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Changing Community Variations in Perceptions and Activeness in Response to the Spruce Bark Beetle Outbreak in Alaska

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Abstract: Local sociocultural processes including community perceptions and actions represent the most visible social impacts of various economic and environmental changes. Comparative community analysis has been used to examine diverse community perspectives on a variety of socioeconomic and environmental issues. However, as the temporal dimension of community processes remains understudied, relatively little is known regarding how such community variations change over time. This study draws on longitudinal survey data from six communities on the Kenai Peninsula, Alaska to explore temporal shifts in community differences in perceptions and activeness in response to forest disturbance associated with an extensive spruce bark beetle outbreak. The surveys were implemented in two phases over a 4-year study period. Results show that while community perceptions on the bark beetle condition waned and coalesced in some ways, significant differences remained or emerged with respect to other facets of local reactions. These shifting variances in community dimensions of the beetle disturbance were related to community positions along the beetle outbreak timeline and general community socioeconomic and biophysical situations (community context). The analysis also revealed community differences and contexts held an even more important role in predicting local responses to beetles in the re-survey. Taken together, findings from this research contribute a better understanding of the persistence and change in community variability as well as the continuity of community contextual effects.

Keywords: longitudinal community comparison; community typology; community context; human ecology; forest insect disturbance

1. Introduction

Community theory constitutes the cornerstone of a key intellectual origin of interdisciplinary research on rural environmental and natural resource issues—human ecology [1,2]. As the primary linkage between humans and nature [3] and between individuals and society [4], community serves as a key scale in social ecological analysis. Sociological community studies have long relied on comparative community analysis in the examination of community characteristics and structures [4–8]. The community framework of human ecology [1] provides a fundamental conceptual base for this approach: communities are differentiable by the interaction of social and natural environmental processes within specific geographic contexts. Comparative community research has been conducted on a variety of themes ranging from local sociodemographic and economic changes to environmental perceptions and behaviors [6,9]. However, despite the inherently dynamic nature of socio-ecological systems, few studies have investigated how community variations with respect to perspectives on social and environmental issues may change over time. Sixty years ago, Reiss [8] lamented the neglect of the temporal dimension in comparative analyses of communities. This critique is just as relevant for the current community research literature (see also [10,11]).

Recent comparative community studies on environmental or natural resource-related problems generally focused on rural communities with intimate ties to natural resources, or the so-called resource-based or resource-dependent communities (e.g., [12–16]). These communities are often particularly vulnerable to the attendant social and environmental impacts of various natural disasters such as droughts, floods, and wildfires. In the past decades, forest insect outbreaks have affected many forest-based communities throughout North America. As a result, the human dimensions of forest disturbance by insects have also become an increasing concern of social scientists in natural resource sociology, geography, environmental planning, and other related fields [17–19]. Community perspectives, attitudes, and actions are major topics of this emerging research area. Given the heterogeneity and dynamics of forest ecosystems, these community-level aspects of the human dimensions of forest disturbances are expected to vary across places and time as well. Additionally, diverse socioeconomic and biophysical situations of local places have been identified as important community contextual factors influencing environmental behaviors including participation in responses to forest insect disturbance and other conservation-related activities [20–22]. Nevertheless, few studies have examined the evolvement of community differences in reactions to environmental change or the changing effects of community context on environmental perceptions and actions.

From late 1980s to early 2000s, Alaska's Kenai Peninsula experienced a massive spruce bark beetle outbreak and a range of subsequent ecological disturbances including wildfire hazard, fish and wildlife habitat loss, and the encroachment of invasive grasses [23,24]. Despite facing a region-wide outbreak and similar risks, communities on the Kenai Peninsula responded in different ways to the disturbance and subsequent forest management activities. Drawing on longitudinal survey data from six Kenai communities, this study explores how community variations in perceptions and activeness (level of action) relating to changing forest landscapes evolve, and how community contextual effects on participation in community responses to forest insect disturbance change over time.

The organization of this paper is as follows. First, we conduct an extensive literature review on various forms of community variability, dynamic community perceptions and actions (framed by local contexts) regarding socioeconomic and environmental changes, and community perceptions and activeness in response to forest insect disturbance. A conceptual framework of community responses to risk and competing research hypotheses on changing community variations in perceptions and activeness are then illustrated. Next, we describe the study communities and situate them in a typology of biophysical and socioeconomic vulnerability, and detail the longitudinal survey design and analytical procedures, including comparisons of major variable values across the study communities and an examination of the community contextual effects on local responses to beetles using multilevel regression modeling. After results from these two stages of data analysis are summarized and discussed, the article concludes with interpretations of key research findings and implications for further study and natural resource management.

2. Community Variability and Comparative Community Analysis

There is a long history of interest in community variations and comparative community analysis [25] in sociology, rural sociology, and related social science disciplines such as anthropology and psychology [6–8,11,26,27]. The sociological emphasis on contextually-based community variability is traceable to Émile Durkheim's focus on characteristics of groups and structures as independent from individual attributes [28]. Pitirim Sorokin also argued that there was no overall perpetual trend in different societies, and that variations through geographical space and fluctuations in historical time should be expected [29,30]. Therefore, community context matters in varying experiences with social and environmental processes.

Early comparative studies of natural resource-based communities during the 1930s and 1940s shaped the orientation of rural and natural resource sociology. For example, Landis [31] vividly depicted the dynamic processes of resource extraction, population change, and community interaction using case studies of three iron mining towns in the Mesabi Range, Minnesota. The Rural Life Studies Series sponsored by the Bureau of Agricultural Economics also offered a comprehensive snapshot of the relationships between land use and social organization in rural America through a set of comparative analyses of six farm communities [32].

More recent comparative community research in rural settings can be largely classified into two types based on their use of community in the analysis: community as both the level and unit of analysis or community merely as the level of analysis [33]. The most straightforward method adopted in studies of the former group is qualitative community case study. Natural resource sociologists and other social scientists have used this approach to examine a range of questions such as community development and poverty alleviation [14,34–36], community wildfire risk perception and preparedness [13,37,38], community-based resource management [39], and local perceptions of and responses to landscape change [40]. Additionally, a large number of the first type of studies also relied on secondary data sources or primary data collected from local key informants [6] to quantitatively analyze community perspectives or mobilization on various economic and environmental issues including economic growth [41–44], community development [45], energy industry [46], environmental quality [47], natural disasters [48], and climate change [49].

Another major thread of comparative rural community analysis employing community as the level and unit of analysis is the construction of community typologies based on specific topics, such as resource dependence [15,50], amenity orientation [51,52], rural sanitation demand [53], community vulnerability and capacity [45,54,55], general rurality [56], and sociodemographic and economic changes [16,57,58]. Most of such analyses measured structural characteristics of local places with data available from public sources (e.g., census and statistical bureaus) and used multivariate statistical techniques (especially factor analysis and cluster analysis) to differentiate community types.

As for comparative community studies in which community is only used as the level of analysis, the unit of analysis is normally the individual. Many community-level social phenomena, such as community attitudes, experiences, and interaction, can often only be appropriately measured through pooling together information obtained from individuals [6,59]. This approach has been applied in the study of a variety of rural community issues including perceived socioeconomic and environmental impacts of energy and industrial development in various regions of the U.S. [60–66], the role of community agency in social wellbeing in rural Pennsylvania and Ireland [67], community perspectives on environmental change and natural resource management in North America [12,19,68,69], and migration effects on community interaction or participation in northeastern U.S. and southwestern China [70,71].

