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Local Ecological Knowledge and Fire Management: What Does the Public Understand?

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As fire management agencies seek to implement more flexible fire management strategies, local understanding and support for these strategies become increasingly important. One issue associated with implementing more flexible fire management strategies is educating local populations about fire management and identifying what local populations know or do not know related to fire management. This study used survey data from three 2010 wildland fires to understand how ecological knowledge and education level affected fire management perception and understanding. Results indicated that increased accuracy in identifying ecological conditions was associated with higher proficiencies in the identification of fire management strategies used for wildfires. Education levels were not significantly related to public perception of fire management but were related to significant differences in accurately identifying ecological conditions. Results suggest that education may play a mediating role in understanding complex wildfire issues but is not associated with a better understanding of fire management.

Keywords: large wildfires, ecological systems, community resilience, education, fire management

Declining vegetative health and increasing human populations in the wildland-urban interface (WUI) have created significant challenges for wildland fire management in the United States (The National Wildfire Coordinating Group Executive Board 2009, Stephens et al. 2013). National policies continue to place a priority on more locally based efforts to address the wildfire problem in the West (Wildland Fire Leadership Council 2011). As fire management shifts toward increasing local resilience through community-based efforts, studies have focused on gaining insight into what factors increase acceptance and understanding of various fire management strategies (Steelman and McCaffrey 2011, 2013). Behavioral hazards research identifies the impact that awareness and perception of natural hazards have on the translation of knowledge into action (Burton 1993, McCaffrey 2004).

Community-based efforts such as Firewise and Fire-Adapted Communities programs depend on residents to take an active role in efforts to address wildfire risk. These programs rely on local community members to conduct risk assessments based on ecological characteristics and fire history to create mitigation plans. They also encourage resident support of land management agencies by providing education about wildfire risk reduction efforts, such as using prescribed fire to manage local landscapes (Fire Adapted Communities 2013). Ultimately, these policy shifts call for a new relationship between residents and land/fire managers (Steelman and McCaffrey 2011). This new envisioned relationship is one of shared responsibility and collaboration between land agencies and communities to mitigate and manage wildfire risk. As a result, two outcomes of increasing importance to the forestry community are the degree to which residents both understand the ecological factors affecting fire conditions in their area *and* the fire management strategies used in light of these conditions. This article investigates whether and how knowledge of ecological conditions is associated with the perception and understanding of appropriate fire management strategies. The following sections provide an overview of two relevant factors—local ecological knowledge (LEK) and education level—that relate to understanding of fire management decisions. Findings from a survey following three wildfires from the 2010 wildfire season are presented along

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with discussion and conclusions to provide insight into how these factors may relate to understanding management decisions on the ground.

LEK and Fire Risk, Fire Ecology, and Fire Management

The relationship between LEK and fire management is not always clear. Nonetheless, there is precedence in the literature for investigating these relationships. There is no singular definition of LEK, so defining our terms is important. Olsson and Folke (2001, p. 87) define LEK as "knowledge held by a specific group about their local ecosystems" and explain that "LEK may be a mix of scientific and practical knowledge." This form of ecological knowledge differs from traditional ecological knowledge, which would include aspects of historical and cultural continuity of resource use (cf. Berkes et al. 2000). As such, our definition of LEK incorporates the knowledge of ecological characteristics typical to fire-prone ecosystems in the western United States such as beetle kill, drought, tree density, steep terrain, blowdown, erodible soils, and age of forest.

Knowledge about ecological characteristics can provide a framework for interpreting and responding to feedback from the local environment to guide the direction of resource management (Olsson and Folke 2001). Natural resource policymakers often invoke this relationship when implementing and administering policies (Ray et al. 2012). Research about LEK in the wildfire context spans a range of how locals understand ecological characteristics and their relationship to wildfire. For instance, LEK ranges from understanding that poor forest health contributes to wildfire risk to a more sophisticated understanding of how exact ecological conditions contribute to specific wildfire risks and lead to specific management actions. What remains unclear is whether the relationship between LEK exists in the context of wildfire response, especially as it relates to perceptions of fire risk, fire ecology, and fire-mitigation practices.

