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Tracing Temporal Changes in the Human Dimensions of Forest Insect Disturbance on the Kenai Peninsula, Alaska

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Abstract A rapidly growing literature on the human dimensions of forest disturbance by insects has emerged over the past decade. As a result, the diverse social and economic impacts of forest disturbances and their implications have become increasingly understood. However, little research has assessed the temporal dynamics of community experience, perceptions, and actions related to changing forest landscapes and risks. Using longitudinal survey data from 2004 to 2008, this study examines the changing human dimensions of forest disturbance in the context of Alaska's Kenai Peninsula spruce bark beetle outbreak. Findings suggest ramifications of forest risks related to bark beetles were more complicated than an issue-attention cycle or timeline of beetle activity would predict. Shifts in perceptions of beetle impacts and forest risks, relationships with land managers, and local interaction and activeness of study communities reflected diverse pathways of temporal changes in human dimensions. Ordinary least squares and panel regression models indicated community participation and indirect risk perception (concern about broader threats to community and ecological well-being) had a consistently strong influence on community activeness in response to the beetle outbreak. Community wildfire experience and the perceived intensity of forest disturbance contributed most to risk perceptions. Implications of these results for forest management and future research are advanced.

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Introduction

Over the past decade, increasing research interest on the interactions between climate change and disturbances, particularly those associated with forest ecosystems, has emerged (Bentz *et al*. 2010; Dale *et al.* 2000, 2001; Fischlin *et al*. 2007; Wolken *et al.* 2011). Such disturbances can be natural or induced by human resource use and management activities. Among the key ecological disturbances in the United States, insect and pathogen outbreaks had the greatest economic and ecological costs and impacted millions of acres of forested areas (Dale *et al*. 2001). The vast majority of research on the impacts of forest disturbance by insects centers on biophysical disturbance regimes. However, a growing consensus among researchers and practitioners is that forest insect disturbance also involves human dimensions (Flint *et al*. 2009). People who live, work, and spend recreation time in forested landscapes are affected by natural disturbances and, in turn, influence management efforts. Given the complex interactions between societal and environmental systems, community residents may perceive and respond to the biophysical impacts of forest disturbance by insects in different ways. Moreover, resource management and risk mitigation approaches following an insect outbreak reflect human decision-making processes and require local community support and collaboration. While insect-induced forest disturbance is normally viewed as primarily a natural phenomenon, sociocultural, economic, and institutional factors are typically the critical determinants of forest management successes or failures (Flint and Haynes 2006).

The human dimensions of forest disturbance by insects are an important interdisciplinary area linking a range of disciplines such as rural sociology, geography, economics, political science, forestry, and environmental planning. Scholars studying the social and economic impacts of forest insects have focused significant attention on varying scales of human reaction such as local residents, tourists, and communities (Flint *et al*. 2009). While the diverse societal impacts of forest disturbances and their implications are increasingly understood, few studies have assessed the temporal dynamics of community experience, perceptions, and actions related to changing forested landscapes and risks.

Ecological disturbance research suggests multiple disturbances overlap or cascade within an ecosystem (Dale *et al*. 2001). Forests distressed by drought or wind may subsequently become vulnerable to insect outbreaks. As an insect infestation spreads across a forested landscape, further disturbances and associated risks, including fire hazards, falling trees, and invasive species, can ensue. Human-induced changes, including timber harvesting and fire suppression, can also contribute to complex forest disturbances. Thus, ecological or forest disturbances are inherently dynamic, while related landscape changes typically evolve over time (Oliver and Larson 1996). Given the cascading nature of disturbance events, the human dimensions of forest insect disturbance are also expected to be dynamic due to the heterogeneity of social and economic processes across landscapes and throughout society.

We use longitudinal survey data from Alaska's Kenai Peninsula to examine changing human dimensions of forest disturbances as the ecological system in which they were situated evolved. The Kenai Peninsula not only experienced a recent and widespread spruce bark beetle (*Dendroctonus rufipennis*) outbreak, but also a number of significant wildfires. Our research focused on whether local risk perceptions and community actions in response to the infestation changed as natural disturbances and hazards varied from one event to another. We address two research questions that structure our analysis and presentation of findings: (1) How did local perceptions of beetle impacts and related forest risks, attitudes toward forest management, and actions in response to the beetle disturbance change over time? (2) What factors contributed to the changes in community risk perceptions and actions related to the beetle outbreak?

Temporal Changes in the Human Dimensions of Forest Disturbance by Insects

The emerging literature on the human dimensions of forest disturbance by insects underscores the necessity for systematic examination over a variety of durations, intensities, and locations. Economic simulation studies of insect impacts often provide dynamic socioeconomic implications of forest disturbances varying by disturbance stages and geographic regions. For example, Abbott *et al*. (2008) found increased timber harvest related to mountain pine beetle outbreaks in British Columbia, Canada, caused a short-term boom to the forest sector followed by an economic downturn due to the long-term decline of timber supplies. Regional sensitivity analysis also displayed distinct variations in the level of vulnerability to potential negative economic impacts (Patriquin *et al*. 2007).

While not directly related to the forest industry, an ancillary economic concern is the effect on property values. A study conducted in Grand County, Colorado, suggested home prices were negatively associated with the number of beetle-killed trees, and dead trees in proximity to a house had a greater depressing effect on property values (Price *et al*. 2010). Similarly, Hansen and Naughton (2013) investigated both spatial and temporal dynamics of beetle-induced economic impacts by assessing how spruce bark beetles and wildfires affected housing prices on the Kenai Peninsula from 2001 to 2010. Their results demonstrated beetle outbreaks and large wildfires were associated with increased property values. Moreover, these positive relations were magnified with time after the disturbance events. While small wildfires decreased home values, their negative effects gradually diminished.

Existing research on the social aspects of forest insect disturbance has examined local attitudes toward impacts, risk perceptions, community contexts and perspectives, and resident or landowner actions (e.g., Chang *et al*. 2009; Flint and Luloff 2007; McFarlane *et al*. 2012; Molnar *et al.* 2007; Müller and Job 2009; Parkins and MacKendrick 2007; Qin and Flint 2012). Although nearly all recent quantitative, survey-based studies in this area employed a cross-sectional research design, comparing experiences across various locations can shed light on the spatial and temporal dynamics of human dimensions of forest disturbances.

Earlier work showed that residents in places with more recent, severer experience of insect disturbance and higher levels of dependence on the forest sector generally had greater knowledge and concern about related impacts, offered more support for intervention, and were less satisfied with forest agency management strategies (Chang *et al*. 2009; Flint 2006; Flint *et al.* 2012; McFarlane *et al*. 2006; McFarlane *et al*. 2012; Parkins and MacKendrick 2007). Flint (2006) suggested that local perceptions of the socioeconomic and ecological effects of forest disturbance were largely influenced by the timing and magnitude of spruce bark beetle outbreaks on the Kenai Peninsula. Other studies indicated risk perceptions were not always related to physical exposure to infestations. Residents in locations where large-scale forest insect attacks had not yet occurred might share a similarly high level of risk perceptions with those from communities experiencing severe disturbance (Hurley *et al.* 2012; Parkins and MacKendrick 2007). Dissemination of information about potential negative impacts can cause a spatial extension of risk beyond the boundaries of strict biophysical assessments (Slovic 1992).

A recent study by McFarlane and Watson (2008) is particularly relevant since they assessed Canadian national park visitors' concern about ecological risk related to mountain pine beetles using survey data collected in 2003 and 2005. These two surveys used different measures of risk perceptions, but included some similar questions on other aspects of beetle management. A close examination of this research's findings revealed the 2005 survey reported a much lower level of knowledge of beetle outbreaks than reported in 2003. This might reflect the fact that half of the respondents to the 2005 survey were non-Canadians but all 2003 respondents were domestic tourists. While the samples were not directly comparable, in both surveys the level of support for controlling beetles was almost the same and positively and significantly related to ecological risk perceptions.