While comparative analysis has been widely employed as an important research strategy in community science literature, the temporal dimension of community processes remains understudied [8,10,11]. Nevertheless, comparative historical studies have been a major stream of research throughout the history of rural sociology. Many early American rural sociological studies focused on the growth and change of rural resource-based communities and trade centers (e.g., [31,72,73]; see also work cited in [74]). Based on the 1980 and 1990 U.S. Census data, Nord and Luloff [15] found the effects of mining dependence on local socioeconomic wellbeing varied across both time and geographic regions. During the 1990s, a series of follow-up analyses were also conducted for the six original Rural Life Studies communities [11]. Overall, these rural communities did not develop as researchers predicted, and their positions on a continuum from stability to instability shifted over the 50-year span.

3. Changing Community Perceptions and Actions

Rural communities dependent on natural resources are situated in a unique interface between society and the environment [3]. Luloff et al. [75] developed a holistic, matrix approach to understanding the complex and dynamic interactions within coupled socio-ecological systems at the community level. The conceptual model lays out three intersecting dimensions of human–nature relationships: (1) the biophysical environment consisting of such elements as topography, climate, vegetation cover, fuel loading, forest insects, and the geographic distribution of settlements; (2) sociodemographic and socioeconomic characteristics including population change, migration trends, land use patterns, institutional relationships, economic structures, and other related features of local places; and (3) social and cultural factors characterizing local populations, such as attitudes, perceptions, beliefs/values, experiences, and actions. Overall, this comprehensive framework recognizes the interlocking nature of environmental, economic, and social conditions for community sustainability. The biophysical and sociodemographic/socioeconomic characteristics provide a structural context for spatial and temporal variations within the sociocultural dimension encapsulating the socially constructed human–environmental landscapes [75–77].

Local sociocultural processes including community perceptions and activeness represent the most visible social impacts of various economic and environmental changes. Since the existing literature on community impacts typically concentrates on specific phases of such changes, the temporal shifts in community perceptions and actions have been relatively overlooked. William Freudenburg and Robert Gramling laid out a typological approach for analyzing the affected physical, socioeconomic, and sociocultural community systems across the planning, implementation, and longer-term adaptation stages of development activities [78,79]. Additionally, a series of longitudinal studies examined the changing impacts of energy development and associated population dynamics on community conditions (e.g., crime risk perception, neighbor relations, and community satisfaction and identity) in four boomtowns of the Intermountain West region [60,61,63,65,80,81]. The analyses showed that the evolution of community perceptions and interaction followed a local boom-bust-recovery cycle, reflecting the significant contextual influences of community sociodemographic and economic conditions. In a more recent study, Willits et al. [82] tracked shifts in community perspectives on shale gas drilling in Pennsylvania and found despite significant increases in the knowledge and concerns about the impacts of drilling among local residents, the widespread support for this industry remained largely unchanged.

In addition to rapid growth in energy development, scholars have investigated changing community perceptions and behaviors in a range of other settings such as general rural community change [83–85], amenity-based development [86,87], wildland fire management [88,89], and natural or technological disasters [90,91]. Several studies particularly examined the potential causes of temporal community dynamics. Using community-level panel data from 99 small towns across Iowa, researchers participating in the Rural Development Initiative at Iowa State University found that higher perceived social integrity contributed to a smaller decline in community attachment and quality of life [84,85], while community structural factors (e.g., number of farms and town size) were related to local social capital and community involvement [83]. Similarly, Matarrita-Cascante [87] maintained that the effects of tourism-driven changes on community satisfaction and perceived quality of life depended on the socioeconomic and cultural settings of localities.

Although spatial and temporal variations in community perceptions and actions are interrelated, these two phenomena have seldom been studied together. One exception is the longitudinal research on the Intermountain West boomtowns cited above. Richard Krannich and colleagues found local perception of social wellbeing varied significantly across their study communities in each study year, and the differences among individual communities changed over time as well [60,61,63,65]. The degree of community variability in these social impact indicators generally decreased with time after periods of growth. Greider et al. [61] demonstrated that while the study community positions regarding perceived community trust did not change over time, community rankings on local identity and solidarity shifted significantly across years. Moreover, community contexts played an important role in shaping perceived impacts of economic and demographic changes as there were substantial differences in the effects of the community change measure on local perceptions across the study sites [61,63].

4. Community Perceptions and Activeness in Response to Forest Insect Disturbance

Continuing the intellectual tradition of community analysis in rural studies, the investigation of community perspectives on the impacts of forest insect outbreaks forms an important theme of the emerging literature on human dimensions of forest disturbances [92]. Parkins and MacKendrick [19] assessed community-level vulnerability in the setting of an extensive mountain pine beetle outbreak in British Columbia, Canada. Perceived degree and nature of beetle impacts, community risk awareness, and the evaluation of beetle management were included as major components in their community vulnerability framework. The researchers found that the level of vulnerability and its influencing factors varied greatly across study communities. Although providing useful insights for community-based vulnerability research, this comparative community analysis was largely descriptive with no statistical technique used to test the significance of community differences in beetle-related attitudes and risk perceptions.

In a similar vein, Qin and Flint [22] examined the community contextual nature of local responses to forest disturbance by mountain pine beetles in north-central Colorado. The results indicated that community biophysical and socioeconomic characteristics directly influenced local participation in community actions related to the beetle outbreak, while also adjusting the relationships of individual-level variables with beetle-related activeness. Multiple regression analysis at the community level revealed substantial differences in the influencing factors of community activeness across nine study sites as well. These study communities experienced different degrees of beetle disturbance and represented different points along an amenity gradient. Further inquiry of community perspectives on beetle impacts showed lower amenity communities with more recent emphasis on resource extraction and higher tree mortality had significantly greater perceptions of threats to human safety and economic interests, lower trust in government land management, and higher faith in forest industry than communities with more amenity orientation and less tree mortality [93]. Taken together, these findings show that broader community contexts framed local reactions to forest disturbance by beetles.

An initial analysis of community response to the spruce bark beetle outbreak on Alaska's Kenai Peninsula also revealed that communities at different stages of the beetle disturbance continuum presented significant spatial variations in perceived beetle impacts and forest risks [12]. Despite the inherently dynamic nature of forest disturbances, little is known about the temporal changes in community variability on perceptions and actions in response to forest insect impacts, or possible shifts in the effects of community context on participation in community response. This study extends the comparative community analysis of the human dimensions of forest insect disturbance by tracking how local community-level differences and community contextual effects evolved over time during the beetle outbreak on the Kenai.

5. Conceptual Approach and Research Hypotheses

Interdisciplinary research on community wellbeing, forest-based communities, and disaster and risk has identified an array of influencing factors of community perceptions and actions in response to forest disturbances [94]. This study adopts a mid-range theoretical model of community response to risk (Figure 1) in structuring the analysis and presentation of findings. Such a social–ecological approach emphasizes the roles of community variations and community risk context consisting of local biophysical and socioeconomic vulnerability conditions. The community context is a multifaceted structural setting in which local sociocultural factors are embedded. The conceptual framework also outlines five additional key determinants of community activeness in response to forest risks: (1) collective community emergency experience; (2) perceived intensity of disturbance; (3) community risk perception; (4) relationship of community residents with land managers; and (5) interactional capacity of local people to work together on common issues.