Researchers have identified the importance of LEK in creating place-based solutions and influencing perceptions that increase the acceptance of appropriate practices for mitigating fire risk (Brenkert-Smith 2011, McCaffrey and Olsen 2012), but empirical evidence for these beliefs is primarily qualitative. According to some studies, residents in fire prone ecosystems have a good understanding of the relationship between forest health and fire risk. For example, Burns and Cheng (2007) conducted key informant interviews to identify public perception of active forest management to mitigate wildland fire risk. Stakeholders believed that the current conditions of the region's forests were unhealthy and forests were overly dense. This LEK contributed to the public perception that forests should be actively managed to improve forest health conditions and protect against large wildfires (Burns and Cheng 2007).

Research has suggested that the public also understands how forest-related conditions contribute to some of the specific circumstances that increase flammability. Residents and scientific experts have been shown to share similar perspectives regarding general drivers of flammability (topography, fuels, and weather), which comprise the three legs of the fire behavior triangle (Ray et al. 2012). McCaffrey (2008) conducted a qualitative analysis of 15 focus group sessions in Arizona, Colorado, California, Montana, and Nevada. A distinct pattern of wildfire risk perception emerged. First, participants generally thought about environmental conditions that would affect the odds of a fire breaking out and influence its behavior. Participants were also able to associate environmental factors with different levels of wildfire risk (McCaffrey 2008). Ray et al. (2012) conducted a qualitative study to document observations of wildfire and landscape changes within the Koyukun Forest in central Alaska. Most residents related flammability not to fire history but to specific vegetative conditions caused by different factors (Ray et al. 2012). Dead or dry vegetation was seen as the primary cause of flammable conditions, followed by dense brush, grass, and spruce-pine. Weisshaupt et al. (2007) also conducted qualitative analysis of focus groups in Idaho, Montana, and Washington to identify themes that emerged after stakeholder discussions. Participants recognized ecological conditions that contributed to the region's wildland fire risk and generally focused on the buildup of fuels in the local forest (Weisshaupt et al. 2007). Disagreement existed between the development and description of current conditions, but residents agreed that their forests were too dense with undergrowth and deadfall. Focus group participants saw these conditions as contributing to the area's recent fire history (Weisshaupt et al. 2007). Fischer and Charnley (2012) and Fischer (2011), working with nonindustrial private forest owners in Oregon, explored the relationship between the perception of local ecological conditions and cooperation in the management of hazardous fuels. Using logistic regression from 505 mail surveys, they found that nonindustrial private forest owners who both perceived a risk to their property and felt that some of this risk came from adjacent public lands were more likely to cooperate with public agencies to address the risk.

Additional research demonstrated that local communities have intricate knowledge of how specific forest-related conditions contribute to fire risk and are associated with perceived appropriateness of fire management strategies. Ryan (2012) surveyed more

Management and Policy Implications

Multiple wildfire management strategies, beyond suppression only, will be needed to address the challenges of large wildfires if we want to create wildfire-resilient landscapes and communities. More flexible fire management means the ability to implement multiple strategies dependent on factors such as fire risk, fire behavior, and ecological conditions. Knowledge about ecological characteristics can provide a framework for interpreting and responding to feedback from the local environment to guide the direction of resource management. This research suggests that increasing knowledge about ecological characteristics may increase a community's understanding of the actual strategy used to manage wildfire response, which is an important step to provide more flexible fire management options for wildfire resilient communities. The policy implication from this research is that efforts to increase locals' understanding about ecological conditions could result in greater tolerance for and appreciation of different fire management strategies. Important activities that could increase knowledge of ecological conditions include collaborative planning, implementation, and adaptive management through the sharing of lessons learned via a range of engagement and communication media. These joint problem-solving activities provide land and fire managers the opportunity to work with residents to improve understanding of land uses, management goals, and strategies.

