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Understanding Gaps Between the Risk Perceptions of Wildland–Urban Interface (WUI) Residents and Wildfire Professionals

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Research across a variety of risk domains finds that the risk perceptions of professionals and the public differ. Such risk perception gaps occur if professionals and the public understand individual risk factors differently or if they aggregate risk factors into overall risk differently. The nature of such divergences, whether based on objective inaccuracies or on differing perspectives, is important to understand. However, evidence of risk perception gaps typically pertains to general, overall risk levels; evidence of and details about mismatches between the specific level of risk faced by individuals and their perceptions of that risk is less available. We examine these issues with a paired data set of professional and resident assessments of parcel-level wildfire risk for private property in a wildland–urban interface community located in western Colorado, United States. We find evidence of a gap between the parcel-level risk assessments of a wildfire professional and numerous measures of residents' risk assessments. Overall risk ratings diverge for the majority of properties, as do judgments about many specific property attributes and about the relative contribution of these attributes to a property's overall level of risk. However, overall risk gaps are not well explained by many factors commonly found to relate to risk perceptions. Understanding the nature of these risk perception gaps can facilitate improved communication by wildfire professionals about how risks can be mitigated on private lands. These results also speak to the general nature of individual-level risk perception.

KEY WORDS: Risk assessment; risk gap; risk perception; wildfire; wildland–urban interface

1. INTRODUCTION

Researchers and risk managers have long recognized that the risk perceptions of the general public and relevant experts are often not well aligned.[1–3] This is not only because of the complexity of hazards and the challenges of thinking about probability[4,5] but also because the public "may simply emphasize different factors in their assessment of risk."[6, p. 40] For example, the risk posed by a natural hazard to private property can be understood as a function of individual attributes of that property, some of which can be affected by risk mitigation actions. Risk gaps will occur if professionals and the public assess the individual risk factors differently or if they aggregate individual risk factors into overall risk differently.

Although some research does not support the assertion that experts and the public judge risk probabilities differently,[7] most analyses find that while

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the risk perceptions of professionals and the lay public are correlated, they differ in many ways, including how risk is defined.[8–11] Different viewpoints can all have their own merits and truths,[9,12,13] but understanding what underlies divergences between the risk perceptions of professionals and the public can shed light on useful information. In the case of hazards to private property, for example, some risk perception gaps may relate to differing perspectives regarding which property characteristics matter for hazards exposure, whereas other gaps may be based on objective inaccuracies, such as incorrect judgment of distances.[5] Although much effort has gone into characterizing and understanding risk perceptions in general, less attention has been directed toward understanding the specific character of divergences between the risk perceptions of professionals and the public.

This article examines these issues in the context of wildfire risk for private property in the wildland–urban interface (WUI). We capitalize on a paired data set that combines data from a resident survey and a parcel-level professional assessment. Both the survey and the assessment include parallel measures of numerous wildfire-relevant property attributes, such as the amount of defensible space and the type of background fuels, in addition to ratings of overall wildfire risk. We investigate whether overall ratings diverge between residents and a wildfire professional, whether observed differences pertain to judgments about property attributes or to how they are aggregated into overall risk measures, and whether observed differences can be systematically explained by other observable factors. Potential explanatory factors considered are those often found to relate to public risk perceptions, such as information sources, social interactions, experience with wildfire, and individual or property characteristics. The subjective risk perceptions of the residents are considered against a baseline of the wildfire professional's risk assessments. Admittedly, the latter are not free of subjectivity. However, in these data, the professional assesses risk based on specific, observable criteria related to the chance a home could survive a wildfire with or without fire suppression, as established by wildfire science.

[5]This is not to imply that either professional assessments or those made by the public are generally "objective." Rather, the term "objective" here specifically refers to differences in the reporting of measureable distances.

Our analyses indicate that gaps exist between the parcel-level risk perceptions of the wildfire professional and property residents for many ways of measuring resident risk perceptions. Overall risk ratings diverge for most properties, as do judgments about many specific property attributes. Some differences come from residents misunderstanding objective characteristics (e.g., distance measures), others appear to relate to differences in perspective (e.g., whether a sign is reflective), and still others relate to differences in the relative contribution of attributes to a property's overall risk level. Understanding the nature of these risk perception gaps can facilitate improved communication by wildfire professionals about how to mitigate risks on private lands. However, we did not find that overall risk gaps are well explained by many factors commonly found to relate to risk perceptions, demonstrating their complexity.