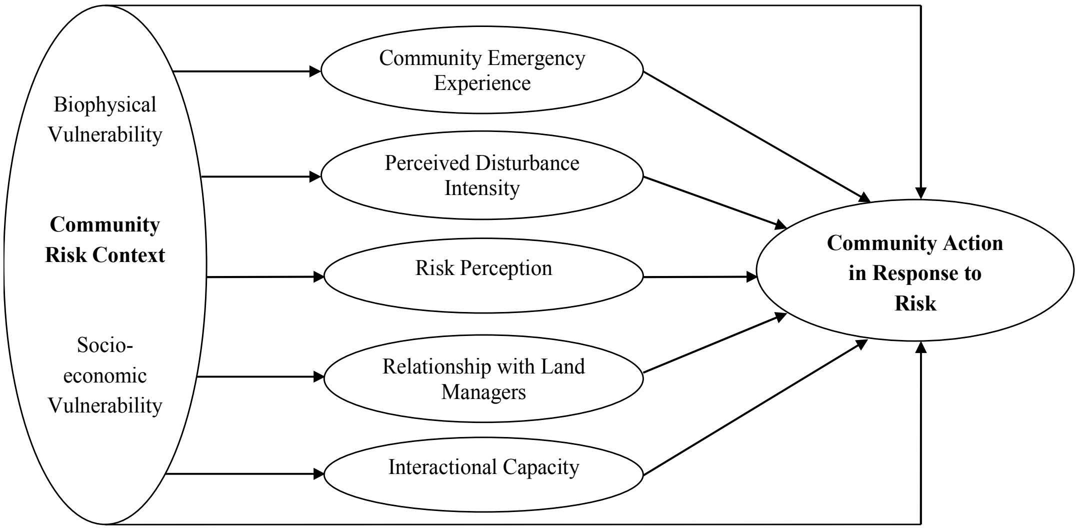

Figure 1. A conceptual model of community perceptions and activeness in response to risk. Source: adapted from [59].

There are competing hypotheses on the dynamics of community variability over time. Previous research on the temporal changes in varied community reactions to different forms of energy development in the Intermountain West suggested that community differences in perceptions and behaviors became less obvious across multiple points of time during a 13-year study period [60,61,63,65]. However, it is unclear how community variability in responses to a common ecological disturbance (e.g., the spruce bark beetle outbreak) may evolve within a smaller geographic region such as the Kenai Peninsula. In an exploratory analysis of the temporal dynamics of risk perceptions in Homer, Alaska, Flint [95] detected a decline in the saliency of spruce bark beetles as a community issue, and a trend of coalescing community concerns over forest and grass fires. Similarly, local reactions to the beetle disturbance may gradually converge at a broader scale, and thus we may expect to find fewer community variations over time where forest risks are collectively experienced by residents living in a similar, shared regional context [96]. As a result, community context may become less important in shaping local responses with time.

On the other hand, the rural and natural resource sociology literature maintains that community perceptions, attitudes, and experiences are key components of the sociocultural dimension of complex local socio-ecological systems, and interact with biophysical, socioeconomic, and sociodemographic conditions at varying spatial and temporal scales [3,75,97]. The interplay of social and natural resource systems is the essence of coupled human–natural systems at different levels including the community [1,2,38,98–101]. From an interactional perspective [4], community typically consists of three elements: (1) a shared territory in which people meet their daily needs ("locality"); (2) a comprehensive system of institutions and associations among local people ("local society"); and (3) a dynamic process of locally oriented collective actions ("community field"). Therefore, local communities continue to be meaningful entities of social and ecological organization in contemporary society.

Community organizational forms represent routinized and distinctive patterns of human–environmental relationships [3]. Since such regularities of human adaptation tend to persist once embodied in ecological forms, initial differences among communities are expected to result in lasting diversification [3,102]. Thus, an alternative hypothesis for this study posits that local communities continue to reveal significant differences in some aspects of the human dimensions of forest disturbances, while new community variations may also emerge with changing forest landscapes and risks. Under this scenario, community context should remain significant in the explanation of local actions in response to beetles.

6. Study Communities

Six Kenai Peninsula communities—Homer, Anchor Point, Ninilchik, Seldovia, Moose Pass, and Cooper Landing (see Figure 2)—were selected for study following a criterion-based process to broadly represent the full spectrum of local spruce bark beetle disturbance intensities and socioeconomic characteristics. These communities represented different points along a timeline of beetle activity and impacts. Cooper Landing was one of the first Kenai communities to experience the beetle outbreak, and the disturbance had generally abated prior to this study. In contrast, the Moose Pass community on its eastern side continued to see active beetle impacts. Forests around these two northern Kenai communities had a greater mix of tree species and did not show the same degree of beetle disturbance as the southern portion of the Kenai Peninsula. Ninilchik, Anchor Point, and Homer saw particularly high tree mortality due to a near mono-culture of spruce. Although beetle activity was expanding across Kachemak Bay toward forested lands near Seldovia at the time of this study, the forest disturbance in this community was not as locally extensive as in the previous three coastal communities.

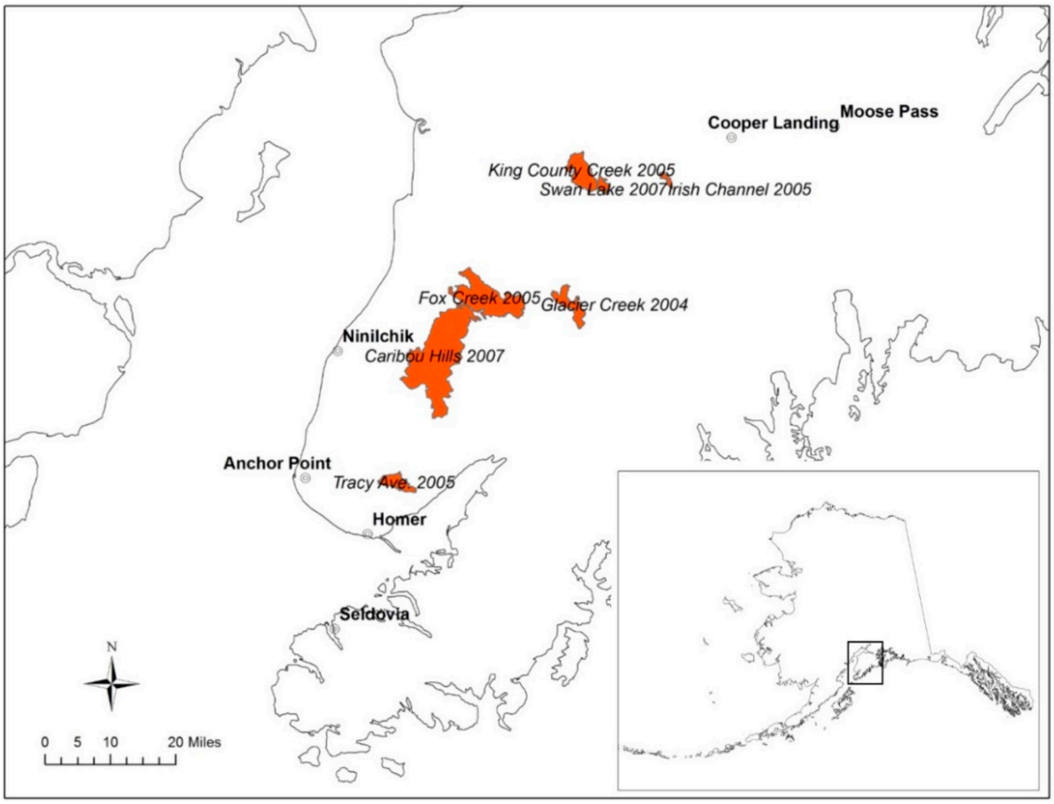

Figure 2. Map of the study communities and major wildfires during March 2004–February 2008 on the Kenai Peninsula, Alaska. Source: [91]. Reprinted with permission of Springer.