than 1,000 residents in the pine barren ecosystem of New Jersey and was able to identify a relationship between knowledge of natural areas and perceptions of fire management. Respondents who self-reported higher levels of ecological knowledge had a better understanding of the selection of specific fire management strategies (Ryan 2012). Ryan (2012) found that these respondents were significantly more supportive of prescribed fire treatments and were also more likely to think that forest and brush fires should be allowed to burn, if they do not threaten lives or property. Brenkert-Smith (2011) interviewed residents of two communities in Colorado to understand homeowner's perspectives on the parcel approach to wildland fire management, where the responsibility falls on each homeowner to mitigate risk in the home ignition zone. Residents demonstrated disagreement with this management approach based on their understanding of local ecological conditions. Residents agreed that wildland fire did not follow property lines and therefore required management across the landscape to ensure a holistic approach toward mitigating risk (Brenkert-Smith 2011).

Residents in some cases appear to be knowledgeable about the relationship between the objectives of fire management strategies and local ecological needs. Cohn et al. (2008) used interview data from case studies of six communities affected by 2000 and 2002 wildfires in Arizona, Colorado, Idaho, Montana, and Utah to uncover individual, household, neighborhood, and community perspectives. Respondents identified existing forest conditions of dense, overstocked understory and high fuel loads as contributing to the magnitude and intensity of the fires that affected their communities (Cohn et al. 2008). In all sites, respondents demonstrated an understanding that extremely dry conditions accompanied by strong or erratic winds, along with inaccessible or steep terrain, contributed to the magnitude of the fire and the selection of specific fire management strategies (Cohn et al. 2008). Public understanding of the ecological conditions also contributed to criticism of wildfire response strategies. Several respondents believed that the fire threatening their community was controllable and could have been put out during its early stages. They attributed environmental conditions and a weak initial attack to the increased wildfire severity. Respondents in several sites also criticized the use of backfires, claiming the absence of ideal environmental conditions, which contributed to escaped burns and unnecessary damage (Cohn et al. 2008).

Although results from most studies support a relationship between LEK in both perceived understanding and acceptance of fire management strategies, there is a limitation in this body of literature in that it focuses on resident perceptions of local conditions associated with their perception of fire risk and management. Although this is an important linkage toward advancing our understanding in this area, it fails to consider the *accuracy* of resident knowledge of ecological conditions in their area as well as the *accuracy* of their understanding of the fire management strategy. By accuracy we meant a respondent's ability to correctly identify the prevalence of specific forest-related conditions in their area. Further, whereas most studies have found support for a relationship between perceived ecological knowledge and acceptance of fire management practice, the overwhelming use of single-informant self-report methodologies makes it impossible to rule out these effects as simply the result of a mono-method bias (Donaldson and Grant-Vallone 2002). Mono-method bias demonstrates the threat that the overuse of a single method has on construct validity specifically related to LEK. This study addressed these limitations by investigating the accuracy of resident knowledge of ecological conditions relative to that of experienced US Department of Agriculture (USDA) Forest Service District Rangers. Accuracy in ecological knowledge is examined in its relationship to both residents' ability to correctly identify the fire management strategy used on a large wildfire and their perception of the appropriateness of this strategy. This investigation is guided by the following hypotheses:

- *Hypothesis 1a*: Accuracy in LEK will be positively related to higher proficiencies in identifying the specific management strategy used during local wildfire response.
- *Hypothesis 1b*: Accuracy in LEK will be positively related to resident satisfaction and perceived appropriateness related to the fire management used on a local wildfire.