To date, there has been limited research on temporal changes in risk perceptions and other human dimensions of forest disturbance by insects. The well-known "issue-attention cycle" model (Downs 1972) suggests local residents' concerns about forest risks decrease as disturbance problems fade from local attention. However, the social amplification of risk framework (Kasperson *et al.* 1988) implies the interactions of evolving forest disturbance events with psychological, sociocultural, and economic processes contribute to increases in the levels and longevity of risk perceptions and related actions. An exploratory study of changing forest disturbances and risk perceptions in Homer, Alaska, found the saliency and contentiousness of the spruce bark beetle issue appeared to decline over time, while also showing a retention and coalescence of community risk perceptions of forest and grass fires (Flint 2007). This study builds upon earlier findings to further explore the temporal dynamics of community attitudes and activeness related to the beetle outbreak on Alaska's Kenai Peninsula.

Methods

Conceptual Approach

This study adopts an integrative conceptual model of community response to risk linking risk perception, community interaction, and local actions (Fig. 1). This framework postulates community activeness is a function of three main constructs: (1) a community's risk context consisting of biophysical and socioeconomic vulnerability; (2) shared community risk perception; and (3) local interactional capacity to work together on community issues. Additionally, it outlines several key factors influencing risk perception: community risk context, perceived intensity of disturbance, relationship/satisfaction with land managers, and community emergency experience. Community interactional capacity is also linked with risk perception since social interaction and information processes are identified as important determinants of perceived risk in the extant social science of risk literature (Brenkert-Smith *et al.* 2013; Kasperson *et al.* 1988).

Study Area

The Kenai Peninsula is a large land area jutting southwest from the south of Anchorage, Alaska. A major spruce bark beetle outbreak in south central Alaska has killed many white spruce (*Picea glauca*) and Lutz spruce (*Picea x lutzii* Little) trees across more than one million acres of forests on the Kenai since the late 1980s and early 1990s (Ross *et al.* 2001). This disturbance significantly altered the appearance of the forested landscape and affected the lives of local residents in communities situated in and near the impacted forests.

Spruce bark beetle infestations led to a series of biophysical outcomes on the Kenai Peninsula including changes in watershed dynamics, fish and wildlife habitat, vegetative cover, and growth of invasive grasses (Ross *et al.* 2001; Werner *et al.* 2006). Several large-scale fires (e.g., Tracy Avenue Fire in 2005 and Caribou Hills Fire in 2007; see Fig. 2) occurred in beetle affected forest stands. As a result, local Kenai residents experienced multiple impacts due to high tree mortality and subsequent ecological disturbances that had corresponding implications for human safety, property value, economic resources, community identity, and quality of life.

Six Kenai Peninsula communities were included in this research: Anchor Point, Cooper Landing, Homer, Moose Pass, Ninilchik, and Seldovia (Fig. 2), selected as they provided a representative combination of timing and magnitude of beetle disturbance, local governance structures, activeness of Native associations, and geographic location relative to the Chugach National Forest (Flint 2006). Together, these communities reflected local variations in sociocultural and economic characteristics and experience with forest disturbance across the study area. The spruce bark beetles had swept over much of the central and lower Kenai Peninsula including Ninilchik, Anchor Point, and Homer by 1998 and resulted in more than 90 % mortality of spruce trees there. Recently, the beetle outbreak spread down the Kachemak Bay toward forests near Seldovia. Cooper Landing encountered the beetles earlier than other study communities and their impacts had declined there by the time this research was initiated, while its neighboring community, Moose Pass, continued to lose trees to beetle activity. Because of the greater mix of tree species in local forests, these two latter communities did not experience the same degree of tree mortality as the southern Kenai Peninsula communities.

Data Collection

This project employed a mixed methods approach (Tashakkori and Teddlie 1998) to collect data at multiple periods of time (2003–2004, 2005–2006, and 2007–2008). Forest data from the Kenai Peninsula Spruce Bark Beetle Mitigation Office and socio-demographic data from the US Census provided general biophysical and socioeconomic information about the study area. In 2003, a total of 115 key informant interviews were conducted

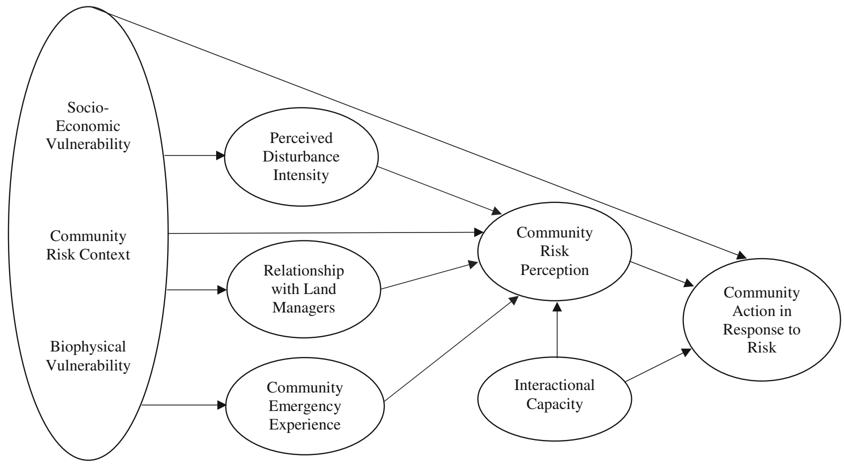

Fig. 1 A conceptual framework of community action in response to risk. Source: Adapted from Flint and Luloff (2007)

across the six study communities to obtain contextual information about the local spruce bark beetle outbreak and how communities responded to its impacts. To ensure representation of broad perspectives within study communities, key informants were identified from a range of resident groups such as school administrators/teachers, business owners, government leaders, community healthcare providers, and newspaper journalists. Based on thematic content analysis of these interviews, in 2004 a mail survey was developed and sent to 2473 households identified from the Alaska Permanent Fund Dividend list in the

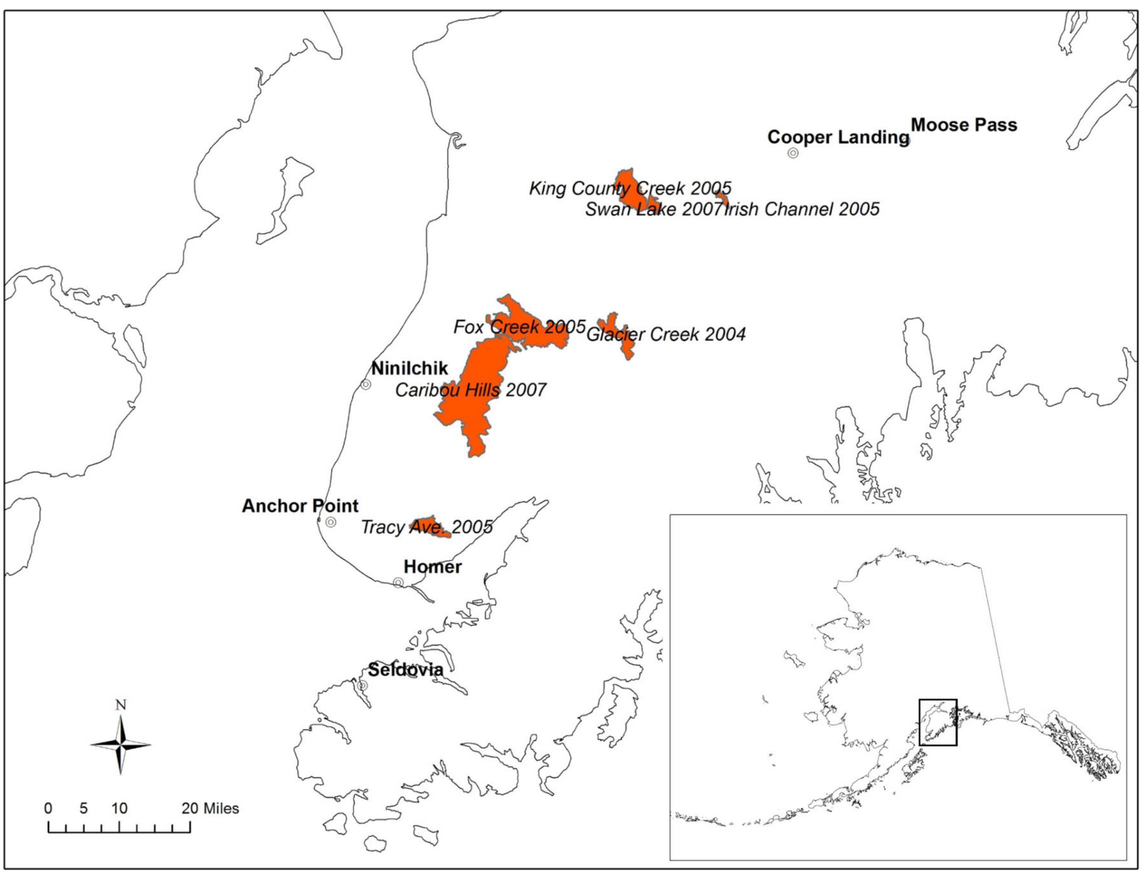

Fig. 2 Map of study communities and major wildfires during March 2004 – February 2008 on the Kenai Peninsula, Alaska. Source: Map produced with spatial data from the online map tool of the Alaska Interagency Coordination Center (http://afsmaps.blm.gov/imf_fire/imf.jsp?site=fire) and the National Atlas of the United States (http://www.nationalatlas.gov/index.html). Accessed July 1, 2014