The six study communities also had varying histories, social cultures, and economies [103]. Homer was the recreation and commercial center in southern Kenai and had a diverse economic base consisting of tourism, fishing, arts, and other sectors. Its population (8920 people) was the largest among the six communities [104]. Anchor Point, situated up the coast from Homer, was settled more recently than the other communities. This community was more conservative in political views than Homer, and its economy relied more heavily on natural resource extraction (e.g., fishing, oil, and timber) in recent decades. It had a population of 1979 and was seeing an influx of retirees purchasing property and building homes.

Ninilchik and Seldovia were the only two study communities with active Alaska Native associations, and had 1025 and 453 residents, respectively. Ninilchik was also the only community in this study with a major timber harvesting operation before the beetle outbreak. Its economy was mainly supported by subsistence and commercial fishing, tourism (especially sport fishing), and logging. Commercial fishing and fish processing were traditionally at the center of Seldovia's economic activities, but it had shifted toward a more tourism-based economy. Seldovia was also the only study community with an incorporated status other than Homer.

Both Cooper Landing and Moose Pass are inland mountain communities located near the Chugach National Forest in the northwest of the Kenai Peninsula. Cooper Landing had 337 residents and was becoming more of a retirement community with a declined school enrollment and an aging population. Recreation and tourism still provided the base of the local economy. The Moose Pass population of 247 people included a higher proportion of younger, working families than Cooper Landing. Recreation, US Forest Service, and the railroad and highway between Seward and Anchorage accounted for much local employment, while other residents commuted to Seward and other nearby cities for work.

In summary, the six communities provided a typical combination of varied biophysical and socioeconomic settings on the Kenai Peninsula. Secondary data from multiple sources were used to understand the broad forest risk contexts of the study communities as well. Based on the tree mortality information obtained from the Kenai Spruce Bark Beetle Mitigation Office, a categorical vegetative cover measure was created indicating the extent of tree mortality in and around each study community: 1 = less than 25% dead trees, 2 = 25%–75% dead trees, and 3 = more than 75% dead trees. An index of socioeconomic vulnerability was also constructed with data from the Alaska Community and Economic Development Office reflecting community status on three 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). These three dichotomous indicators were summed into a composite community context variable (scale ranging from "0" low socioeconomic vulnerability to "3" high socioeconomic vulnerability; Cronbach's alpha reliability coefficient = 0.76). As a result, the two community-level measures created a general biophysical and socioeconomic vulnerability typology of the six communities (see Table 1) [105].

Table 1. A vulnerability typology of the study communities [a].

	Lower Socioeconomic Vulnerability	Higher Socioeconomic Vulnerability
Lower Biophysical Vulnerability	Seldovia	Cooper Landing, Moose Pass
Higher Biophysical Vulnerability	Homer	Anchor Point, Ninilchik

[a] Biophysical vulnerability values by community: Cooper Landing = 1; Seldovia, Mosse Pass = 2; Homer, Anchor Point, Ninilchik = 3. Socioeconomic vulnerability values by community: Homer = 0; Seldovia = 1; Ninilchik, Cooper Landing, Moose Pass = 2; Anchor Point = 3. In addition to the two criteria included in this typology, the six communities represented different points on a spatio-temporal continuum of spruce bark beetle activity.

7. Methods

7.1. Survey Administration

We collected longitudinal data from the six communities on the Kenai Peninsula using a mixed methods approach [106] combining secondary data, key informant interviews, and mail surveys. This study draws on quantitative survey data from two phases across a 4-year time period: 2004 and 2008 (referred to throughout the paper as Phase I and Phase II, respectively). Both surveys were administered using a modified tailored design method [107]. In Phase I, a mail survey was sent to 2473 households that were included on the Alaska Permanent Fund Dividend list of the six communities. A sample of 800 households was randomly selected in Homer, while all households in the other five communities were included in the survey. A total of 1088 completed surveys were received across the six study communities (46% response rate after adjusting for undeliverable surveys). Several large wildfires (e.g., Tracy Avenue Fire in 2005 and Caribou Hills Fire in 2007; see Figure 2) occurred in beetle-affected forests following the first survey. In Phase II, follow-up surveys were mailed to the original 1088 respondents in Phase I and 912 households newly sampled from a database purchased from USADATA, Inc. (New York, NY, USA). In the re-survey effort, 766 surveys were completed and returned, resulting in a 42% response rate after accounting for undeliverable surveys. Among these respondents, 433 also participated in the Phase I survey. This study used the two full survey datasets from both study phases (N = 1088 and N = 766, respectively) to examine changes in community variations on beetle-related perceptions and activeness during the study period. Findings on temporal changes within individual study communities from the analysis of the panel survey data (N = 433) are discussed elsewhere [91].

7.2. Measurement of Variables

The construction of variables for this study built on the conceptual model of community activeness in response to risk discussed above (Figure 1). Major constructs in this framework were operationalized using identical measures in both the Phase I and Phase II surveys. Variables measuring local attitudes about beetle impacts as well as several individual-level sociodemographic indicators were also included in the analysis.

Community emergency experience. Both surveys inquired about recent local experience with wildfire. A dichotomous indicator of community emergency experience (0 = no experience, 1 = experience) was created based on responses to this question. The percentage of local residents reporting wildfire occurrence reflected the aggregate level of community wildfire experience.

Perceived disturbance intensity. Respondents were asked to describe the degree of spruce tree mortality and natural re-growth in and around their communities. Possible values of these two variables ranged respectively from "1" (no spruce trees are dead) to "5" (almost all spruce trees are dead) and from "1" (no natural re-growth) to "5" (a lot of natural re-growth).

Risk perception. Perception of forest risks stemming from the beetle outbreak was measured by respondents' level of concern about potential threats including forest fire, grass fire, falling trees, decline in fish and wildlife habitat, increased erosion and runoff, loss of community identity tied to the forest, loss of forest as an economic resource, and loss of scenic and aesthetic quality (responses ranged from "1" not concerned to "5" extremely concerned). Exploratory factor analysis (using principle components factoring with varimax rotation) revealed two factors among these variables: (1) direct risk perception or perception of immediate threats to personal property and safety (forest fire, grass fire, and falling trees); and (2) indirect risk perception or perception of broader threats to community and ecological wellbeing (all other five items). Composite index variables were created by calculating the mean response value of each risk perception category (Cronbach's alpha reliability coefficients = 0.74 for direct risk perception and 0.83 for indirect risk perception in both study phases).

Attitudes about beetle impacts. Respondents were asked whether or not their communities had experienced a number of beetle-related impacts, and rated relevant impacts using a scale from "1" (very negative) to "5" (very positive) if they perceived such impacts from the beetle outbreak. The potential impacts included in the surveys were: creation of jobs and economic opportunities, logging and land clearing, expanded timber and chip export industry, rejuvenation of forest, loss of privacy, emergent views, affected property values, fire hazard, visual/aesthetic loss, falling trees, harvesting cost, tourism sector, trails and forest accessibility, forest and ecological awareness, wildlife and fish habitat, availability of firewood and/or building timber, emotions such as worry or fear, land use conflicts, emotions such as grief or sadness, and surface erosion and runoff.