Formal Education in Local Ecology and Fire Management Knowledge

In addition to the relationships between LEK and fire risk, fire ecology, and fire management, other variables, such as educational level have been identified as related to perceptions associated with wildland fire management. There are many other variables that may have been included in this article such as residency type and length of residency. Because of space constraints, we focused on bringing some additional empirical rigor to the variables that were most prevalent in the literature. Findings from empirical research investigating the relationship between educational level and wildfire management are mixed. Other research has demonstrated no significant association between education level and fire management perception (Shindler and Toman 2003, Fried et al. 2006, Lim et al. 2009, Toman et al. 2011). These studies focused on fuels management and treatment programs using both quantitative and qualitative methods to evaluate a possible relationship. Fried et al. (2006) evaluated focus group discussions and resident surveys from across the country but did not identify a significant relationship between educational attainment and acceptance of fuel management practices. Shindler and Toman (2003) disseminated surveys and "quiz like" questionnaires to residents in and around fire prone ecosystems to evaluate longitudinal demographic differences that contributed to fuel treatment acceptance and understanding. Their study also did not find education level as a significant predictor of either understanding or supporting prescribed fire and mechanical thinning as a practice to mitigate fire risk.

Yet others have found a significant relationship between education and fire management perception. These studies indicated that individuals with higher education levels demonstrated concerns associated with fire, increased fire-mitigation approval and preference, and advocacy for fire management in rural landscapes (Eriksen and Gill 2010, McCaffrey and Olsen 2012). Some scholars believe that the unclear relationship between education level and fire management perception is a result of the influence of community engagement and group membership (McCaffrey 2008, Gordon et al. 2010). Eriksen and Gill (2010) conducted resident interviews in fire-prone areas, identifying educational level as an important predictor for fire management perception related to sentimental attachment to wildlife. Residents who completed higher levels of education considered environmental impact as an important factor in accepting fire management strategies. Absher and Vaske (2006) devel-

oped a composite demographic variable that included the highest education level and found that education level influences the acceptance of prescribed fire and thinning strategies based on the assumption that increased understanding of fire ecology and fuels accumulation is associated with increased education. Lim et al. (2009) discovered a significant positive relationship between education and concern for fire management outcomes. Residents with higher levels of education illustrated a decreased level of concern related to the side effects of prescribed fire, thus demonstrating an increased level of support for related fire management strategies. Other studies have identified a positive relationship between education level and engagement with restoration activities (Ostergren et al. 2006), behavioral change associated with climate change (Semenza et al. 2008), and agency trust (Winter and Cvetkovich 2008).

Collectively, this body of work suggests two competing propositions. Research regarding the direct linkage between education level and fire management perception and understanding has received mixed results. Further, there appears to be a growing body of literature that supports the proposition that education level is a stronger predictor of general local knowledge but not necessarily fire management knowledge. To help clarify this relationship, we investigated three hypotheses:

- *Hypothesis 2a*: The education level of local residents will be positively related to their satisfaction with and perception of the appropriateness of fire management strategies used on a local wildfire.
- *Hypothesis 2b*: The education level of residents will be positively related to higher proficiencies in identifying the fire management strategy used on a local wildfire.
- *Hypothesis 2c*: The education level of residents will be positively associated with greater proficiencies in identifying accurate forest-related conditions.

Methods

The population of interest for this study included the communities and USDA Forest Service District Rangers associated with three 2010 wildland fire events. These included the Tecolote Fire in New Mexico, the Schultz Fire in Arizona, and the Bull Fire in California. Wildfire selection criteria for this study included response by a Type I or Type II Federal Incident Management Team, proximity and threat to a local community, and the presence of evacuations or road closures.

Table 1. Sample areas with associated response rates.

Fire name	Sample perimeter (miles)	Surveys disseminated	Surveys collected	Response rates (%)
Tecolote	10	1,130	113	10
Schultz	5	1,496	311	21
Bull	15	1,000	155	16

This study used mail surveys to residents in the WUI based on Dillman's (2007) total design method and document analysis of ICS-209 daily incident status fire reports. Phone surveys were conducted with a USDA Forest Service District Ranger on the Sante Fe National Forest (New Mexico), the Coconino National Forest (Arizona), and the Sequoia National Forest (California) to understand the ecological conditions in each area where a wildfire occurred. USDA Forest Service District Rangers were given an initial list of seven forest-related conditions that may have been present before the fire event and asked to identify any additional conditions that may have been present (see Supplemental Material).[S] The list of seven conditions mirrored the conditions included in mail survey items presented to residents. USDA Forest Service District Rangers were then asked to identify which of the conditions were most prevalent. The response given by each USDA Forest Service District Ranger was used as a point of reference for match analysis with the exclusion of additional conditions identified.