six communities. In total, 1088 of the mailed surveys were completed and returned, resulting in a response rate of 46 % after accounting for undeliverable surveys. Quantitative data collected from this survey provided baseline information for the longitudinal analysis of changing human dimensions of forest insect disturbance in this study.

Following the Tracy Avenue Fire, follow-up phone interviews were conducted in 2005 with 21 of 35 Homer key informants interviewed earlier. A short questionnaire was then mailed to the 366 original respondents from Homer in 2006; 233 completed surveys were received (a response rate of 74 % after accounting for those undeliverable). In the fall of 2007, in-depth interviews were replicated with 45 of the former 115 key informants across all six communities. An additional 36 key informants were identified and interviewed to assure diverse community-wide perspectives were represented. A re-study mail survey was administered in 2008 to the original 1088 respondents from the 2004 survey and 912 households newly sampled from a purchased USADATA database (USADATA Inc., New York, NY, United States). The three mail surveys used a modified tailored design method (Dillman *et al*. 2009) to increase response rates. A total of 766 surveys were returned in the 2008 effort (a 42 % response rate after accounting for those undeliverable); of these 433 were completed by those who also returned the 2004 survey. Data collected from respondents to both surveys were merged to create a panel dataset, which was used together with the full survey datasets from 2004 (N=1088) and 2008 (N=766) for the quantitative analysis presented here. In-depth interpretations of qualitative information from the study communities are discussed elsewhere (Gordon *et al*. 2013).

Measurement of Variables

Table 1 presents the measurement of variables included in the analysis of this study. Biophysical data from the Kenai Peninsula Spruce Bark Beetle Mitigation Office were used to indicate the spatial and temporal diffusion of the spruce bark beetle disturbance across the Kenai Peninsula. These data originated from aerial insect surveys undertaken by the Alaska Region Forest Service and the Alaska Department of Natural Resources. Two variables (percentage and categories) indicating vegetative cover condition within the census designated area around each community were created for both 2004 and 2008. A related biophysical community contextual variable was included to measure local experience with wildfire based on answers to relevant questions in the two surveys. Additionally, a composite socioeconomic vulnerability index and a dependency ratio indicator were used to control for local socioeconomic characteristics. Relevant socio-demographic data were obtained from the Alaska Community and Economic Development Office and the US Census. All other major constructs from the conceptual model of community response to forest disturbance (Fig. 1) were measured by identical variables in the 2004 and 2008 surveys (see Table 1). A set of individual socio-demographic indicators was also included at both times.

Analytical Procedures and Methods

Statistical analysis of the survey data was organized by our two research questions (see above). Non-parametric statistical techniques were used for analysis involving ordinal data. The Wilcoxon matched-pair signed-rank test (non-parametric alternative to the paired t-test) and McNemar's test (for paired dichotomous data) were used to determine whether responses to major survey questions (e.g., reported community wildfire experience, perceived beetle impacts and forest risks, and community activeness) changed from 2004 to 2008. These procedures were applied to the panel survey dataset (N=433) consisting of those respondents who completed both surveys. A series of difference scores was also computed using these data to display changes over the 2004–2008 study period. Next, bivariate correlations among major variables in the two full surveys (N=1088 and N=766) were assessed with Spearman's rho statistic. Finally, multiple regression models with both ordinary least squares (OLS) and first-difference (fixed effects) procedures were used to evaluate influencing factors of changing risk perceptions and community response to forest disturbance, using the two aggregate survey datasets and the panel dataset respectively. In OLS regression, it is generally appropriate to treat ordinal variables as interval when the sample size is large and the distributions of variables are approximately normal (Jamieson 2004; Wallace 1977). The differencing method can also be readily applied to nominal and ordinal data in two-period fixed effects regression analysis (Allison 2009).

Results

Changes Between the 2004 and 2008 Panel Data (N=433)

Comparisons between survey respondents' perceived tree mortality and the measured tree mortality for the six study communities are shown in Table 2. Although the biophysical measurements of beetle impacts on forests (% of forests killed) remained unchanged from 2004 to 2008, the reported level of forests killed by beetles declined across the study area and particularly in Homer, Anchor Point, Cooper Landing, and Ninilchik; the perception changes were in the same direction for Seldovia and Moose Pass (with the fewest number of cases) but were not significant. The measured and perceived values of tree mortality were almost significantly correlated at the community level for both periods (rho=0.77, p=0.07, N=6 for both surveys), suggesting these two indicators of forest loss were largely consistent across the study communities.

Table 1 Measurement of major variables

Constructs	Variables	Measurement
Biophysical vulnerability	Measured tree mortality	Percentage of forests killed by beetles
	Vegetation cover condition[a]	Scale range: 1–3 (1=less than 25 % dead trees, 2=25–75 % dead trees, 3=more than 75 % dead trees)
Socioeconomic vulnerability	Socioeconomic vulnerability[a]	Based on exploratory factor analysis, a composite index was constructed by summing values of three variables indicating community socioeconomic conditions: (1) poverty rate relative to the borough average (0=lower than average, 1=higher than average); (2) presence of a local high school within the community (0=yes, 1=no); and (3) incorporated status (0=yes, 1=no). Scale range: "0" low to "3" high
	Dependency ratio[a]	Community dependency ratio relative to the borough average 0=lower than borough average, 1=higher than borough average)
Community emergency experience	Community wildfire experience	Whether or not community has experienced wildfire (0=no, 1=yes)
Perceived disturbance intensity	Perceived tree mortality	Scale range: 1–5 (1=no spruce trees are dead, 5=almost all spruce trees are dead)
	Perceived natural regrowth	Scale range: 1–5 (1=no natural regrowth, 5=a lot of natural regrowth)
	Perceived beetle impacts	Whether or not community has experienced a series of beetle-related impacts such as creation of jobs and economic opportunities, expanded timber industry, loss of privacy, affected property values, and land use conflict (0=no, 1=yes); also rate relevant impacts on a scale from 1 to 5 (1=very negative, 5=very positive).
Community risk perception	Direct/Indirect risk perception[b]	Rate concern about a series of forest risks on a scale from 1 to 5 (1=not concerned, 5=extremely concerned). Factor analysis revealed two factors among these variables: (1) direct risk perception/perception of immediate threats to personal property and safety (forest fire, grass fire, and falling trees); and (2) indirect risk perception/perception of broader threats to community and ecological well-being (loss of community identity tied to the forest, loss of forest as an economic resource, decline in fish and wildlife habitat, increased erosion and runoff, and loss of scenic/aesthetic quality). Composite index variables were created by calculating the mean response value of each risk perception category.
Relationship with land managers	Satisfaction with land managers[b]	Rate satisfaction with a list of forest management entities on a scale from 1 to 5 (1=very dissatisfied, 5=very satisfied). Factor analysis revealed two factors among these variables: (1) satisfaction with local land managers (private individuals and landowners, local community groups/government, Native associations, local fire department, and private logging companies); and (2) satisfaction with government land managers (Kenai Peninsula Borough, State Forestry, US Forest Service, and State Parks). Composite index variables were created by calculating the mean response value of each land manager category.
Interactional capacity	Community participation[b]	Whether or not has participated in the following general community activities in the past 12 months at the time of survey: (1) attending a local community event; (2) contacting a public official about some local issue; (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; and (6) serving on a local government or advisory commission, committee, or board. Only one factor emerged in exploratory factor analysis. Responses to the six items (0=no, 1=yes) were summed as a composite measure.
	Community communication	A composite variable calculated as the mean value of two measures assessing the level and quality of community communication (responses ranged from "1" very poor to "5" excellent)
	Total number of information sources	Whether or not get information about forest issues from any of the 14 listed sources, such as newspaper, radio, local fire