Relationship with land managers. The surveys included a series of questions relating to satisfaction with how the beetle outbreak and forests were managed by the following entities: (1) private individuals and landowners; (2) local community groups or government; (3) Native associations; (4) local fire department; (5) private logging companies; (6) Kenai Peninsula Borough; (7) State Forestry; (8) US Forest Service; and (9) State parks (possible responses ranged from "1" very dissatisfied to "5" very satisfied). Two general categories emerged from exploratory factor analysis: (1) satisfaction with local land managers (entities #1–5); and (2) satisfaction with government land managers (entities #6–9). Composite indices were created for the two factors by computing the mean response value for related questions (Cronbach's alpha reliability coefficients = 0.71 and 0.71 for local management entities, and 0.91 and 0.92 for governmental management authorities in Phases I and II, respectively).

Interactional capacity. Two variables were used to measure interactional capacity in the analysis. The first was an indicator of a respondent household's level of participation in six types of community activities over the prior 12 months at the time of each survey: (1) attending a local community event (e.g., a school concert or community parade); (2) contacting a public official about some general community issue (e.g., the provision of services like fire protection); (3) working with others in the community to try and deal with a community issue or problem; (4) attending any general public meeting in the community (like a school board meeting or a planning meeting); (5) serving as an officer in a community organization; and (6) serving on a local government or advisory commission, committee, or board. As only one factor emerged in exploratory factor analysis, dichotomous responses to the six items (0 = no, 1 = yes) were summed as a composite community participation measure (Cronbach's alpha reliability coefficients = 0.74 and 0.75 respectively for the two study phases). The second community interaction indicator represented respondents' level of communication about forest risks. Respondents were asked to identify whether or not they relied on any of the 14 formal or informal sources of information listed in the surveys, such as newspaper, radio, word of mouth, local fire department, community meetings, borough beetle office, and State Forestry. A measure of the total number of information sources (with a possible range of 0–14) was created based on responses to these questions.

Community response to the beetle outbreak. Respondents to the surveys indicated whether they had taken any of the following community-related actions in response to the spruce bark beetle outbreak: (1) participation in a neighborhood or community effort to clear trees; (2) attendance at an informational meeting; (3) attendance at meetings or other actions to support timber sales on borough or state land; (4) participation in community cone or seed gathering; (5) attendance at meetings or other actions to oppose timber sales on borough or state land; (6) clearing public trails; (7) consulting with public officials or foresters; and (8) participation in efforts to preserve natural forests (responses codes as "0" for no and "1" for yes). Exploratory factor analysis revealed a common dimension underlying these eight variables. A composite community activeness index was then created by summing the dichotomous responses (Cronbach's alpha reliability coefficients = 0.63 and 0.61 respectively for the Phase I and Phase II surveys).

Sociodemographic characteristics. Six indicators of individual sociodemographic characteristics were also included in the survey data of both study phases. These variables were age, gender (0 = female, 1 = male), Native Alaskan status (0 = no, 1 = yes), length of residence (years lived in community), annual household income (1 = less than $50,000, 2 = $50,000 to $100,000, and 3 = more than $100,000), and education attainment (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, 6 = advanced degree such as Master's, J.D., and Ph.D.) [108].

7.3. Analytical Techniques

Community variations were examined accordingly using the chi-squared test (applied to both aggregate datasets and pairs of the study communities) for dichotomous variables as well as one-way analysis of variance (ANOVA) and the Kruskal–Wallis one-way ANOVA by ranks method (the non-parametric version of one-way ANOVA) with post hoc tests for numeric and ordinal data, respectively. Regression analysis using community activeness as the outcome variable was also conducted to evaluate community contextual effects on local responses to beetles. In this study, respondents were nested within individual communities in the survey data. Multilevel regression modeling was particularly suitable for this analysis since community differences in the explained variable could be captured by the random component of the intercept.

The effects of community context on action in response to the beetle outbreak were assessed through a multi-stage modeling process. At first, a null model (also known as random intercept-only model) was estimated to assess whether community activeness varied significantly across the study communities and to check the degree of non-independence in this variable across survey respondents. The significance of the random intercept was evaluated with a likelihood ratio test based on comparing the deviances of this model and an alternative model in which the intercept effect was fixed. The intraclass correlation (ICC) of the null model was also calculated to estimate the proportion of the total variance in the outcome variable accounted for by differences across communities in the level of beetle-related activeness. Next, both the intercept and the coefficients of individual-level explanatory variables were allowed to vary across communities. The effects of components with non-significant random effect estimates were then set as fixed in the final model including all the independent variables and sociodemographic indicators.

Both the comparative community analysis and the multilevel regression modeling were conducted separately for the two full survey datasets, and results were then compared with each other to identify temporal changes in community differences and community contextual effects. All statistical analyses were conducted with SPSS Software Version 21 (IBM, Armonk, NY, USA). The significance of all statistical tests was set at the 0.05 level. Marginally significant results ($p < 0.10$) were also indicated in the presentation of results and selectively included in the discussion considering the exploratory nature of this study.

8. Results

8.1. Comparative Community Analysis

Community wildfire experience. Table 2 shows that differences among communities in wildfire experience changed considerably between the two study phases, and were highly related to major wildfire events on the Kenai within this period (see Figure 2). Survey data from Phase I indicated community experience with forest fire was the lowest in Seldovia and was significantly higher in the other five communities. Its level was also significantly lower for Homer and Ninilchik respondents than for those from Anchor Point, Moose Pass, and Cooper Landing. While Seldovia still had lower exposure to wildfire than all other communities but Moose Pass in Phase II, the level of fire experience declined greatly in Moose Pass and Cooper Landing and became significantly lower than in Homer, Anchor Point, and Ninilchik. Additionally, Ninilchik had increased experience with wildfire and indicated a higher level of fire emergency than Homer and Anchor Point, which were no longer different on this variable in the re-survey.

Perceived disturbance intensity. The degrees to which respondents described spruce tree mortality varied across the study communities in similar patterns in the two surveys (Table 2). In Phase I, the perception of dead trees was found to be highest in Ninilchik and Anchor Point, followed by Homer and Moose Pass, and was lowest in Cooper Landing and Seldovia. However, Cooper Landing respondents no longer differed significantly from those from Moose Pass or Seldovia on this aspect in Phase II. Community variations in perceived tree regeneration remained largely unchanged during the study period. At both times of survey, Homer respondents indicated the largest amount of natural re-growth, which was only significantly greater than that reported by those in Ninilchik.

Risk perception. While the aggregate survey data revealed limited changes in local direct risk perception (including concerns over forest fire, grass fire, and falling trees), community positions regarding this indicator remained largely the same during the two phases (Table 2). In both surveys, the lowest direct risk perception was found among Seldovia respondents who differed significantly from Homer, Anchor Point, and Ninilchilk respondents. Homer respondents also had lower concerns over these risks than those from Anchor Point. Additionally, in Phase II, the direct risk perception in Cooper Landing declined substantially and became significantly lower than in Anchor Point and Ninilchilk (the two communities with the highest direct risk perceptions).

Table 2. Comparisons of community variations on major variables in the analysis [a].