Resident surveys were mailed during the fall/winter of 2010 and winter/spring of 2011. Surveys were designed to capture local perception of appropriateness of and satisfaction with specific fire management strategies used, LEK, and fire management understanding. The initial survey was pilot-tested in the summer of 2009 and revised based on feedback from participants. The resident sample frame was created using geographic information system (GIS) maps delineating a 5- to 15-mile perimeter of each fire. Perimeters varied based on the density of the population in the WUI and the size needed to obtain an appropriate sample. These maps then allowed the research team to assemble a list of residents within the appropriate fire perimeter from data from the local assessor's offices. Public, corporate, and trust lands were not included. A total of 3,626 surveys were sent out. The response rates varied from 10 to 21% for all fires (Table 1) for a total of 579 surveys across all 3 fires.

The relatively low response rates warranted a follow-up telephone survey to test for nonresponse bias. An abbreviated telephone survey was administered to 10% of the nonrespondents. Survey data were uploaded into SPSS for statistical analysis. We did identify significant differences related to age, gender, residency type, and length of residency. Nonrespondents were more likely to be younger and female, to live in an urban area, and to have lived in the community for less time. To understand the potential influence of these demographic factors toward respondent LEK and fire management strategy, tests of difference and correlation analysis were run. We did not identify any significant differences or relationships based on these demographic variables.

To analyze accuracy of respondents' LEK, we used a framework developed by Booysen (2002) for the creation of an additive composite index called the "ecological knowledge index." First, we had to transform the ordinal survey item related to the identification of specific forest-related conditions posed to residents into a dichotomous variable that would allow for match analysis between their identification of prevalence and identifications made by the related district forest ranger. Survey participants were asked to identify the prevalence of seven forest-related conditions on a four-point Likert scale. The dichotomous variable classified responses of "none" or "minimal" as an identification of nonprevalence, whereas responses of "moderate" and "severe" were classified as an identification of prevalence. Any response of "don't know" was left as is. Nonresponse to items in otherwise completed surveys were recoded as "don't know." Next, the aforementioned

[S] Supplementary data are available with this article at http://dx.doi.org/10.5849/jof.14-026.

Table 2. Spearman correlation output: ecological knowledge and education levels associated with understanding and appropriateness of fire management strategies.

Variables	Ecological knowledge	How satisfied were you with management of the fire?	To what extent do you feel you understood the strategy that was taken for managing the fire?	To what extent do you feel this strategy was appropriate for managing the fire?	What is the highest level of formal education you have received?
Ecological knowledge index					
Correlation coefficient	1.000	0.095*	0.129†	−0.109†	0.223†
Significance (two-tailed)		0.043	0.006	0.016	0.000
No.	493	452	444	484	471
What is the highest level of formal education you have received?					
Correlation coefficient	0.223†	−0.001	−0.008	0.019	1.000
Significance (two-tailed)	0.000	0.977	0.858	0.650	
No.	471	554	548	592	628

* $P \leq 0.05$.
† $P \leq 0.01$.

transformed variable served as the input for match analysis that compared the transformed dichotomous variable of prevalence and the conditions identified as being prevalent by each district forest ranger. The output match variable was computed, utilizing an if/then comparison function where a match was assigned a value of 1 and a nonmatch was assigned a value of 0. Responses of "don't know" or missing data were also assigned a value of 0 designating an incorrect identification due to a lack of assessment. Once the match variable was created for each forest-related condition, the results were added together to create the "accuracy of LEK" variable. This index had a maximum value of seven, representing a correct identification of all conditions.

Correlation analysis was conducted to identify possible relationships between the accurate identification of local ecological conditions and self-reported measures of fire management strategy satisfaction, fire management strategy understanding, fire management strategy appropriateness, and formal education level. Linear regression analysis was conducted to understand the influence of the accuracy of LEK variable and formal education level on perceived fire management satisfaction, understanding, and appropriateness.