Table 1 (continued)

Constructs	Variables	Measurement
		department, borough spruce bark beetle office, US Forest Service, and word of mouth. A composite variable measuring the total number of information sources was created based on the sum of responses to these items (0=no, 1=yes).
Community action in response to risk	Community activeness in response to the spruce bark beetle outbreak[b]	Whether or not has taken the following actions in response to the spruce bark beetle outbreak: (1) participated in a neighborhood or community effort to clear trees; (2) participated in community cone or seed gathering; (3) attended an informational meeting; (4) attended meetings or other actions to oppose timber sales on borough or state land; (5) attended meetings or other actions to support timber sales on borough or state land; (6) cleared public trails; (7) consulted with public officials or foresters; and (8) participated in efforts to preserve natural forests. Responses to the eight items (0=no, 1=yes) were summed as a composite measure based on the results of exploratory factor analysis.
Socio-demographic controls	Socio-demographic characteristics	Age, gender (0=female, 1=male), Native Alaskan status (0=no, 1=yes), years lived in community, annual household income (eight levels ranging from "1" less than \$15,000 to "8" \$150,000 or more in the 2004 survey; three levels - "1" less than \$50,000, "2" \$50,000 to \$100,000, and "3" more than \$100,000 - in the 2008 survey), and education (six categories ranging from "1" less than a high school degree to "6" advanced degree)

Biophysical and socioeconomic vulnerability measures were constructed from secondary data. All other measures were created with data collected through the mail surveys

[a] Values of the vegetation cover condition, socioeconomic vulnerability, and dependency ratio variables remained the same for individual study communities from 2004 to 2008

[b] Results of exploratory factor analysis were based on the full 2004 survey data. See Flint and Luloff (2007) for further details

Despite the substantial adjustment in the perceived level of tree mortality, there was little change in the amount of natural regrowth of trees reported by respondents between the two survey periods (Table 2). Although survey data from 2008 revealed no change in community wildfire experience of respondents across the whole study area, an examination of variations across communities demonstrated a significant increase of fire experience in Homer and Ninilchik, while the proportions of respondents from Cooper Landing and Moose Pass who reported community fire incidents greatly decreased.

Perceptions of fire risks related to beetle outbreaks largely stayed the same or even increased among all communities, but concerns about falling trees and most of the indirect risks (threats to community and ecological well-being) significantly declined (Table 2). Further analysis at the community level showed these changes largely reflected decreases in relevant risk perceptions in Homer. Seldovia respondents still had relative low levels of concerns, and became less worried about falling trees and the loss of community identity tied to the forest in 2008. Concern about fallings trees and loss of scenic quality also declined in Cooper Landing. Overall, only Cooper Landing had a marginally significant decrease in the perception of direct risks (concern about immediate threats to personal property and safety), while there was a significant decline of indirect risk perception in Homer. Residents of Anchor Point, Ninilchik, and Moose Pass indicated little or no change in their direct and indirect risk perceptions.

The extent to which respondents recognized impacts from spruce bark beetle activity reduced significantly across study communities for all of those directly related to local economy (e.g., creation of jobs and economic opportunity, expanded timber and chip export industry, and land use conflict) and for those ecological and psychological effects of particular economic/social importance such as surface erosion and run-off, and emotions of worry, fear or grief (Table 3). Changes in the identification of other problems such as fire hazards were not significant. There was considerable community variation regarding the differences in perceived impacts between 2004 and 2008. Respondents from Homer, Ninilchik, Seldovia, and Anchor Point all reported lower levels of selected economic, environmental, and emotional impacts. The rates of perceived impacts did not decline in Cooper Landing or Moose Pass; Cooper Landing residents actually showed an increased degree of concern over affected property values.

Local residents' attitudes about some of the potential impacts of beetle outbreaks also changed with time since the 2004 survey (Table 3). In most cases, respondents to the re-survey viewed economic effects related to the forest industry as less positive or even negative, but felt less negative about

Table 2 Community wildfire experience, biophysical assessment of tree mortality, perceived disturbance intensity, and risk perceptions

Variables	Seldovia		Homer		Anchor Point		Ninilchik		Moose Pass		Cooper Landing		Total	
	2004	2008	2004	2008	2004	2008	2004	2008	2004	2008	2004	2008	2004	2008
% reporting wildfire	13.3	23.3	74.5*	84.0*	87.4	83.8	82.3*	96.3*	100.0**	41.2**	93.3***	40.0***	77.2	77.2
% of forests killed	42.6	42.6	82.0	82.0	75.1	75.1	93.6	93.6	24.6	24.8	18.2	18.4	56.0	56.1
Perceived tree mortality	2.79	2.53	3.91*	3.75*	4.17**	3.98**	4.27$^{(*)}$	4.12$^{(*)}$	3.94	3.83	3.50*	3.16*	3.94***	3.75***
Perceived natural regrowth	3.25	3.25	2.75	2.73	3.13	2.99	3.33	3.29	3.12	3.12	2.55	2.74	2.99	2.95
Direct risk perception	2.94	2.80	3.72	3.63	3.86	3.94	3.91	3.89	3.76	3.88	3.61$^{(*)}$	3.27$^{(*)}$	3.73	3.68
Forest fire	3.28	3.20	4.01	3.95	4.06	4.18	4.15	4.25	4.06	4.11	4.07	3.80	4.00	4.00
Grass fire	2.24	2.41	3.67	3.80	3.98	4.07	4.02	4.18	3.44	3.69	3.57	3.37	3.70$^{(*)}$	3.80$^{(*)}$
Falling trees	3.36*	2.73*	3.47**	3.15**	3.51	3.57	3.55	3.31	3.78	3.71	3.20$^{(*)}$	2.63$^{(*)}$	3.48**	3.24**
Indirect risk perception	2.62	2.58	3.22*	3.00*	3.31	3.25	3.15	3.27	3.28	3.35	2.91	2.65	3.17*	3.07*
Fish & wildlife habitat	2.70	2.72	3.36***	2.91***	3.31*	3.01*	3.26	3.24	3.39	3.41	3.03	2.45	3.26***	2.97***
Erosion & runoff	2.85	2.66	3.56	3.39	3.45	3.52	3.34	3.39	3.17	3.13	2.76	2.83	3.38	3.32
Community identity	2.45*	2.07*	2.74$^{(*)}$	2.53$^{(*)}$	2.66	2.64	2.52	2.73	3.06	2.94	2.40	2.27	2.65$^{(*)}$	2.56$^{(*)}$
Economic resource	2.17	2.28	2.81	2.80	3.42	3.36	2.99	3.35	2.78	2.82	3.03	2.83	2.97	3.00
Scenic quality	3.10	3.10	3.56*	3.35*	3.71	3.67	3.62	3.56	4.00	4.06	3.30*	2.83*	3.58*	3.44*

Given as means of variables except for the first two indicators. Changes in ordinal scale variables between the two surveys were assessed with the Wilcoxon matched-pair signed-rank test. Although this technique examines whether the population median of the differences between two paired samples is 0, mean values of these variables are reported here since in many cases variable medians were the same for both surveys even when the Wilcoxon test statistic was significant. Case numbers by community: Seldovia (N=30), Homer (N= 166), Anchor Point (N= 106), Ninilchik (N= 82), Moose Pass (N= 18), Cooper Landing (N= 31), Total (N= 433). Same for Tables 3 and 4

Considering the exploratory nature of this study, marginally significant results are also indicated in the table. Same for Tables 3, 4, 5, 6 and 7