Variables	Time	Seldovia	Homer	Anchor Point	Ninilchik	Moose Pass	Cooper Landing	Total [b]
Community wildfire experience (% reporting wildfire)	Phase I	16.7 [H, A, N, M, C]	73.1 [S, A, M, C]	84.3 [S, H, N]	72.1 [S, A, M, C]	90.2 [S, H, N]	85.3 [S, H, N]	73.3 ***
	Phase II	22.8 [H, A, N, C]	85.0 [S, N, M, C]	81.6 [S, N, M, C]	95.8 [S, H, A, M, C]	35.5 [H, A, N]	50.0 [S, H, A, N]	76.7 ***
Perceived tree mortality	Phase I	2.76 [H, A, N, M, C]	3.94 [S, A, N, C]	4.17 [S, H, C, (M)]	4.24 [S, H, M, C]	3.83 [S, C, N, (A)]	3.36 [S, H, A, N, M]	3.92 ***
	Phase II	2.63 [H, A, N, M]	3.76 [S, A, C, (N)]	3.99 [S, H, M, C]	3.99 [S, C, (H), (M)]	3.56 [S, A, (N)]	3.03 [H, A, N]	3.71 ***
Perceived natural regrowth	Phase I	2.83	3.16 [N]	2.96	2.81 [H]	2.82	3.15	3.00 **
	Phase II	3.06	3.25 [N]	3.01	2.72 [H]	3.00	3.13	3.05 ***
Direct risk perception	Phase I	3.15 [H, A, N]	3.76 [S, A]	3.98 [S, H, (C)]	3.90 [S]	3.61	3.58 [(A)]	3.78 ***
	Phase II	3.17 [H, A, N]	3.66 [S, (A), (N)]	3.93 [S, C, (H)]	3.94 [S, C, (H)]	3.65	3.22 [A, N]	3.71 ***
Indirect risk perception	Phase I	2.91 [A, N]	3.27	3.35 [S, C]	3.35 [S, C]	3.06	2.89 [A, N]	3.24 ***
	Phase II	2.90	3.08	3.30 [C]	3.31 [C]	3.19	2.64 [A, N]	3.13 ***
Satisfaction with local land managers	Phase I	2.85 [M, N]	3.00 [M, (N)]	3.02 [M]	3.19 [S, (H)]	3.46 [S, H, A]	3.21	3.07 ***
	Phase II	2.85	3.15	3.02	3.10	3.18	3.07	3.08
Satisfaction with government land managers	Phase I	2.78	2.81	2.56	2.68	2.80	2.66	2.70
	Phase II	2.94	3.18 [A, C]	2.77 [H]	2.98 [(C)]	2.91	2.54 [H, (N)]	2.95 ***
Community participation	Phase I	3.17	3.36 [A]	2.84 [H, C, M]	3.13 [(C)]	3.55 [A]	3.80 [A, (N)]	3.20 ***
	Phase II	3.64 [A, N]	3.28 [A]	2.60 [S, H, C]	2.82 [S, C]	3.16	3.80 [A, N]	3.09 ***
Number of information sources	Phase I	5.43	5.74 [N]	5.21	5.03 [H]	5.89	5.88	5.45 *
	Phase II	5.19	6.14 [(A)]	5.46 [(H)]	5.56	5.72	6.05	5.76 *
Community activeness	Phase I	1.40 [M]	1.49 [M]	1.34 [M, C]	1.31 [M, (C)]	2.53 [S, H, A, N]	1.92 [A, (N)]	1.49 ***
	Phase II	1.24 [M]	1.20 [M, C]	1.05 [M, C]	1.04 [M, C]	2.63 [S, H, A, N]	1.78 [H, A, N]	1.24 ***

[a] Given as mean values of variables except for the level of community wildfire experience. Superscript codes indicates a significant (or nearly significant if with brackets) difference between the two communities according to the results of post hoc tests. Codes for communities: S = Seldovia, H = Homer, A = Anchor Point, N = Ninilchik, M = Moose Pass, C = Cooper Landing. Cases by community in Phase I/Phase II: Seldovia (*N* = 88/58), Homer (*N* = 366/277), Anchor Point (*N* = 308/191), Ninilchik (*N* = 195/147), Moose Pass (*N* = 54/32), Cooper Landing (*N* = 77/61), Total (*N* = 1088/766). Same for Table 3; [b] Asterisks indicate the statistical significance of differences among all communities. $^{(*)}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

In Phase I, indirect risk perception (concerns over broader threats to community and ecological wellbeing) was lowest in Seldovia and Cooper Landing and highest in Anchor Point and Ninilchik. The difference between the two sets of communities was significant. The Phase II data showed that only Cooper Landing respondents had lower indirect risk perception than those from Anchor Point and Ninilchik, while Seldovia no longer differed significantly from these two communities with respect to this category.

Relationship with land managers. Overall, community variations in satisfaction with local land mangers decreased substantially between Phase I and Phase II, and the reverse was true for community differences in satisfaction with governmental managing entities (Table 2). In Phase I, Moose Pass respondents reported significantly higher levels of satisfaction with local land managers than those from Seldovia, Anchor Point, and Homer. Seldovia had the lowest level of satisfaction and also differed significantly from Ninilchik. All these differences lost statistical significance in Phase II. With respect to satisfaction with government land managers, there was no significant difference among the six study communities in Phase I. Analysis of the Phase II survey data indicated significant variability across communities in average satisfaction with government land managers. Homer respondents had a significantly higher level of satisfaction than those from Cooper Landing and Anchor Point.

Community interaction and activeness. Table 2 also indicates that general community participation was found to be higher in Cooper Landing, Moose Pass and Homer than in Anchor Point, while Cooper Landing had a nearly significantly greater level than Ninilchik in Phase I. The follow-up survey found community participation in Cooper Landing and Seldovia was greater than that in Anchor Point and Ninilchik, and it was also significantly lower in Anchor Point than in Homer. Although the aggregate community variation in the number of information sources was statistically significant in both surveys, a few obvious differences were found between specific communities in either study phase.

Initial survey results on community action in response to the beetle outbreak showed that Moose Pass had a higher level of community activeness than all other communities except Cooper Landing, which had significantly or almost significantly greater activeness than Anchor Point and Ninilchik. In Phase II, the differences between Moose Pass and other study communities in beetle-related activeness remained significant, while Cooper Landing respondents also became significantly more active in community response than those from Homer, Anchor Point, and Ninilchik.

Attitudes about beetle impacts. As shown in Table 3, community variances in attitudes about beetle impacts also changed over the 4-year span. In Phase II, differences among individual communities in the rating of beetle effects on jobs and economic opportunities, timber industry, logging and land clearing, fire hazard, trail and forest accessibility, ecological awareness, and firewood availability all became non-significant. Mean responses for the attitudes on beetle impacts in the aggregate Phase I and Phase II data suggested that the perceptions of job creation and expanded forest industry changed from positive to negative, while general attitudes about the other five outcomes remained the same (neutral, negative, or positive). The extents to which community perspectives on loss of privacy, visual/aesthetic loss, falling trees, and the impact on tourism varied across the study area became statistically significant in Phase II. Post-hoc analyses revealed these changes were mostly caused by relevant ups or downs in the mean response values of Cooper Landing, Seldovia, and/or Anchor Point, and the resulting significant differences among them. Generally, respondents in Seldovia and/or Anchor Point viewed these impacts more negatively than those from Cooper Landing. Community-level differences in attitudes toward the beetle impacts on emergent views and property values held similar patterns in both surveys. Homer tended to differ with some of the other communities (particularly Anchor Point and Ninilchik) on these items. No significant difference was found among the six communities with respect to other perceived beetle impacts (generally viewed as negative) in either survey.

Table 3. Comparisons of community variations on attitudes about selected beetle impacts [a].