In the next section, we review relevant literature on wildfire risk perceptions. We then introduce our case study of the Log Hill Mesa community in western Colorado and the data sources and methods. The following section presents results pertaining to our three testable hypotheses, and the final section concludes with a discussion of this study's findings and its broader relevance for encouraging wildfire risk mitigation and for understanding the public's perceptions of risk.

2. BACKGROUND: NATURAL HAZARDS RISKS AND RISK PERCEPTIONS

Risk can be defined as the product of *probability*, the unconditional likelihood of a hazardous event occurring, and *consequence*, the magnitude of impacts conditional on such an event occurring.[14,15] Accordingly, wildfire risk for residential property is a combination of the chance of a wildfire starting on, or spreading to, that property and the damage wildfire would cause on that property. The probability of wildfire is substantial and growing for many communities throughout the western United States, where wildfire severity, size, and frequency have been increasing[16–18] and will likely continue to increase.[17,19] As the WUI continues to grow,[20,21] more homes and residents will be exposed to this hazard. The Home Ignition Zone concept[22] has facilitated the development of a set of specific, measurable actions that WUI residents can take to reduce the consequences of wildfire on their properties. Analysis has shown that reducing fuels and combustibility in the Home Ignition Zone, and increasing firefighter

access, can reduce the consequences of wildfire to individual properties.[23–26]

Although residents can implement numerous measures to mitigate wildfire risks on their properties, much research has focused on the observation that residents often do not implement risk reduction measures to the level expected or desired by wildfire professionals. Residents' risk perceptions are often found to be fairly high,[6,27] but the concept of "risk perception" has been operationalized in many different ways, including some researchers treating "concern" as analogous to risk perception.[28–30] Many studies have linked homeowner willingness to undertake wildfire risk mitigation to higher perceptions of wildfire risk.[6,29,31–40] Risk perceptions have been found to be positively associated with a willingness to participate in a hypothetical market for wildfire risk reduction[41] and in a cost-shared wildfire risk mitigation program for private property.[42] However, relationships between risk perceptions and mitigating wildfire risks are complex and influenced by many other factors.[43,44] In general, research has found perceiving wildfire risk to be a necessary, but insufficient, condition for residents to decide to implement wildfire risk mitigation behaviors.[27] This result is consistent with more general findings of natural hazards research: risk perceptions often only weakly predict risk mitigation behavior.[45–47]

Perhaps confounding this complexity is the fact that although by definition WUI properties face an elevated probability of wildfire versus other homes, the risks faced by individual properties vary widely with individual property attributes. This pertains both within and across different study populations. Many studies have noted that research populations were selected in part because of high risk levels, as rated by the researchers and/or wildfire professionals. Some even have included property-level assessments for that selection; for example, Ryan[48] categorized surveyed homes by risk level "based on site conditions such as prevailing winds and proximity to dense forests," although this information was not incorporated into published analysis beyond noting that 28% of survey respondents' homes had "higher" risks. However, most studies that investigate WUI residents' wildfire risk perceptions have not accounted for within-sample variation in risks.

Some studies have examined whether observable variables related to the probability of wildfire help explain residents' risk perceptions, with varying results. Based on a literature review, Kumagai *et al.*[49] proposed that people will be "unduly optimistic" about the probability of hazards where they live. However, Brenkert-Smith *et al.*[50] found higher perceived consequences of wildfire among respondents with properties rated as having high/extreme fire risk, based on fuel levels in land cover data, as well as higher perceived probability and consequences of wildfire among respondents who perceived neighbors' vegetation as more dense. Similarly, Blanchard and Ryan[51] positively associated homeowner wildland fire risk perceptions with whether a home was in a heavily vegetated area or not, and Carroll *et al.*[52] found forest landowners in drier regions to have greater awareness of the threat of wildfire. McCaffrey[11] observed that focus group participants rated their area's wildfire risk lower if they lived within the WUI rather than near it, but this pattern was reversed when rating their own houses' wildfire risks. In contrast, Schulte and Miller[53] suggested that survey respondents in a Colorado WUI community were unaware of the role of physical conditions in determining wildfire risk because they found no relationship between residents' risk perceptions and property-specific wildfire hazard, as measured by slope, vegetation, and aspect. Fischer *et al.*[30] modeled a positive, significant relationship between crown fire potential and nonindustrial private forest owners' level of concern about wildfire. In other contexts, researchers have found weak but positive relationships between resident risk perceptions and locations identified by experts as facing higher probabilities of flooding,[54,55] high hurricane winds,[56] and climate change impacts.[57]

