, the likelihood ratio test based on comparing the deviances of the null model and an alternative model in which the effect of intercept was fixed revealed a significant random effect of the intercept ($X^2$= 15.853, df=1, $p$<0.001). In general, the likelihood ratio test is more robust and should be trusted more when conflicting

with the Wald test (Hayes 2006). Therefore, this first step of multilevel modeling confirmed that overall the nine study communities differed significantly in the level of beetle-related activeness.

The sociodemographic controls and independent variables were introduced into the analysis in the second step. To examine whether the relationships between level-1 predictors and beetle-related action were influenced by community context, both the intercept and the coefficients of independent variables were initially allowed to vary across communities. However, none of the random effect estimates for these coefficients was significantly different from zero. Thus only the intercept was estimated as a random effect while the effects of all the independent variables were set as fixed in the multilevel modeling at this and the next two stages. The comparison of MLM Model 2 and OLS Model 1 demonstrated two important differences between these two models estimated with the same group of variables but using different procedures. Household income was positive and significant in its relationship with beetle-related action in OLS Model 1, but dropped from significance in MLM Model 2. All other previously significant variables retained their statistical significance in MLM Model 2. Additionally, the influences of education and faith in forest industry increased substantially and became significant factors in the multilevel counterpart.

MLM Model 3 included the biophysical vulnerability indicator and the community amenity index in the multilevel regression analysis. The impacts of the significant variables in the previous model (MLM Model 2) were not affected much by introducing these two community-level variables to the analysis. The community amenity index was positive and marginally significant in its relationship with beetle-related action in this model. Its effect declined notably compared to OLS Model 2. The biophysical indicator was no longer significant in its relationship to resident activeness in MLM Model 3. The reduced impacts of community-level variables were anticipated as multilevel modeling accounted for community contextual effects to some extent by allowing for the embedded data structure. Overall, the differences in the effects of sociodemographhic controls and independent variables between MLM Model 3 and OLS Model 2 show exactly the same pattern with those between MLM Model 2 and OLS Model 1.

The last step of the multilevel modeling process tested whether community context modified the relationships of individual-level independent variables with beetle-related action. A series of cross-level interactions between community characteristics and level-1 predictors (e.g., biophysical indicator * risk perception, and amenity index * community participation) were added to the analysis. A final reduced model (MLM Model 4) was estimated by systematically eliminating nonsignificant interaction terms. Four interaction terms were statistically significant in the reduced model (albeit a weak effect for the interaction between amenity index and faith in forest industry). Both of the two interactions involving faith in forest industry were negative and significant in their relationships with beetle-related action. This means that faith in forest industry had a larger effect on beetle-related action in communities with lower proportions of forests infected by beetles or smaller amenity index scores. By contrast, the positive coefficients of the two interaction terms associated with community participation indicate that higher tree mortality values and amenity indices of communities enhance the effects of community participation on beetle-related action. Due to the confounding effects of cross-level interactions, the two community contextual variables and community participation became insignificant in the reduced model. However, the impact of faith in forest industry increased materially in this model compared to MLM Model 2 and MLM Model 3. All other previously significant variables retained their significance in MLM Model 4.

## Community Regression Models

OLS regression was also used for evaluating multivariate relationships with participation in action related to the MPB outbreak at the community level. Because respondents from the same community might have correlate errors, we used the Durbin-Watson statistic to check the independence of observations. Results showed that the independence assumption was met for all the community OLS regression models. The full regression model for each community included all variables in the aggregate OLS regression analysis except the two community-level indicators. A final reduced model was then obtained by systematically eliminating nonsignificant variables. Table 3 shows a comparison of the reduced regression models of beetle-related action for the nine study communities. Models for each community revealed substantial differences and no two community models were identical. Interactional capacity was the only conceptual construct that was constantly strong and statistically significant in its effect on beetle-related action in all community models. Educational attainment was not statistically significant in any of the community models. All the other variables contributed significantly to the reduced models for some communities but not others. This suggests that the factors influencing action in response to beetle disturbance in forests are conditioned by community contexts.

It should be noted that the relationships of several significant variables with beetle-related action varied distinctly across community models. Females were likely to act more than males for Breckenridge, while the reverse was the case for Dillon, Granby, and Walden. For respondents from Dillon and Vail, length of residence was positive in its relationship with beetle-related action.