$^{(*)}p<.10$, $^{*}p<.05$, $^{**}p<.01$, $^{***}p<.001$

Table 3 Percentage of respondents reporting selected beetle impacts and average rating of impacts

Variables		Seldovia		Homer		Anchor Point		Ninilchik		Moose Pass		Cooper Landing		Total	
		2004	2008	2004	2008	2004	2008	2004	2008	2004	2008	2004	2008	2004	2008
Job creation	%	63.0**	25.0**	85.4***	59.5***	82.9***	58.8***	87.8***	68.5***	50.0	50.0	64.5	60.7	80.8***	58.0***
	Rating	3.06	2.40	3.22*	2.96*	3.37***	2.67***	3.32*	3.02*	3.13	3.00	2.68	2.73	3.24***	2.85***
Timber industry	%	59.3**	18.5**	93.9***	68.1***	88.7**	68.5**	88.9**	72.9**	22.2	20.0	27.6	26.9	81.8***	61.0***
	Rating	2.75*	2.10*	3.32	3.00	3.48***	2.83***	3.46***	2.99***	3.00	2.88	2.38*	2.76*	3.34***	2.90***
Land use conflict	%	44.4	28.6	59.7***	41.2***	48.6(*)	41.8(*)	49.4*	31.8*	83.3	69.2	46.7	52.0	54.0***	40.0***
	Rating	2.00	2.42	2.31	2.47	2.26	2.30	2.43	2.46	2.07	2.11	2.14	2.50	2.28	2.41
Affected property value	%	34.6	25.9	75.5*	67.1*	73.5	68.1	71.3*	57.7*	55.6	66.7	20.0(*)	46.2(*)	66.8*	61.0*
	Rating	2.60	2.57	2.68(*)	2.88(*)	2.22	2.38	2.42	2.45	2.00	2.45	2.00	2.80	2.46	2.63
Impact on tourism	%	34.6*	14.3*	44.4(*)	34.1(*)	40.6	31.5	40.7	30.4	18.8	28.6	17.2	29.6	39.3**	31.0**
	Rating	2.50	2.45	2.28*	2.72*	2.25	2.51	2.34(*)	2.93(*)	1.75	2.43	1.80(*)	3.06(*)	2.27**	2.70**
Loss of privacy	%	51.9	50.0	87.7	84.7	88.7	88.9	87.8	88.0	94.4	88.2	40.0	51.9	82.6	82.0
	Rating	2.27*	1.88*	1.91**	2.35**	1.89(*)	2.13(*)	2.03*	2.41*	1.71*	2.31*	2.44	3.06	1.95***	2.32***
Surface erosion and runoff	%	66.7*	34.6*	75.8(*)	67.8(*)	75.2	78.5	75.3	72.7	61.1	42.9	41.4	51.9	72.0*	67.0*
	Rating	2.11	2.08	2.03*	2.33*	2.01	2.10	2.05	2.02	2.10	2.11	2.00	2.35	2.04	2.19
Emotions (worry, fear, or anxiety)	%	59.3	46.4	73.3*	60.4*	67.6	63.8	60.5	65.3	77.8	71.4	60.0	52.0	67.8*	61.0*
	Rating	2.53	2.4	2.25	2.38	2.23	2.12	2.06	2.23	2.23	2.33	2.17(*)	2.53(*)	2.22	2.30

Given as percentages of survey respondents and means of rating variables. Other potential impacts from spruce bark beetle activity include logging and land clearing, rejuvenation of forests, emergent view, fire hazards, visual/aesthetic loss, falling trees, harvesting cost, trails and forest accessibility, forest awareness, wildlife and fish habitat, availability of firewood and/or building timber, and emotions such as grief or sadness. Results about these items are not included here but available upon request

(*) $p<.10$, * $p<.05$, ** $p<.01$, *** $p<.001$

several socioeconomic and ecological threats (e.g., the impact on tourism, loss of privacy, fire hazards, and falling trees). This pattern generally held true for all study communities, with some notable exceptions. For example, Homer respondents' opinion on logging and land clearing impact turned from negative to somewhat positive, while those from Cooper Landing considered expanded timber and chip export industry as a less negative effect. Moreover, Seldovia residents became more negative in their perception of privacy loss due to dead trees, but reacted more positively about the resulting emergent views.

The general level of satisfaction with how forests and the beetle outbreak had been managed increased significantly for both composite satisfaction variables and for all entities except private landowners and Native associations (Table 4). Respondents from all communities except Moose Pass exhibited higher satisfaction with one or more of the land managers, with Homer and Anchor Point residents reporting the highest increases. Cooper Landing respondents became much less satisfied with local community groups or government, but viewed the performance of private logging companies significantly more positively. The decrease in satisfaction with Native associations was nearly significant in both Anchor Point and Ninilchik. Only Homer displayed obvious changes (increases) in the two satisfaction indices, and Anchor Point also had an almost significant increase in the aggregate satisfaction with agency forest management.

General community participation declined in the study area as a whole between 2004 and 2008, but community communication remained at the same level (Table 4; see Table 1 for details on the computation of relevant composite variables). Further analysis indicated only Ninilchik had a significant decrease in this indicator of community interaction capacity. There was also a significant increase in the total number of sources about forest issues in the aggregate data and in the subsamples of Ninilchik and Homer. Finally, the analysis revealed a substantial reduction in the combined activeness index across the study communities and particularly in Homer and Moose Pass.

Community Activeness Models

Bivariate correlations among major variables in the two full survey datasets are presented in Table 5. Results from the 2004 survey showed community wildfire fire experience, vegetation cover, perceived tree mortality, direct and indirect risk perceptions, and community participation and communication were significantly related with community response to the beetle outbreak. However, local experience with fire, perceived tree mortality, and community communication were no longer significant in their bivariate relationship with community activeness in the 2008 results, while the relationships between other variables and community response were largely unchanged.

Table 6 summarizes results of the 2004 and 2008 OLS regression models of community activeness related to beetle impacts and those from the fixed effects regression analysis using a first-difference procedure. Community wildfire

Table 4 Satisfaction with land managers, community interaction, information sources, and community activeness

Variables	Seldovia		Homer		Anchor Point		Ninilchik		Moose Pass		Cooper Landing		Total	
	2004	2008	2004	2008	2004	2008	2004	2008	2004	2008	2004	2008	2004	2008
Local entities	2.81	2.83	3.01^{*}	3.17^{*}	2.91	3.07	3.08	3.14	3.14	3.31	2.92	2.95	2.98^{**}	3.11^{**}
Private landowners	3.09	3.14	3.18	3.11	3.06	3.14	3.20	2.97	3.56	3.50	3.48	3.57	3.18	3.15
Local groups/government	2.67	2.58	2.76^{*}	3.06^{*}	2.34^{*}	2.68^{*}	2.59^{*}	2.88^{*}	3.36	3.43	3.08^{*}	2.41^{*}	2.66^{**}	2.87^{**}
Native associations	2.40	2.54	2.50	2.69	$2.73^{(*)}$	$2.49^{(*)}$	$3.16^{(*)}$	$2.90^{(*)}$	2.25	2.40	2.56	2.38	2.69	2.65
Local fire department	3.48	3.05	3.71	3.79	3.34^{*}	3.62^{*}	3.46	3.56	3.40	3.64	2.50	2.77	$3.46^{(*)}$	$3.58^{(*)}$
Logging companies	2.83	2.53	2.64	2.88	2.86	3.02	2.99	3.11	3.00	3.38	2.70^{*}	3.30^{*}	2.80^{**}	2.99^{**}
Government entities	2.80	3.30	2.89^{**}	3.20^{**}	$2.57^{(*)}$	$2.83^{(*)}$	2.53	2.86	2.73	3.00	2.45	2.60	2.69^{***}	2.99^{***}
Kenai Peninsula Borough	2.76	3.18	2.92	3.04	2.50	2.62	2.56	2.85	3.06	3.22	2.39	2.54	2.70^{*}	2.88^{*}
State Forestry	$2.92^{(*)}$	$3.50^{(*)}$	2.74^{***}	3.25^{***}	2.47^{*}	2.86^{*}	2.54	2.99	2.86	3.06	2.33	2.68	2.61^{***}	3.06^{***}
US Forest service	$2.70^{(*)}$	$3.26^{(*)}$	2.73^{**}	3.22^{**}	2.46	2.68	2.38	2.75	2.41	3.00	2.45	2.75	2.55^{***}	2.95^{***}
State Parks	2.29^{*}	3.13^{*}	2.98	3.17	2.61	2.82	2.54	2.73	2.46	2.43	2.54	2.61	$2.71^{(*)}$	$2.93^{(*)}$
Community participation	3.73	3.67	3.45	3.41	2.92	2.83	3.30^{*}	3.00^{*}	4.11	3.44	4.03	4.23	3.38^{*}	3.27^{*}
Community communication	2.86	2.63	3.40	3.46	2.84	2.92	3.11	3.01	3.33	3.58	$3.08^{(*)}$	$3.52^{(*)}$	3.15	3.19
Number of information sources	4.21	4.37	5.26^{*}	5.74^{*}	4.23	4.66	4.15^{**}	4.99^{**}	5.78	5.00	5.83	5.80	4.79^{**}	5.21^{**}
Community activeness	1.35	1.24	1.57^{**}	1.28^{**}	1.45	1.29	1.32	1.23	3.83^{**}	2.94^{**}	2.14	2.16	1.62^{**}	1.40^{**}