To understand the relationship between accurate identification of local ecological conditions, education level and accuracy in identifying specific fire management strategies used on local wildfires, a strategy match variable was created. The related survey item that asked respondents to identify the specific strategy used for their fire served as the initial input. Respondent identification of a fire management strategy was compared with the actual strategy used and identified in the ICS-209 report to create a dichotomous strategy match variable. The computation of this variable used the same if/then comparative approach used in the creation of the eco-match variable. Binomial logistic regression analysis was used with the accuracy of the LEK variable serving as the independent variable and the strategy match variable as the dependent variable to understand the odds ratio between the two measures. A χ^2 test was conducted between educational level and the strategy match variable to understand whether there was a difference in the identification of fire management strategies based on formal education.

Finally, to understand the role that LEK played as a mediating factor between formal education and fire management identification, a dichotomous ecological knowledge variable was created (eco-knowledge $\geq$4) based on the accuracy of LEK variable. We identified the median value of the accuracy of LEK variable to be 4. The dichotomous variable (eco-knowledge $\geq$4) was created as a conservative delineation of high proficiency (accuracy of LEK $\geq$4) and low proficiency (accuracy of LEK $<$4). A χ^2 test was conducted between the aforementioned dichotomous variable and the self-reported formal education survey item to gain insight into potential differences associated with educational level.

Results

Most survey respondents felt "very satisfied" (57%; $n = 258$) with fire management decisionmaking, believed they "somewhat understood" (55%; $n = 244$) the strategy used and felt the strategy was "very appropriate" (55%; $n = 266$) to manage the fire. Nearly 86% ($n = 352$) of the residents identified ecological needs as "somewhat" or "very important" in the appropriateness of fire management strategies with almost 54% ($n = 219$) stating it was "very important." Survey participants viewed ecological needs as an important factor in their perception of appropriateness of fire management decisions. Direct suppression was used to manage each fire with 50.4% ($n = 240$) of respondents making a correct identification of the strategy used. The remaining respondents either identified incorrect strategies (26.7%; $n = 127$) or designated that they did not know the fire management strategy (22.9%; $n = 109$).

A Spearman ρ nonparametric correlation (Table 2) indicated that the accuracy of the LEK variable was weakly but positively related to the respondent's perceived understanding of fire management strategies, $r_s(444) = 0.129$, $P < 0.01$. The accuracy of the LEK variable also exhibited a weak, positive relationship with respondent satisfaction of how the fire was managed, $r_s(452) = 0.095$, $P < 0.05$. The accuracy of the LEK variable was weakly negatively associated with the perceived appropriateness of the fire management strategy, $r_s(484) = -0.109$, $P < 0.05$. Ecological knowledge accuracy was weakly positively associated with education level, $r_s(471) = 0.223$, $P < 0.001$. In addition, a χ^2 test indicated that the percentage of participants who identified the correct management strategy for their fire did not differ based on education level, $\chi^2(4, N = 471) = 0.68$, $P > 0.05$.

Table 3. Logistic regression output predicting relationship between ecological knowledge and fire management understanding* across three fires.

Predictor	*B*	Wald x^2	*P*	exp(*B*)
Ecological knowledge index	0.198	12.385	<0.001	1.219
Tecelote		15.527		
Shultz	−0.988	9.125	0.003	0.372
Bull	0.249	0.069	0.793	1.068
Constant	−0.493	5.894	0.015	0.611

$a = B$ (constant); $b = B$ (ecological knowledge index, Tecelote, Shultz, Bull); x = ecological knowledge index.
* Dependent variable: strategy match.

Table 4. Frequencies of accuracy of LEK variable and the probability of correct fire management identification.

Accuracy of LEK variable	Frequency	Probability of correct fire management identification
	(%)	
0.00	17.6	38
1.00	10.8	43
2.00	14.4	48
3.00	9.5	53
4.00	27.4	57
5.00	14.6	62
6.00	4.9	67
7.00	0.8	71

Table 5. χ^2 output: percentage of respondents who exhibited high and low proficiencies in identifying the prevalence of LEK based on education level.