**Table 3** Comparison of reduced OLS regression models of participation in beetle-related actions for study communities, given as standardized coefficients

| | Breckenridge | Dillon | Frisco | Granby | Kremmling | Silverthorne | Steamboat Springs | Vail | Walden |
|---|---|---|---|---|---|---|---|---|---|
| Sociodemographic controls | | | | | | | | | |
| Age | | | 0.200 * | | | 0.341*** | | | |
| Gender | 0.179** | −0.154* | | −0.177* | | | | | −0.198** |
| Years lived in community | | 0.212** | | −0.167* | | | | 0.215** | |
| Household income | 0.163* | 0.233** | 0.168(*) | 0.205** | | | | 0.175* | |
| Educational attainment | | | | | | | | | |
| Perceived disturbance intensity | | | | | | | | | |
| Describe loss of trees | | | | | | | 0.246** | 0.215** | |
| Describe lack of re-growth | | | | | | | 0.152(*) | | |
| Risk perception | 0.134* | 0.136(*) | | 0.213** | | | | | |
| Confidence in resource management | | | | | | | | | |
| Faith in forest industry | | 0.155(*) | | | | −0.104(*) | 0.175* | | |
| Trust in forest management | | | −0.166(*) | | −0.357*** | −0.130* | | −0.160(*) | −0.132* |
| Personal experience with emergencies | 0.222** | | | | 0.251** | | 0.196* | | |
| Interactional capacity | | | | | | | | | |
| Community participation | 0.476*** | 0.308*** | 0.279** | | 0.178* | 0.326*** | | 0.402*** | 0.275*** |
| Number of information sources | | 0.252** | 0.174(*) | 0.308*** | 0.285** | 0.316*** | 0.173* | | 0.374*** |
| $R^2$ adjusted | 0.422*** | 0.460*** | 0.221*** | 0.225*** | 0.318*** | 0.383*** | 0.181*** | 0.380*** | 0.353*** |
| F value | 20.899*** | 13.395*** | 6.974*** | 8.651*** | 15.198*** | 22.601** | 6.532*** | 13.393*** | 27.461*** |
| Cases | 137 | 103 | 106 | 132 | 123 | 175 | 126 | 102 | 195 |

(*) = $p<.10$; * = $p<.05$; ** = $p<.01$; *** = $p<.001$

However, the same variable was negatively related to beetle-related action for Granby respondents. Moreover, for Dillon and Steamboat Springs, those with more faith in forest industry had higher level of beetle-related action. The reverse was found for those from Silverthorne. These results provide additional support for the modifying impact of community context on the relationships between individual-level factors and participation in action in response to the beetle outbreak.

## Discussion and Conclusion

Responding to calls for using appropriate methods to assess community context, this article examines the community contextual effects on human response to forest disturbance by mountain pine beetles in north central Colorado. Previous studies on community contextual influences on environmental behavior (e.g., Dolisca *et al.* 2009; Macht *et al.* 2007) focused on the effects of community characteristics that were independent from those of individual-level variables, whereas other processes linking community contexts and individual behavior have generally been neglected. The community-context conceptual framework of human response to forest disturbance by insects identifies three mechanisms that may explain the impact of community contexts on human actions on the beetle outbreak: (1) the direct effects of community contextual factors; (2) the indirect effects of community characteristics mediated through individual-level variables; and (3) the conditional effects of community contexts on the relationship between individual-level variables and beetle-related actions. This study empirically evaluated the community contextual effects through these three conceptual lines.

In the full OLS regression model (OLS Model 2), both the biophysical vulnerability indicator and the community amenity index added significantly to explaining beetle-related activeness when accounting for variations in individual-level predictors. The effects of both contextual variables on participation in beetle-related actions reduced in the multilevel modeling process (MLM Model 3). While the amenity index was still marginally significant in its influence on beetle-related action, the biophysical indicator was not significant in this model. In both OLS Model 2 and MLM Model 3, the community amenity index had a relatively stronger influence on beetle-related action than the biophysical contextual factor. This suggests that people's environmental actions are shaped more by the structural backdrop of socioeconomic and environmental community features than by the purely technical assessment of biophysical risk.