Given as means of variables

$^{(*)}p<.10$, $^{*}p<.05$, $^{**}p<.01$, $^{***}p<.001$

Table 5 Spearman's rank correlations among major variables

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. Community activeness		.02	−.19**	−.02	.06(*)	.04	.01	.12**	.10**	−.05	−.05	.42**	.04	.36**
2. Community wildfire experience	.14**		.46**	−.01	.02	.32**	−.01	.37**	.28**	.04	.02	.03	.07(*)	.13**
3. Vegetation cover	−.12**	.14**		−.05	.10**	.39**	−.02	.20**	.13**	.05	.10*	−.15**	−.04	.01
4. Socioeconomic vulnerability	−.02	.15**	.01		−.09*	.13**	−.11**	.11**	.09*	−.05	−.16**	−.14**	−.20**	−.10**
5. Dependency ratio	.04	.25**	.13**	−.02		.05	.14**	−.01	−.04	.03	−.03	.01	.20**	.07
6. Perceived tree mortality	.07*	.15**	.37**	.14**	.05(*)		−.10**	.35**	.27**	−.06	−.15**	−.06	−.04	.06
7. Perceived natural regrowth	.04	.01	.01	−.07*	.09	−.11**		−.07(*)	−.19**	.15**	.18**	−.01	.23**	.07
8. Direct risk perception	.06*	.15**	.16**	.11**	.05(*)	.26**	−.14**		.59**	−.06	−.06	.00	.04	.21**
9. Indirect risk perception	.10**	.11**	.13**	.04	.01	.14**	−.23**	.46**		−.12**	−.11**	.03	.06	.17**
10. Satisfaction with local managers	.06(*)	.06(*)	−.03	.04	−.03	.00	.10**	−.07*	−.20**		.51**	.01	.23**	.10**
11. Satisfaction with government managers	.01	−.00	−.02	−.09**	−.01	−.13**	.13**	−.11**	−.07*	.42**		.08*	.23**	.12**
12. Community participation	.44**	.13**	−.10**	−.11**	.02	−.03	.02	.04	.08*	.02	.10**		.13**	.30**
13. Community communication	.08**	.00	−.03	−.18**	.09	−.03	.12**	−.05(*)	.01	.19**	.20**	.12**		.17**
14. Number of information sources	.30**	.15**	−.05	−.08*	.07*	−.05	.04	.10**	.14**	.02	.13**	.29**	.11**	

The parts below and above the diagonal of the matrix show Spearman's rank correlations among variables in the full 2004 and 2008 survey data (N= 1088 and N= 766) respectively

(*)p<.10, *p<.05, **p<.01

experience and direct risk perception were not significant in relation to local response to the beetle outbreak in both OLS models, while vegetation cover, dependency ratio, years lived in community, educational attainment, indirect risk perception, and general community participation were consistently related to community actions. Indicators of perceived disturbance intensity and relationships with local and government land managers only contributed to explaining the level of community response in the 2004 model. The two OLS models explained a similar amount of variation (about 25 %) in community activeness.

The fixed effects regression model had only three variables with a significant or nearly significant relationship with community activeness. Community wildfire experience, indirect risk perception, and community participation were positively associated with community response to forest disturbance. Although the F statistic for this model was significant at the .05 level, it apparently had much lower explanatory power than the OLS models. This largely reflected that the difference score method focused on variation within the time period but did not include the explanatory effects of the average values of dependent variables. Nevertheless, our primary interest was with testing the relationships among major conceptual constructs in the human dimensions of forest insect disturbance rather than maximizing the explained variation in analytical models. The intercept of −0.246 in the panel data model was highly significant, suggesting community response was expected to substantially decrease from 2004 to 2008 even for those residents who did not display any change in the explanatory variables.

Risk Perception Models

All of the four contextual variables, the two perceived disturbance intensity measures, relationships with local and government land managers, community participation and communication, and the total number of information sources were significantly (or marginally significantly) correlated with direct/indirect risk perception or both in 2004 (Table 5). Dependency ratio and community interactional capacity indicators became unrelated with both of the two risk perceptions in the re-survey. The bivariate relationships between direct risk perception and satisfaction with local and government land managing entities also became non-significant in 2008. In both analyses, the perceptions of direct and indirect risks were significantly related with each other.

Table 7 presents results of the multivariate analysis of the influencing factors of risk perceptions. Among all variables in the OLS regression analysis, only local experience with wildfires, perceived loss of trees, and the total number of information sources were consistently important in their relationships with both direct and indirect risk perceptions. Respondents indicating community wildfire experience, higher levels of perceived tree mortality, and more information sources had greater perception of forest risks. At both survey times, males indicated greater concern about direct forest risks than females, while perceived natural regrowth,

Table 6 Comparison of regression models of community activeness

Variables	2004 OLS	2008 OLS	Panel model
Constant	−0.515	0.074	−0.246**
Community-level variables			
Community wildfire experience	0.013	0.004	0.098(*)
Vegetation cover	−0.126***	−0.171***	–[a]
Socioeconomic vulnerability	0.009	0.027	–
Dependency ratio	0.070(*)	0.066(*)	–
Socio-demographic controls			
Age	−0.061(*)	−0.053	–
Gender (male=1)	−0.021	0.062	–
Native Alaskan (Native=1)	0.055	0.083*	–
Years lived in community	0.097**	0.197***	–
Household income	−0.041	−0.007	–
Education	0.083*	0.082*	–
Perceived disturbance intensity			
Perceived tree mortality	0.070(*)	0.037	−0.051
Perceived natural regrowth	0.068(*)	0.045	0.065
Risk perception			
Direct risk perception	−0.001	0.038	0.017
Indirect risk perception	0.101*	0.118*	0.119(*)
Relationship with land manager			
Satisfaction with local managers	0.091*	−0.040	−0.036
Satisfaction with government managers	−0.077*	−0.011	0.041
Interactional capacity			
Community participation	0.382***	0.358***	0.146*
Community communication	0.029	−0.041	0.032
R^2 adjusted	0.236	0.265	0.055
F value	11.896***	10.884***	1.921*
N	713	563	306

Given as standardized regression coefficients

[a] Variables were differenced out in the panel regression model

(*) $p<.10$, * $p<.05$, ** $p<.01$, *** $p<.001$

satisfaction with local land managers, and community communication were highly related with indirect risk perception. The two socioeconomic vulnerability measures, perceived regrowth, relationships with local and government land managers, and community communication were significant or almost significant in one of the OLS models of direct risk perception. Vulnerable vegetation cover condition also had a positive and significant effect on indirect risk perception in the 2004 analysis. In sum, the 2008 OLS models accounted for a considerably larger proportion of the variation in both types of risk perception than the 2004 models.