In addition, the hazards approach to wildfire risk emphasizes that homeowners can mitigate their risks because wildfire risk is a function not only of the probability of wildfire on the property (as determined by the types of variables assessed in the studies mentioned above) but also the consequences of a wildfire (as determined in part by mitigation actions on the property). However, few studies have accounted for heterogeneity in both the probability and consequences of wildfire on individual properties by comparing property-specific assessments with resident perceptions of both measures. Winter and Fried[41] developed resident perceived and professionally assessed measures of the regional probability of wildfire based on land cover and historical fire ignition data and the conditional probability of a home being destroyed in the event of a wildfire based on three specific risk mitigation behaviors, but they assigned a uniform wildfire probability for the entire region. They reported a mean perceived

probability (0.41) that exceeded the assessed value (0.15), and although mean consequence ratings were nearly equal for respondents (0.54) and the professional assessments (0.55), the two ratings were only moderately correlated ($r = 0.35$), suggesting substantial, unaligned heterogeneity. Collins[58] assessed home ignitability and property landscape hazard for surveyed properties in northern Arizona. Based on dichotomous categorization of these characteristics, he found that survey respondents with lower home ignitability or lower property landscape hazard had lower mean perceptions of the wildfire hazard to their home structure than those with higher levels of either. Similarly, Collins[59,60] found positive but far from perfect correlations between perceived and assessed wildfire hazard ratings in Arizona and California WUI communities, with explicitly differentiated measures of consequence and likelihood.

Despite observing relatively weak correlations between perceived and assessed risk ratings, none of these studies offer further insight into how the two diverge or why. In contrast, numerous studies have investigated whether numerous other resident characteristics can explain risk perceptions, often finding mixed results. For example, wildfire risk perceptions are often found to correlate with personal experiences with wildfire, although either positively or negatively.[6,28,29,51,61–64] Risk perceptions have often, but not always, been associated with demographic characteristics such as age, income, education, and sex.[9,47,65] Previous research has found that risk perceptions correlate with receiving information from expert sources and from informal sources such as neighbor interactions,[50,66–69] whereas findings about the role of media information have been more mixed.[47,50,70,71] However, without simultaneously controlling for the heterogeneity in the probability and consequences to a property, it cannot be known whether such correlations relate to variation in residents' risk perceptions, per se, or to variation in the attributes related to the probability and consequences of wildfire on their properties.

3. METHODS

As demonstrated above, substantial research has assessed the public's risk perceptions and relationships of these with risk mitigation actions, whereas comparatively little research has systematically addressed whether, and if so, how and why, the risk perceptions of the public and of relevant professionals diverge for individual, property-level risks. This article does so by investigating three specific hypotheses, each of which is the alternative to a testable null hypothesis as described.

3.1. Hypotheses

> Hypothesis 1: Residents and a wildfire professional do not rate the wildfire risk to individual properties the same.

Resident risk perception can be measured many ways. First, we investigate the degree to which possible measures relate to each other. We then focus on a categorical risk perception measure constructed to focus on the specific attributes addressed by the wildfire professional's wildfire risk assessment. To assess whether a risk gap exists, we test the null hypothesis that the resident and professional assessments come from similar distributions.

> Hypothesis 2: These risk ratings differ in multiple ways, including: (i) at the level of risk-related attributes and (ii) in the way these attributes are aggregated into an overall rating.

Property-level wildfire risk perception is an aggregated concept combining assessment of property attributes and of the attributes' contribution to risk. We investigate potential differences in both. Specifically, we test the null hypotheses of (i) equivalence of professional and resident ratings for each of 10 property attributes associated with wildfire risk, and (ii) equivalence of residents' implicit weighting of these attributes when assessing overall wildfire risk to the weights used by the professional.