The strong correlations found between community contextual variables and individual level predictors indicate the potentially important role community context plays in motivating or constraining participation in beetle-related actions. The multilevel regression analysis also showed that the relationships between individual-level explanatory variables and beetle-related action were more complicated than intuitively envisioned. The influences of local residents' faith in forest industry and community participation on beetle-related activeness can be either enhanced or depressed by specific socioeconomic and/or biophysical community contexts. In addition, the OLS regression analysis at the community level further highlighted community variations in response to forest disturbance by beetles. These results imply that acknowledging and incorporating diverse community contexts is critical in the natural resource management process following a forest disturbance. The same management measures may work very differently in different community contexts. For example, the analysis suggested that though interactional capacity was consistently significant in its influence on taking actions in response to the beetle outbreak across all communities, efforts to fostering community participation and involvement would be especially effective in promoting beetle-related activeness in communities with larger proportions of forests damaged by beetles and/or higher amenity status.

In conclusion, this study provides empirical support for the three hypothesized pathways of community contextual influences on human actions in response to forest disturbances. Community biophysical and socioeconomic characteristics had direct and significant impacts on participation in beetle-related actions. They also showed strong influences on the key individual-level constructs in the conceptual model and on their relationships with beetle-related activeness. Taken together, these findings reveal that community context matters in the human dimensions of ecological disturbances of forests by insects.

## Implications

Community context has implications for natural resource management and risk mitigation strategies related to forest disturbances. Since communities vary in their sociocultural, economic, and environmental characteristics, different communities are expected to experience and respond to forest disturbances and risks in varying ways. There is no simple assumption that the same forest management policies and strategies apply equally to all community contexts. An appreciation of the local context of human-environment interactions necessitates efforts to increase public involvement and incorporate diverse community perspectives into natural resource management. Tailoring resource management approaches to community contexts in the planning stage can facilitate the implementation process

and help achieve the goals of restoring ecological systems and improving social well-being. In a sense, the importance of community context concerning the human dimensions of ecological systems provides further support and justification for community-based natural resource management practices.

This study also has several methodological implications for assessing the community context of environmental and natural resource issues. First, community contexts are often described with rich narratives obtained from typical qualitative methods, while the quantitative methods commonly employed in the community-related research are unable to capture community contextual effects on human behavior (Luke 2005). This research demonstrates that local community contexts can be quantitatively evaluated with an array of statistical techniques including both traditional methods such as bivariate correlation and OLS regression, and relatively novel methods such as multilevel modeling, GIS, and community indexing. The combination of multiple analytic methods in this study presented a more complete picture of the effects of community characteristics on participation in beetle-related actions.

Second, all the methods described in this article can be applied to other environmental social science research that values community context. In the case of relatively large-scale community survey studies, multilevel modeling is a particularly useful tool to evaluate the community contextual effects of interest to researchers. It not only takes into account the community-embedded nature of respondents in the data, but also allows testing whether the relationships between predictor variables and the outcome variable vary across communities or are contingent on community characteristics. Multilevel regression analysis often requires a sufficiently large sample size, particularly at the group level (Maas and Hox 2005). One limitation of this study is the relatively small number of study communities, which might restrict the likelihood of detecting significant random effects of individual-level variables in multilevel modeling. However, this technique was complemented by OLS regression analysis for aggregate data and for each community that provided additional information for interpreting community context. Examining data at the community level is particularly informative for community-based survey research involving a manageable number of study communities. Therefore, it is important to have balanced and adequate community samples in the designing phase of such studies.

Third, it should be acknowledged that mail survey methods such as those used in this study are costly, both in time and financial resources. Advanced effort to build awareness of the survey (via interviews, advertising, public meetings, and pre-survey notice) can reduce costs associated with multiple mailing waves to increase response. Given the diversity of communities situated in dynamic ecological and social systems, a mixed methodology combining both qualitative and quantitative methods can enhance our understanding of the diverse community contexts. This framework emphasizes the opportunity to incorporate different types of data to investigate community contexts from multiple viewpoints. In addition, there exist both temporal and spatial heterogeneities in communities across changing landscapes. Therefore, longitudinal studies in the same study area and synthetic analyses of cross-sectional empirical findings from different community circumstances are especially important in further research on the community context of societal-ecological relationships.

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