Community wildfire experience and the degree of perceived tree mortality were positively related with both direct and indirect risk perceptions in the fixed effects regression models. The panel data analysis also illustrated higher satisfaction with local land managers was associated with higher perception about indirect risks, while perceived natural regrowth of trees and the relationship with governmental agencies were negatively related with such concern. Although community communication and the number of information sources were positively related to direct and indirect risk perceptions in nearly all of the OLS models, they were not significant in either of the first-difference models. Since the intercepts of the two panel data models were also non-significant, the risk perceptions of those persons who had no change in these explanatory factors remained largely the same during the study period.

Discussion

The existing literature on the human dimensions of forest insect disturbance reveals a necessity for tracing temporal changes in local attitudes and activeness related to social and ecological risks. Likewise, the dynamic changes of risk perceptions of social and environmental problems across different time periods have been understudied (Loewenstein and Mather 1990; Rogers 1997). Recent research on the societal impacts of climate-related hazards also highlights the need for longitudinal analysis on the relationship between risk perception and adaptation or mitigation behaviors (Bubeck and Botzen 2013; Siegrist 2013)[1]. This study contributes to the literature on forest disturbances and risks by examining the temporal dynamics of the human dimensions of the spruce bark beetle disturbance on the Kenai Peninsula, Alaska.

Changes in the Perceptions of Beetle Impacts and Forest Risks

Survey data from 2004 suggested the six Kenai study communities were located at different points along a spatial-temporal continuum of the beetle outbreak, and the severity of local beetle activity was particularly linked to different community experiences with beetle impacts and risk perceptions. The 2008 re-study indicated perceived forest damage by beetles decreased in most of the communities despite the largely unchanged local biophysical conditions and reported natural regrowth. The degree to which local residents recognized specific economic, social, and ecological impacts of the beetle outbreak generally declined in those communities where beetle activity was very active or was increasing (Homer, Anchor Point, Ninilchik, and Seldovia), but stayed largely the same in Cooper Landing and Moose Pass, which experienced the outbreak earlier. Indirect risk perception and

[1] There are several longitudinal studies of risk perception and responses related to transport safety and H1N1 influenza in the past years (e.g., Ibuka *et al.* 2010; Nordfjærn and Rundmo 2010; Sherlaw and Raude 2013).

Table 7 Comparison of regression models of direct and indirect risk perceptions

Variables	Direct risk perception			Indirect risk perception		
	2004 OLS	2008 OLS	Panel model	2004 OLS	2008 OLS	Panel model
Constant	2.925***	2.162***	0.093	2.828***	2.127***	0.004
Community-level variables						
Community wildfire experience	0.109**	0.274***	0.147**	0.074*	0.158***	0.150**
Vegetation cover	0.049	−0.015	–[a]	0.079*	−0.011	–[a]
Socioeconomic vulnerability	0.036	0.089*	–	0.049	0.046	–
Dependency ratio	0.064(*)	−0.040	–	0.023	−0.045	–
Socio-demographic controls						
Age	0.084*	0.031	–	0.030	0.047	–
Gender (male=1)	−0.131***	−0.107**	–	−0.056	−0.114**	–
Native Alaskan (Native=1)	0.048	0.062	–	0.017	0.091*	–
Years lived in community	−0.118**	−0.002	–	−0.029	−0.056	–
Household income	−0.050	−0.047	–	−0.114**	−0.047	–
Education	−0.064	−0.013	–	0.083*	0.007	–
Perceived disturbance intensity						
Perceived tree mortality	0.169***	0.232***	0.137*	0.076(*)	0.223***	0.152**
Perceived natural regrowth	−0.073*	−0.029	−0.064	−0.209***	−0.155***	−0.158***
Relationship with land manager						
Satisfaction with local managers	−0.051	−0.080(*)	−0.015	−0.171***	−0.114*	0.107(*)
Satisfaction with government managers	−0.078(*)	0.006	0.077	0.017	−0.052	−0.107(*)
Interactional capacity						
Community participation	0.051	−0.014	−0.005	0.056	0.004	−0.019
Community communication	−0.024	0.081*	−0.025	0.071(*)	0.173***	−0.021
Number of information sources	0.129***	0.171***	0.038	0.125***	0.131***	0.042
R^2 adjusted	0.144	0.268	0.053	0.148	0.241	0.088
F value	7.018***	11.848***	2.106*	7.207***	10.290***	3.601***
N	726	567	309	726	568	309

Given as standardized regression coefficients

[a] Variables were differenced out in the panel regression model

(*) $p<.10$, * $p<.05$, ** $p<.01$, *** $p<.001$

community activeness in response to forest disturbance also decreased significantly in the study area as a whole. Taken together, these findings further displayed a trend of declining saliency and urgency of bark beetle issues found in early analysis (Flint 2007) and represented a local version of the issue-attention cycle regarding ecological problems (Downs 1972).

The analysis based on the panel data also demonstrated that some forest risks remained the focus of people's attention longer than others, and that direct experience with forest hazard events might have reinforced related risk perceptions. Likely due to several large-scale wildfires in the study area between the two surveys, there was no significant change in perceptions of forest and grass fires in these study communities. Indeed, the panel data revealed a nearly significantly increase in concern about grass fire. The consistently high perceptions of fire-related risks epitomize a social amplification of risk phenomenon (Kasperson *et al.* 1988), in which direct emergency experience retains or enhances risk perceptions. In addition, non-fire related risk perceptions and local response to beetle impacts did not decline in all of the study communities. The insignificant intercepts of the panel regression models of direct and indirect risk perceptions also indicated neither kind of concern would simply become more attenuated with time since the occurrence of the beetle outbreak. These results suggest a strong staying power of risk perception which was observed by a study of the dynamic relationship between risk perception and hazard events in two Texas communities as well (Rogers 1997).

Recent research also showed perceived impacts and threats related to insect disturbance might be heightened by the distribution of information about potential risks and economic dependence on forests (Hurley *et al.* 2012; Parkins and MacKendrick 2007). Both community communication and the total number of information sources were significant in their positive relationships with indirect direct perception in most or all of the OLS models. These are largely consistent with the results of a recent study that found social interactions and the use of information sources were related to wildfire risk perceptions (Brenkert-Smith *et al*. 2013). Nonetheless, none of the measures of community interaction and information sources had a significant effect in our panel regression models of risk perceptions. This shows the social processes of forest risks related to bark beetles are more complicated than previously conceived.

Beetle Activity Timeline and Changing Human Dimensions

Results from the community-level analysis revealed some components of the human dimensions of forest disturbance were particularly related to the timeline of the bark beetle activity. Residents in communities experiencing intense beetle activity became much less positive, or negative, in their attitudes about potential economic benefits of the outbreak, likely reflecting the gradual decline in timber production following a short-term expansion of the forestry sector. This finding is generally consistent with the simulated impacts of previous economic modeling research on forest insect disturbance (e.g., Abbott *et al.* 2008; Patriquin *et al*. 2007). Among the six communities, Seldovia was at the early side or perhaps the fringe of the beetle outbreak timeline and had not experienced active disturbance at the time of the first survey. Examination of the panel data revealed Seldovia residents at the time of the re-survey had become more negative in their perception of privacy loss due to dead trees and shared a similar attitude with the 2004 survey respondents from Homer, Anchor Point, Ninilchik, and Moose Pass. The differences between Seldovia and other communities in concerns about forest and grass fires also fell from 2004 to 2008. Further, some community activities in response to bark beetles, such as attending meetings related to timber sales and consulting with public officials or foresters, were more connected to the temporal scale of beetle activity and were hence expected to have a lower level of participation over time.

Although biophysical conditions play an important role in shaping local attitudes and responses, our results indicated not all of the human factors involved in changing forest disturbance systems were directly related to the timeline of the beetle outbreak. Further analysis using ANOVA found that the severity of beetle activity indicated by respondents ("increasing," "at its peak or very active," "declining," or "over and gone") in the 2004 survey was only correlated with changes in the relationship with government land managers and indirect risk perception during the study period. More specifically, those 2004 respondents who reported beetle activity was declining were more likely to have increased satisfaction with agency forest management and lower indirect risk perception in the re-survey than those who said the beetle outbreak was at peak level or very active. Thus, local residents apparently had more positive sentiments about the management practices of governmental authorities and were less concerned about broader threats to community and the environment as beetle impacts became less salient.