> Hypothesis 3: Differences between the risk ratings by residents and the professional are correlated with wildfire information sources, neighbor interactions, experience with wildfire, and demographics

Previous research suggests numerous potentially explanatory factors of a risk perception gap between the professional and residents, due to findings of correlations with risk perceptions. These factors include: wildfire information sources, neighbor interactions, experience with wildfire, and demographics. We investigate whether any of these factors correlate with observed risk perception gaps by testing null

hypotheses of statistical independence between measures of the factors and of the gaps.

3.2. Study Area and Data Sources

We investigate these hypotheses for properties in a WUI community in the Log Hill Mesa Fire Protection District (LHMFPD) of Ouray County, Colorado. This area experiences frequent wildfires, with an average of three reported wildfires each year between 1989 and 2010.[72] According to the U.S. Census Bureau,[6] residents in this community tend to be highly educated, wealthier, and older than general U.S. or Colorado populations; approximately half of residents are retired. Ouray County Assessor data show approximately 600 residences in this community, with an average finished area of 2,870 square feet and a median lot size of 5 acres. Some lots in the community are as large as 160 acres.

In 2012, the West Region Wildfire Council (WRWC) collaborated with numerous agencies, including relevant fire departments, the Colorado State Forest Service, and the Bureau of Land Management—Southwest District Fire Management, to develop a community-level Community Wildfire Protection Plan (CWPP) for LHMFPD.[72] As part of the CWPP process, a wildfire professional assessed the wildfire risk on private properties through a combination of onsite visits, information on the Ouray County Assessor's website, and aerial photography.[7] The wildfire professional assessed the 10 attributes described in Table I related to a structure's wildfire survivability, firefighter access, and evacuation potential. This assessment is grounded in the Home Ignition Zone concept[22] and is related to assessments with the Colorado Springs Fire Department, the Wildfire Hazard Information Extraction Model, and Boulder County's Wildfire Hazard Identification and Mitigation System. These professional assessments unite the leading edge of wildfire science with the actual calculus used by firefighting professionals for prioritizing which homes to defend against a wildfire, considering firefighter safety as well as the chances of successful fire suppression and property protection. To limit the influence of professional judgment and improve generalizability of the assessment to data collection by other professionals or to other locations, these 10 attributes (described in Table I) focus on directly observable and measurable property conditions. Rather than subjectively assess overall risk through expert judgment, the professional assigned properties an overall wildfire risk rating category (*assessmentRiskCategory*) based exclusively on the weighted sum of these 10 attributes.

After developing and refining a survey instrument, the WRWC implemented a mail survey of all LHMFPD residential properties with a structure of at least 800 square feet: the same population as the wildfire risk assessments. The 14-page household survey elicited information on respondents' perception of, and attitudes toward, wildfire risks on their property, as well as on numerous related topics such as housing situation, social interactions, information sources, experiences with wildfire, and demographic characteristics. Respondents also answered 12 questions about the 10 property attributes listed in Table I, with responses corresponding to the values assigned to each attribute.[8] Survey participation was encouraged in a letter signed by the local fire chief and up to two follow-up mailings.

Of 608 surveys mailed in June 2014, 140 were undeliverable and 291 were returned completed by February 2013, for a total response rate of 62%. Respondent demographic statistics match U.S. Census data for Log Hill Village,[9] namely, 68% report completing college, the median reported income was between $75,000 and $99,999, and the mean respondent age was 62.

Because the professional assessment data are independent of the household survey data, we can analyze whether assessed risk levels differ between properties of survey respondents and properties of those who did not respond. As reported elsewhere,[73] the distribution of the professional's risk ratings did not statistically differ between properties with and without survey responses. In other words, we are not concerned about nonresponse bias with respect to parcel-level wildfire risk ratings, suggesting that

[6]Based on data for Loghill Village Census Designated Place (CDP): a subset of the LHMFPD with 345 housing units in 2010.

[7]When a characteristic was not directly observable through this combination of sources, the highest risk rating was assumed for that category. This is primarily relevant on certain properties for two of the 10 attributes: the presence of a (wooden) deck and other combustibles being near the structure.

[8]Twelve questions correspond to 10 attributes because *addressVisibility* and *deckType* were described by two questions each, corresponding to the dual dimensions of the ratings. For example, *addressVisibility* is based on a combination of "Is your house number posted at the end of your driveway?" and "Is the posted number reflective?" See the complete survey text[73] for further details.

[9]Based on data for Loghill Village Census Designated Place (CDP): a subset of the LHMFPD with 345 housing units in 2010.