Variables	Time	Seldovia	Homer	Anchor Point	Ninilchik	Moose Pass	Cooper Landing	Total [b]
Job creation	Phase I	3.03	3.23	3.40 ^{C}	3.45 ^{C}	3.08	2.73 $^{A, N}$	3.29 ***
	Phase II	2.64	2.86	2.69	2.91	2.81	2.79	2.80
Logging and land clearing	Phase I	2.75 ^{N}	2.90 ^{N}	3.15	3.24 $^{S, H}$	2.77	2.96	3.02 **
	Phase II	2.53	3.05	2.93	2.99	2.88	3.15	2.97 (*)
Expanded timber industry	Phase I	2.58 $^{H, A, N}$	3.30 ^{S}	3.45 $^{S, (C)}$	3.46 $^{S, (C)}$	3.00	2.64 $^{(A), (N)}$	3.33 ***
	Phase II	2.36	2.95	2.81	2.86	2.54	3.04	2.86
Loss of privacy	Phase I	2.24	2.05	1.99	2.06	1.95	2.47	2.05 (*)
	Phase II	1.91 ^{C}	2.21	2.22 $^{(C)}$	2.38	2.24	2.82 $^{S, (A)}$	2.26 *
Emergent views	Phase I	3.25	3.66 $^{A, N, M}$	3.23 ^{H}	3.16 ^{H}	2.75 ^{H}	3.16	3.36 ***
	Phase II	3.53	3.59 $^{A, N, C}$	3.08 ^{H}	3.03 ^{H}	3.14	2.92 ^{H}	3.29 ***
Affected property values	Phase I	2.62	2.75 $^{A, N, (M)}$	2.34 ^{H}	2.40 ^{H}	2.11 $^{(H)}$	2.56	2.52 ***
	Phase II	2.57	2.84 $^{A, N}$	2.38 ^{H}	2.45 ^{H}	2.39	2.79	2.61 ***
Fire hazard	Phase I	2.72 $^{H, M, (A)}$	2.11 ^{S}	2.26 $^{(S)}$	2.36	1.86 ^{S}	2.45	2.24 **
	Phase II	2.21	2.12	2.22	2.42	2.32	2.57	2.25
Visual/aesthetic loss	Phase I	2.18	2.02	2.12	1.99	1.80	2.26	2.06
	Phase II	2.00	2.17	1.97 ^{C}	2.23	1.96	2.49 ^{A}	2.13 **
Falling trees	Phase I	2.14	2.07	2.19	2.05	1.86	2.36	2.11
	Phase II	2.02	2.13	2.03 ^{C}	2.32	2.17	2.58 ^{A}	2.17 *
Tourism sector	Phase I	2.29	2.34	2.40	2.23	2.40	2.89	2.35
	Phase II	2.26 ^{C}	2.68	2.53	2.75	2.33	3.08 ^{S}	2.64 *
Trails and forest accessibility	Phase I	2.62	2.30 $^{A, N}$	2.65 ^{H}	2.70 $^{H, (M)}$	2.21 $^{(N)}$	2.45	2.49 **
	Phase II	2.13	2.32 $^{(N)}$	2.31	2.68 $^{(H)}$	2.08	2.61	2.39 *
Ecological awareness	Phase I	3.38	3.64 ^{N}	3.49	3.27 $^{H, (M)}$	3.77 $^{(N)}$	3.67	3.53 *
	Phase II	3.87	3.68	3.43	3.51	3.57	3.49	3.58
Availability of firewood/timber	Phase I	3.49 $^{C, (A)}$	3.80	3.89 $^{N, (S)}$	3.51 $^{A, C}$	3.85	4.11 $^{S, N}$	3.78 ***
	Phase II	3.48	3.61	3.49	3.54	3.83	3.73	3.58

[a] Given as mean values of variables. Superscript codes indicates a significant (or nearly significant if with brackets) difference between the two communities according to the results of post hoc tests. Codes for communities: S = Seldovia, H = Homer, A = Anchor Point, N = Ninilchik, M = Moose Pass, C = Cooper Landing; [b] Asterisks indicate the statistical significance of differences among all communities. (*) $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

8.2. Multilevel Regression Analysis

Table 4 summarizes results of the multilevel regression analysis using survey data from Phases I and II. Likelihood ratio tests revealed a significant random effect of the intercept in both null models. The ICC values of the two models were 0.067 and 0.143, meaning that 6.7% and 14.3% of the total variance in community response to forest disturbance were accounted for by differences across the study communities in average activeness level, respectively. None of the random effect estimates for the coefficients of individual-level explanatory variables was significantly different from zero in the analysis. Thus, the effects of all these variables were set as fixed in the final models while only the intercept was estimated as a random effect.

Table 4. Comparison of multilevel regression models of community activeness [a].

Variables	Phase I		Phase II	
	Null Model	**Final Model**	**Null Model**	**Final Model**
Intercept	1.641 ***	−1.654 **	1.461 **	−0.995 (*)
Community Emergency Experience				
Community wildfire experience		0.001		0.024
Perceived Disturbance Intensity				
Perceived loss of trees		0.154 *		0.030
Perceived natural re-growth		0.116 *		0.064
Risk Perception				
Direct risk perception		−0.007		0.003
Indirect risk perception		0.114 (*)		0.131 *
Relationship with Land Managers				
Satisfaction with local land managers		0.171 *		−0.092
Satisfaction with government land managers		−0.143 *		−0.068
Interactional Capacity				
Community participation		0.318 ***		0.253 ***
Number of information sources		0.124 ***		0.131 ***
Sociodemographic Controls				
Age		−0.005		−0.007
Gender (male = 1)		−0.028		0.233 *
Native Alaskan (Native = 1)		0.156		0.465 *
Length of residence		0.015 ***		0.022 ***
Household income		−0.073		0.021
Educational attainment		0.083 *		0.098 *
Likelihood ratio test statistic (random effect of intercept) [b]	16.674 ***	15.673 ***	27.575 ***	18.048 ***
Residual variance	2.461 ***	1.825 ***	1.913 ***	1.427 ***
Individual-level pseudo R square	n/a	0.258	n/a	0.254

[a] Given as estimates of fixed effects except for the random intercept. N = 1086 and N = 691 respectively for Phases I and II; [b] The significance of the likelihood ratio test statistic can be tested against a chi-squared distribution with one degree of freedom. (*) $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

The multilevel regression modeling revealed several independent variables (indirect risk perception and the two interactional capacity indicators) with consistently strong influences on community activeness. Respondents reporting greater indirect risk perception, more information sources, and higher levels of community participation were more active in community response to the beetle outbreak. Measures of perceived beetle intensity and satisfaction with land managers were significantly related to community actions only in the final model of Phase I. Nevertheless, our primary interest here was in assessing the role of community context in framing local beetle-related activeness. For both study phases, the random intercept was still highly significant (according to the likelihood ratio test statistic) when explanatory variables and sociodemographic controls were included in the analysis, thus confirming the community-embedded nature of respondents in the survey data. Community wildfire experience did not show a significant effect in either of the two final models. This largely reflected that community contextual effects were incorporated in the multilevel analysis that allowed for the nested data structure. Overall, these two models explained a similar proportion of the variation (about 26%) in community activeness not already accounted for by community differences.