Survey data from both 2004 and 2008 demonstrated perceived loss of trees and risk perceptions were significantly related with biophysical assessments of impacted forests (Table 5). This implied a temporal transition in local attitudes and other social aspects of forest disturbance across the six study communities. However, the longitudinal analysis revealed the shifting experience, perceptions, and response of individual communities represented diverse pathways of temporal changes in human dimension. Communities located at the earlier phase of the temporal continuum of bark beetle activity did not simply follow the paths of those with longer occurrence of the outbreak. The results illustrated communities at similar stages of the beetle outbreak exhibited different patterns of changes in perceived beetle impacts and risks and in the relationships with land managers, while there might also be large fluctuations in these factors within communities due to changing experience with disturbance and hazards.

Comparisons of OLS and Panel Regression Models

The panel regression analysis confirmed the correlation between higher satisfaction with government entities and lower indirect risk perception found in the bivariate analysis of the 2004 and 2008 aggregate data.[2] Satisfaction with local managing entities was negatively associated with this concern in the OLS models as well, but the direction of the relationship switched to positive in the first-difference score regression model. Previous research also indicated a positive relationship between public trust in forest management and perceived ecological and social risks related to beetle disturbance (McFarlane *et al*. 2012). The results suggested relationships with local and government managers might affect indirect risk perception in very different ways. This likely reflected the fact that local entities promoted community awareness of risks while governmental agencies mainly served as risk protectors attempting to alleviate public concern of potential hazards (Sjöberg 1999). The mechanisms underlying these relationships are in need of further investigation combining both qualitative and quantitative data in future studies.

Few prior studies on the human dimension of forest disturbance related to insects have collected information from the same group of survey respondents at multiple points of time. While the panel dataset and the two full survey datasets showed consistent patterns of changes in major variables in the analysis, there were still discrepancies between them regarding some aspects,

[2] The analysis of the 2006 Homer re-survey data also revealed a significant negative relationship between indirect risk perception and satisfaction with government land managers (Flint 2007).

particularly for those communities with smaller survey samples. For instance, analysis using the panel data demonstrated Moose Pass residents had a significant decrease in community response to the beetle disturbance, but the comparison of 2004 and 2008 full survey data revealed local activeness actually increased slightly in this community. Multivariate analyses based on the two types of dataset also generated some different results. In general, the first-difference score method identified fewer significant relationships between community activeness or risk perceptions and their explanatory variables. For example, community communication and the number of information sources were positively related with risk perceptions in OLS regression analysis, but their coefficients were dramatically smaller and no longer significant in the first-difference regression models. Therefore, the relationships found between them and risk perceptions in conventional OLS models might be spurious and reflect the correlations between these two variables and some time-invariant factors with stable effects on perceived forest risks. By contrast, community wildfire experience was not related to local activeness level in either of the OLS models, but had an almost significant effect in the panel regression model. This was also the case for satisfaction with government managing authorities in the regression analysis of indirect risk perception.

Since the difference score procedure controls for unmeasured factors with time-invariant effects on dependent variables, the results of longitudinal analysis employing this approach are usually more robust than those from cross-sectional analysis. Despite the differences between the OLS and fixed effects regression models, the analysis indicated community participation and indirect risk perception had a consistently strong influence on local actions related to the spruce bark beetle outbreak, while community fire experience and the perceived intensity of forest disturbance contributed most to risk perceptions. These findings further improve our understanding of the relationships between individual constructs in the conceptual model of community action in response to risk (Fig. 1).

Conclusions and Implications

Changing climate parameters at local, regional, and global levels can exacerbate the frequency, duration, and magnitude of forest disturbances (Dale *et al.* 2001). The human dimensions of ecological disturbances constitute an important topical area in the literature on vulnerability and adaptation to global environmental change. Local communities affected by climate-related natural disturbances are often located in wild-urban interface (WUI) areas representing complex and dynamic social-ecological systems (Field and Burch 1988; Paveglio *et al.* 2009). Recent studies conducted in the Kenai region have collected abundant background information about local communities threatened by forest insect outbreaks. The present research advances this literature by reporting on a longitudinal assessment of community attitudes and responses related to changing forest landscapes. The results revealed the temporal and spatial variations in community experience, perceptions, and actions in changing forest disturbance regimes were more complicated than what would be dictated by biophysical factors alone. Human-environment interactions in WUI areas are structured by the interactions of coupled biophysical, economic, and socio-cultural processes (Brennan *et al.* 2008; Luloff *et al.* 2007). On the Kenai Peninsula, spruce bark beetle activity, economic base, cultural traditions, social vulnerability, and adaptive capacity together shaped local patterns of shifting perceptions of beetle impacts and risks, relationships with land managers, and community interaction and activeness. In turn, they formed distinct scenarios of temporal and spatial dynamics in the human dimensions of forest disturbances.

Findings of this study have direct implications for forest management and policy making in dynamic social and ecological processes following forest insect outbreaks. The analysis suggested a more positive relationship with governmental land managers in those communities experiencing active beetle activities and high fire risks at the time of the re-study. The significant increase in satisfaction with governmental managing entities found in Homer contrasted with the results of the 2006 follow-up survey in this community (Flint 2007). Although key informant interview data from Homer in the summer of 2005 revealed a rather dramatic increase in satisfaction with how the beetle outbreak had been managed, survey data from 2006 indicated satisfaction with forest management had declined for all agencies. Taken together, these findings demonstrated the temporally sensitive relationship between local residents and governmental authorities. Moreover, the results highlighted the necessity for land managers to regularly communicate with local stakeholders so as to track the changing social and economic dimensions of forest disturbances, and help community residents develop a more informed reaction to forest management and policy.

The study showed local people generally became more adaptive to forest disturbances and felt less negative about those risks with no immediate threats to safety and property over time. Although the timeline of spruce bark beetle activity is useful for predicting possible changes in some aspects of local attitudes and actions following the outbreak, forest managers should not simply assume relationships with residents would be less contentious regarding resource management strategies as the saliency of beetle issues declines. Kenai communities at different stages of forest disturbances all experienced wide changes in related perceptions and actions. However, higher levels of community participation and concern over broader threats to community well-being were consistently associated with more active community response to the beetle outbreak. Thus, it is important to continue to involve community residents in management decision making and risk mitigation programs, and to build upon any possible positive public sentiments to improve relationships with local community groups.

Previous survey-based studies on the human dimensions of forest disturbance by insects (e.g., Chang *et al*. 2009; Flint and Luloff 2007; Flint *et al.* 2012; Hurley *et al*. 2012; Kooistra and Hall 2014; Mackenzie and Larson 2010; McFarlane *et al*. 2006; McFarlane and Watson 2008; McFarlane *et al*. 2012; Molnar *et al*. 2007; Müller and Job 2009; Parkins and MacKendrick 2007; Qin and Flint 2012; Rossi *et al*. 2010) analyzed similar conceptual constructs (e.g., perceived impacts, risk perception, relationship with land managers, and actions in response to disturbance) with different measures in a variety of ecological and geographic settings, including spruce bark beetles in Alaska (Kenai Peninsula) and southeast Germany (Bavarian Forest National Park), mountain pine beetles in Canada (southern British Columbia and western Alberta) and the United States (northern Colorado and southern Wyoming), southern pine beetles in the United States South, Sirex woodwasps in major forestry provinces of South Africa, and other forest pests (emerald ash borers, spruce budworms, and forest tent caterpillars) in Canada (in southern Ontario, New Brunswick, and Saskatchewan respectively). This body of knowledge can be further advanced with a more integrated approach to tracing temporal changes and spatial variations across different contexts. A holistic methodological strategy in research on society and natural resources issues involves the coordination among researchers and the replication of research designs and instruments across geographic regions (Luloff *et al*. 2007). Comprehensive studies incorporating different spatial-temporal scales and community contexts can more accurately interpret the complicated interactions within coupled social and biological systems. Future research in this area can be improved with better longitudinal survey data with larger sample sizes and more time points. The research scope can also be expanded to engage in relevant topics such as community risk perception of climate change, vulnerability and adaptation, wildfire prevention and mitigation, and amenity migration. A synthesis of these elements should provide a more complete understanding of the relationships between society and natural disturbances, and enhance the prospect of building community capacity to adapt to environmental change.

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