Accuracy of LEK variable ≥4	Education level				
	Some HS/HS diploma/GED	Some college	Bachelor's degree	Some graduate school	Graduate degree
	(%)				
Low proficiency	72	60	43	46	41
High proficiency	28	40	57	54	59

Low proficiency: ≤3 conditions correctly identified; high proficiency: ≥4 conditions correctly identified. HS, high school.

Communities affected by the Tecolote, Shultz, and Bull Fires were evaluated to understand how residents' ecological knowledge compared with the identification of forest-related conditions made by each USDA Forest Service District Ranger. A logistic regression analysis was conducted, with the model $e^a + bx$, to predict fire management understanding using the accuracy of the LEK variable across all fires as well as for each fire (Table 3).

A test of the full model against a constant-only model was statistically significant, indicating that the accuracy of the LEK variable served as a predictor for higher proficiencies in fire management strategy identification ($\chi^2 = 31.696$, $P < 0.001$ with $df = 3$). Nagelkerke's R^2 of 0.083 indicated a weak, positive relationship and the Wald criterion demonstrated that ecological knowledge was significantly associated with understanding of fire management strategies ($P < 0.001$).

As shown in Table 4, the more ecological conditions a respondent could accurately identify, the higher the probability of the respondent also correctly identifying the specific fire management strategy used. This relationship identified a continuum on which a respondent who was not able to correctly identify any of the ecological conditions had a 38% probability of identifying the correct fire management strategy, whereas residents who were able to correctly identify the prevalence of all seven conditions had a probability of 71% of identifying the correct fire management strategy.

A χ^2 test revealed a relationship between education level and LEK. The percentage of respondents who exhibited higher proficiency in correctly identifying the prevalence of forest-related conditions differed based on education level, $\chi^2(4, n = 471) = 0.204$, $P < 0.001$.

As Table 5 demonstrates, respondents who have attained a collegiate degree were more likely to correctly identify four or more ecological conditions than respondents whose educational experience ranged from some high school experience to some college experience.

Discussion and Implications

For residents to better understand the issues facing wildland fire management, collaborative efforts should focus on improving understanding about prevalent ecological conditions that may affect fire management decisionmaking. Evidence from the Tecolote, Shultz, and Bull Fires demonstrated that respondent accuracy in identifying local ecological conditions was associated with an increase in odds of making a correct identification of the specific strategy used. Respondents who were able to make accurate identifications of seven forest-related conditions had a 71% probability of identifying the appropriate fire management strategy, whereas respondents who were unable to make any correct identification had a probability of 38%.

LEK may also affect resident acceptance of fire management strategies. Our data identified a significant, yet weak, positive relationship between the accuracy in the LEK variable and respondent satisfaction of how the fire was managed. A significant negative relationship was found to be related to the accuracy of the LEK variable and perceived appropriateness of the strategy used. Our findings support those of Cohn et al. (2008) that people who have greater LEK may be more informed and more critical stakeholders in the process.

Formal education level does not play a statistically significant role in public perception or understanding of fire management but is associated with LEK. Individuals who completed higher levels of formal education did not rate fire management differently or have a better understanding of the specific strategies used. Education level *did* serve as a significant predictor for LEK. Those residents who had the opportunity of participating in collegiate studies had a higher proficiency in identifying forest-related conditions. The results of our study indicated that formal education may play a *mediating* role in the understanding of complex environmental issues such as fire management and climate change but did not demonstrate

a direct association between ecological conditions and accuracy in identifying fire management decisions. These results support previous research suggesting that education level serves as a predictor for the acceptance of flexible fire management strategies with the assumption being that increased understanding of fire ecology and fuels accumulation is associated with increased education (Absher and Vaske 2006).

Ultimately, there does seem to be a relationship between LEK and proficiency in fire management strategy identification, but education level does not seem to have the same direct, statistically significant relationship. This raises interesting questions about the factors that drive understanding and acceptance of fire management. Education level seems to be weakly tied to LEK, which in turn is weakly associated with fire management acceptance and understanding. Significant variations in these relationships remain unexplained.