Table I. Resident Survey and Professional Assessment Ratings of Individual Property Attributes Associated with Wildfire Risk

Variable[a]	Description	Values[b]	Points	Survey[a]	Assessment[a]	p[c]
addressVisibility	House number posted at driveway entrance	Present and reflective	0	29%	4%	0.000
		Present, not reflective	5	62%	87%	
		Not visible	15	9%	10%	
numberOfRoads	Number of roads that could be used to get out of community	Two or more	0	68%	62%	0.127
		One	10	32%	38%	
drivewayWidth	Width of driveway at narrowest point	>24′ (more than two cars wide)	0	4%	72%	0.000
		20′–24′ (two cars wide)	5	23%	23%	
		<20′ (one car wide)	10	73%	4%	
topographyDistance	Distance to dangerous topography (ridge, steep drainage, or narrow canyon)	>150′	0	83%	85%	0.364
		50′–150′	30	10%	5%	
		<50′	75	8%	9%	
vegetationType	Dominant vegetation type on property and immediately surrounding properties	Light (grasses)	25	2%	16%	0.000
		Moderate (light brush and/or isolated trees)	50	47%	56%	
		Heavy (dense brush and/or dense trees)	75	51%	28%	
roofType	Roofing material	Tile, metal, or asphalt shingles	0	98%	98%	0.706
		Wood (shake shingles)	200	2%	2%	
sidingType	Exterior siding covering majority of residence	Noncombustible (stucco, cement, brick, stone)	0	50%	35%	0.000
		Log or heavy timbers	20	10%	9%	
		Wood or vinyl siding	60	40%	55%	
deckType	Balcony, deck, or porch	None/noncombustible	0	17%	2%	0.000
		Combustible (wood)	20	83%	98%	
vegetationDistance	Closest distance from house to overgrown, dense, or unmaintained vegetation	>150′	0	12%	10%	0.001
		30′–150′	50	46%	29%	
		10′–30′	75	34%	51%	
		<10′	100	8%	11%	
combustiblesDistance	Closest distance from house to combustibles other than vegetation (e.g., lumber, firewood, propane tank, hay bales)	>30′	0	59%	6%	0.000
		10′–30′	10	31%	5%	
		<10′	30	11%	89%	

[a]Variable names appended by "*Survey*" when referring to resident survey results and "*Assessment*" when referring to professional assessment results.
[b]Wording reflects that presented in resident survey.
[c]p values refer to Wilcoxon matched-pairs signed-rank test of different distributions.

survey results are representative of the risk levels in the community.

More details of both data-collection efforts, including a copy of the entire text of the survey, are provided in previously published, publicly available sources.[72,73] The analysis below focuses on properties for which matched survey and assessment data are available.

3.3. Measures of Risk and Risk Perception

The survey data allow for nine different measures of residents' wildfire risk perceptions. Descriptions of these nine measures are shown in Table II. Six of these correspond to questions asked on the survey that pertain to overall wildfire risk (*surveyRiskRating*, *isPropertyAtRisk*), concern about wildfire (*concerned*), the likelihood of wildfire on the property (*fireProbability*), or the likelihood of property damage due to wildfire (*fireConsequence*, *loseHomeLikely*). Although all might be considered measures of wildfire risk, the last two categories correspond separately to the probability (*fireProbability*) and the consequences (*fireConsequence*, *loseHomeLikely*) of wildfire. The remaining three wildfire risk perception measures (*jointProbability*, *surveyRiskSum*, *surveyRiskCategory*) are constructed from responses to other questions.

Table II. Potential Measures of Parcel-Level Wildfire Risk Perception, with Descriptive Statistics from Survey Results