9. Discussion

In summary, this study found that communities on the Kenai Peninsula showed spatio-temporal variations in local perceptions and actions related to the spruce bark beetle disturbance. There was a range of possible patterns of changing community differences regarding the variables in the analysis: no significant community variation in either phase, similar degrees of variations (largely same or changed patterns), and reduced or increased variations (Table 5). The three categories of changed variability (similar extents of variations with changed patterns, reduced variations, and increased variations) altogether accounted for 63% of all the outcomes. This research provides some supporting evidence for both the reduction and the continuance hypotheses regarding changing community variability. Although the analysis indicated community variations in some perspectives (e.g., attitudes about many of the socioeconomic impacts of spruce bark beetles and satisfaction with local land managers) reduced over time, significant differences among communities remained with respect to many other facets of local reactions to the beetle outbreak. In fact, there were more variations across the study communities on some aspects in the Phase II survey, such as satisfaction with governmental land managing entities and community activeness. These results are in contrast with the generally decreasing trend of community differences in social impacts from rapid growth found in the Intermountain West region [60,61,63,65], and suggest that the evolvement of community variances might be contingent on specific temporal scales, issues of interest, and regional conditions. Moreover, the multilevel regression analysis revealed that community differences and contexts held an even more important role in predicting local responses to beetles in the re-survey.

Table 5. Summary of changing community variations.

Dimensions	Change in Community Variations					Total Numbers of Variables
	No Significant Variation in Either Phase	Similar Degrees of Variations (Largely Same Patterns)	Similar Degrees of Variations (Changed Patterns)	Reduced Variations	Increased Variations	
Community emergency experience			1			1
Perceived disturbance intensity		1		1		2
Risk perception		1		1		2
Relationship with land managers				1	1	2
Community interaction and activeness			1		2	3
Attitudes about beetle impacts	8	1	1	6	4	20
Total (% of total)	8 (27%)	3 (10%)	3 (10%)	9 (30%)	7 (23%)	30

The research findings provide empirical support for the basic role of community in longitudinal ecological investigation. The interrelationships between humans and natural resources are hierarchically nested within socio-ecological systems at different scales [3,101,109]. While community and region are highly interdependent, this study suggests community is a more readily observable unit of analysis than region. The changing community variations in perceptions and activeness in response to the beetle disturbance were not in line with what a shared regional context would predict. Such temporal dynamics of community differences mirrored the evolving landscape heterogeneity resulting from disturbed forest ecosystems [110]. The interactions of biophysical, socioeconomic, and sociocultural processes within individual communities produced diverse pathways of temporal changes in local human dimensions. Further analysis of shifts within the study communities using the panel survey data also confirmed this general trend [91].

Crow and Allan [10] argued changing community processes can be assessed by community typologies incorporating a time dimension. This study suggests combining such typologies with longitudinal comparative analysis can improve the tracking of community temporal dynamics. The analysis revealed that shifting variations in community experience, perspectives, and actions relating to the beetle outbreak were associated with community positions on the beetle outbreak timeline and general community vulnerability situations (see Table 1). Adjusted differences in wildfire experience and perceived tree mortality across communities mainly reflected changes in Seldovia, Moose Pass, and Cooper Landing, which were at the two ends of the temporal continuum of beetle activity and had lower biophysical vulnerability. In contrast, Homer, Anchor Point, and Ninilchik (the three communities with higher biophysical vulnerability) contributed most to the evolving community variances in attitudes toward those beetle impacts related to local economy including the creation of jobs and economic opportunity, expanded timber industry, and logging and land clearing. Risk perceptions also varied across the study communities in different ways in the two study phases due to relevant changes in Anchor Point, Ninilchik, and Cooper Landing. Finally, while most of the adjustments in community variations in satisfaction with government land managers during the 4-year study period could be attributed to corresponding alterations in Homer (the only community with higher biophysical vulnerability but lower socioeconomic vulnerability), changing community differences in the level of actions in response to beetles mainly reflected the decline of community activeness in Homer, Anchor Point, and Ninilchik.

Community typologies can help researchers identify clusters of cases with general similarities in biophysical, sociocultural, and economic characteristics [75]. While not fully explaining communities variations in various dimensions, a typological approach can be used to organize data for subsequent comparative community analysis. The results suggest that community differences in some aspects of local response to the beetle outbreak were closely related to particular categories of the community vulnerability typology. For instance, the two communities with higher biophysical and socioeconomic vulnerability (Anchor Point and Ninilchik) ranked consistently high on perceived tree mortality and direct and indirect risk perceptions but low on community participation and activeness. By contrast, Cooper Landing and Moose Pass (communities with lower biophysical vulnerability but higher socioeconomic vulnerability) were more similar with each other in collective emergency experience and community activeness than with other study communities.

A comparable study on community response to the mountain pine beetles in north-central Colorado [93] also found local perceptions of forest disturbances were associated with community groups with distinct biophysical and amenity contexts. Comparative community analysis and community context studies are two interrelated streams of inquiry in community research. Community social scientists have employed a range of methods to capture community contextual effects, such as typology construction, multi-level modeling, social network analysis, qualitative comparative analysis, and typical statistical analyses involving context variables [22,26,45,111]. This study shows that while community contextual understanding provides an important backdrop for the comparison of community cases, longitudinal comparative community research can in turn enrich the depiction of varied community contexts.

10. Conclusions

This analysis of community differences and community contextual effects across two points in time is a useful step forward beyond the prevailing cross-sectional approach in existing comparative community studies. The Kenai Peninsula study area may seem quite homogeneous from a regional lens. Given the common experience with the spruce bark beetle outbreak, any initial differences in community responses may be expected to gradually become less important. However, the analysis revealed that the temporal dynamics of community variations were more complicated than previously conceived. There are two key findings from this research: (1) the persistence and change in community differences in beetle-related perceptions and actions; and (2) the continuity of community contextual effects on community activeness. On one hand, the significant role of community context sheds light on the evolvement of community variability in response to forest disturbance. On the other hand, the temporal changes in such community differences appear to be contingent on local biophysical and socioeconomic conditions.

While not implying these contextual influences fully explain the shifting perceptual and behavioral dimensions of forest disturbances, this study takes an initial step in identifying generalizable patterns of evolving community variations across human–natural landscapes. Further research combining both quantitative and qualitative data can enhance the understanding of how local sociodemographic, socioeconomic, and environmental factors interact with each other to affect the unfolding of community differences within the sociocultural dimension. Additionally, the analysis indicated substantial changes in community variations even within a relatively small timeframe. Similar longitudinal comparative analyses need to be replicated in other geographic areas and with a longer time span to increase understanding of the dynamic and multifaceted human community dimension of forest disturbances.

Findings from this research can inform regional forest management on the Kenai Peninsula and elsewhere regarding diverse and changing community contexts of human responses to forest disturbances. Natural resource managers have begun to realize community residents respond to forest insect outbreaks and accompanying forest management approaches in very different ways. Although communities on the Kenai were located at different points on a spatial and temporal continuum of spruce bark beetle activity, resource managers should not assume variations through time are always captured by variations across space. Directly assessing the temporal dimension of community comparison can help forest managers better anticipate changes in human dimensions over time. In addition, the results suggest that community differences in experience, perceptions, attitudes, and actions related to forest disturbances cannot be simply expected to reduce and eventually disappear with time. Identifying concerns and issues where significant and lasting variances may exist across local communities can facilitate the planning and implementation of relevant management strategies. Finally, both comparative analysis of community cases and community typology can be of practical use for sustainable resource management and community development. While each community is a unique ecological unit in terms of biophysical and socioeconomic characteristics, an integration of these two commonly used approaches can better support community and natural resource research, and improve the incorporation of varying community contexts into social and ecological sustainability practices at broader scales. Monitoring contextual differences in communities over time can help resource managers develop nuanced adaptive strategies under changing environmental conditions.

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