There is more room for investigating these questions from a research perspective focusing on the source of ecological knowledge. One direction forward may be to better understand community engagement and group membership and its mediating role between education and ecological knowledge, as suggested in the qualitative literature on the topic (McCaffrey 2008, Gordon et al. 2010). Historically, traditional ecological knowledge is defined as a cumulative body of knowledge, practice, and belief passed down over time (Berkes et al. 2000). Although this study did not focus on the aforementioned nexus, it is apparent that there are complex relationships at play. It is important to gain insight into the factors that contribute to information source choice as well as the differences that affect understanding of fire management strategies.

Discussion of Limitations

When the results of this study are interpreted, there are a few limitations to consider. First, the lack of empirical research regarding respondent accuracy in the identification of local ecological conditions does not allow for the transfer of lessons learned or prevalidated measures that may inform this study. The body of related literature for this study has been predominantly focused on a relationship between LEK and fire management perception and understanding predicated on respondent self-reported measures. To overcome potential threats to validity, we used a methodology outlined by Booysen (2002) that provided a framework for the construction of a composite additive index that was compatible with this study. Because this study used methods that have not been directly applied to this construct, the outcomes of this study should be viewed as an initial attempt to understand a potential relationship between accuracy in identifying local ecological conditions and fire management perception and understanding.

Second, there was a relatively low response among the three communities of interest even though Dillman's (2007) total design method was used. Based on recent trends, this outcome seems to align with a noticeable decline in the response rate for mail surveys across the board (Dillman et al. 2014). This limitation could not be overcome using telephone, online, or in-person sampling methods because we were interested in attaining a large sample of a very select population that could not be strategically sampled through other methods in an economically feasible manner. We obtained an adequate sample to provide the necessary statistical power to test the hypothesized associations and our data demonstrated good variability across both independent and dependent variables which increases our confidence in the robustness of our analysis.

Finally, the ecological conditions questions that were the basis of the accuracy of LEK were not posed to nonresponse survey participants. We believed that including the related questions would elongate the survey and produce answers that lack thought and quality as cited by best management practices for handling nonresponse (Dillman 2007). We took the approach of understanding the demographic differences among the nonrespondents and exploring the potential influence on accuracy of LEK as well as respondent accuracy in identifying the specific strategy used on the fire that affected their community. Statistical analysis did not identify a significant difference or association between the variables. Even though we believe that nonresponse does not present a threat to validity to our results, there is the potential that our findings underrepresent urban female residents. Future researchers should explore the feasibility of including such questions in a nonresponse survey looking at the quality of responses and respondent feedback related to inclusion of the items.

Conclusion

Policymakers, natural resource managers, and scientists have identified a relationship between declining forest health across the national landscape and the increasing risk of catastrophic wildfire, which threatens both landscapes and communities (Arno and Allison-Bunnell 2002, The National Wildfire Coordinating Group Executive Board 2011, Mason et al. 2012). For nearly a decade, national policies have encouraged federal, state, and local agencies responsible for wildland fire management to work collaboratively with communities to mitigate their fire risk (Williams et al. 2012). Research offers evidence that better understanding of natural resource management issues can shape public perception of and support for various wildfire management strategies (Cheng and Daniels 2003, Martin et al. 2007, McCaffrey 2008). Multiple studies have also identified formal education as providing a foundation for understanding local environmental issues (Cheng and Daniels 2003, Depoe et al. 2004, Gordon et al. 2010).

Local understanding of the fire management strategy and perceptions of the appropriateness of the strategy may be important preconditions for accepting the fire management strategy. We need to better understand what is driving the public's understanding of fire management strategies and how they are perceived. We believe that flexible fire management means the ability to implement multiple strategies dependent on factors such as fire risk, fire behavior, and ecological conditions. Fostering a shared understanding between managers and local communities will continue to be important as fire management agencies want to implement more flexible fire management strategies in the face of more complex fires in the WUI.

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