Variable	Description	Responses	*N*	Mean	*SD*	Median
surveyRiskRating	"Homes are assessed for overall wildfire risk based on the items asked about in questions 3.1–3.10 above. What do you think is your home's current overall wildfire risk rating?"	Low/Moderate/High/Very High/Extreme	256	n/a	n/a	Mod.
isPropertyAtRisk	"Your property is at risk of wildfire."	1: Strongly Disagree to 5: Strongly Agree	252	n/a	n/a	4
fireProbability	"What do you think is the chance that a wildfire will start on or spread to your property this year?"	0–1; increments of 0.1	251	0.33	0.20	0.3
fireConsequence	"If a wildfire starts on or spreads to your property this year, what do you think is the chance that your home will be destroyed or severely damaged?"	0–1; increments of 0.1	253	0.47	0.27	0.5
jointProbability	The joint probability of a wildfire destroying or severely damaging one's home this year.	= *fireProbability* * *fireConsequence*	251	0.18	0.17	0.12
loseHomeLikely	"If there is a wildfire on your property, how likely do you think it is that … your home would be destroyed?"	1: Not likely to 5: Very likely	246	n/a	n/a	3
concerned	"Are you concerned about wildfire risk affecting your current residence?"	0: No or 1: Yes	255	0.93	0.25	1
surveyRiskSum	Weighted sum of resident's assessment of 10 property attributes related to wildfire risk.	25–595 points	256	197.03	65.55	195
surveyRiskCategory	Results of *surveyRiskSum* separated into categories following the professional's metric.	Low/Medium/High/Very High/Extreme	256	n/a	n/a	High
assessmentRiskCategory	Categorization of the weighted sum of property risk attributes as assessed by the professional.	Low/Medium/High/Very High/ Extreme	256	n/a	n/a	High

The variable *jointProbability* is the product of *fireProbability* and *fireConsequence*.

The specific wording of the question for *surveyRiskRating* guided respondents to consider the same property attributes as the professional when determining a property's overall risk rating. The question also offered five qualitative response categories (Low, Moderate, High, Very High, Extreme) that match the overall risk categories for the weighted sum of the 10 attributes from the professional assessment (*assessmentRiskCategory*). However, respondents were not informed of the specific point system that the professional used for aggregating these attributes into a weighted sum, nor how this weighted sum was placed into categories. In contrast, *surveyRiskSum* and *surveyRiskCategory* correspond to the application of this point system and its categorization, respectively, to respondents' answers about the 10 property attributes.

4. RESULTS

4.1. Overall Risk Perceptions

Table III presents pair-wise Spearman's rank correlation coefficients between the nine risk perception measures described in Table II. Although most of the measures correlate with each other significantly, the extent of correlation varies. For example, *fireProbability* and *fireConsequence* correlate strongly with each other, but they do not appear to correlate in similar ways with the other risk perception measures. The variables *surveyRiskRating*, *loseHomeLikely*, *surveyRiskCategory*, and

Table III. Spearman Rank Correlation Coefficients Between Residents' Responses for Risk Perception Measures Shown in Table II

	survey RiskRating	*isProperty AtRisk*	*fire Probability*	*fire Consequence*	*joint Probability*	*lose HomeLikely*	*concerned*	*survey RiskSum*	*assessment RiskCategory*
surveyRiskRating	1.00	–	–	–	–	–	–	–	0.26***
isPropertyAtRisk	0.43***	1.00	–	–	–	–	–	–	0.04
fireProbability	0.33***	0.29***	1.00	–	–	–	–	–	0.12
fireConsequence	0.52***	0.35***	0.39***	1.00	–	–	–	–	0.19**
jointProbability	0.51***	0.38***	0.85***	0.79***	1.00	–	–	–	0.17**
loseHomeLikely	0.61***	0.30***	0.24***	0.71***	0.53***	1.00	–	–	0.24***
concerned	0.17**	0.30***	0.09	0.11	0.13*	0.17**	1.00	–	-0.05
surveyRiskSum	0.38***	0.15*	0.12	0.24***	0.23***	0.35***	0.09	1.00	0.28***
surveyRiskCategory	0.38***	0.13*	0.10	0.23***	0.21***	0.31***	0.08	0.91***	0.28***

Notes: Missing observations deleted pairwise; *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

surveyRiskSum all correlate more strongly with consequences of wildfire (*fireConsequence*) than with probability of wildfire (*fireProbability*), which is consistent with the specific wording of the questions and also with respondents focusing more on the risks to their particular property than on a background level of risk. In contrast, *isPropertyAtRisk* correlates similarly with *fireProbability* and *fireConsequence*, suggesting equal weighting of probability and consequences in unprompted assessment of risk.

The variables *surveyRiskCategory* and *surveyRiskSum* are two alternatively coded versions of the same measure, so as expected they share similar correlations with most other measures. One measure, *concerned*, stands out for generally lower correlations than most other measures, including not statistically significant correlations with *fireProbability* or *fireConsequence* at a 5% level. As Table II shows, 93% of respondents answered "yes" when asked "Are you concerned about wildfire risk affecting your current residence?" The low levels of correlation of that response with most other measures suggest that a binary question about concern is not a particularly meaningful measure of risk perceptions here.

The final column of Table III shows correlation coefficients with the professional's categorical wildfire risk rating (*assessmentRiskCategory)*. All but *isPropertyAtRisk*, *fireProbability*, and *concerned* are significantly correlated with *assessmentRiskCategory* at a 5% or stronger level, demonstrating that most of the resident risk perception measures are at least related to the professional's measure. If we assume the professional assessment to measure parcel-level wildfire risk reasonably accurately, some measures (*surveyRiskRating*, *fireConsequence*, *jointProbability*, and *loseHomeLikely*) are superior measures of that risk than others (*isPropertyAtRisk*, *fireProbability*, *concerned*). However, with possible correlation coefficients ranging from 0 (no correlation) to 1 (perfect correlation), the low correlation values of all variables (0.17–0.28 for significant estimates) suggest substantial independence between the variation of each measure and that of *assessmentRiskCategory*. Thus, this final column of Table III presents evidence of an overall risk perception gap between the professional and residents.

More definitive evidence comes from Table IV, which depicts the percentage of properties in each *assessmentRiskCategory* in the top panel and the percentage of these that residents assigned to each *surveyRiskRating* response in the middle panel and to each *surveyRiskCategory* in the lower panel. The variable *assessmentRiskCategory* is shown vertically across all panels; horizontal categories refer to the two survey-based measures. Recall that *surveyRiskRating* asked respondents to consider the same attributes the professional considered when determining a property's risk rating; this measure explicitly addresses the same aspects of risk for both the professional and resident. The variable *surveyRiskCategory* is constructed from residents' responses to individual attributes and therefore measures an implicit risk perception using the same metric as the professional.

Despite this careful correspondence of measures, responses differ substantially. For each comparison, Wilcoxon matched-pairs signed-rank tests strongly reject the null hypothesis that responses follow the same distribution ($p < 0.001$ in both cases). Overall, 50% of respondents rated their property as Moderate Risk, whereas the professional rated 65% of properties as High Risk. The two ratings match for 29% of properties; 53% of respondents

Table IV. Distribution of Professional Categorical Ratings (Top Panel), and the Percentage of Properties in Each *assessmentRiskCategory* Assigned Each *surveyRiskRating* (Middle Panel) or *surveyRiskCategory* (Bottom Panel) in the Resident Surveys

	Professional's Categorical Rating (*assessmentRiskCategory*)					$n = 256$
Category	Low	Moderate	High	Very High	Extreme	Total
Number of points	25–150	151–175	176–270	271–330	331–595	
All properties	10%	12%	65%	9%	4%	100%
Responses to survey question (*surveyRiskRating*) by *assessmentRiskCategory*						
Low	36%	10%	8%	4%	9%	11%
Moderate	52%	55%	53%	39%	18%	50%
High	12%	32%	28%	48%	55%	30%
Very High	0%	3%	8%	9%	18%	7%
Extreme	0%	0%	3%	0%	0%	2%
Total	100%	100%	100%	100%	100%	100%
Weighted sums of survey attributes (*surveyRiskCategory*) by *assessmentRiskCategory*						
Low	40%	48%	19%	17%	9%	24%
Moderate	16%	16%	13%	13%	9%	14%
High	40%	29%	61%	39%	55%	53%
Very High	4%	6%	5%	22%	9%	7%
Extreme	0%	0%	1%	9%	18%	2%
Total	100%	100%	100%	100%	100%	100%

underrated their wildfire risk relative to the professional whereas 18% overrated it. These respondents are assigned binary indicator variables for *underRate* and *overRate*, respectively, for further analysis. Although *surveyRiskCategory* and *assessmentRiskCategory* appear more closely matched, a similar pattern persists in the lower panel, with the weighted sum of the residents' responses placing them in a lower category than the professional for 37% of responses, versus 15% being in a higher risk category and 48% being in similar categories. Overall, these results present evidence in favor of alternative Hypothesis 1 that a gap exists between the residents' and wildfire professional's wildfire risk perceptions, with many residents underestimating their risk relative to the professional's assessment.

4.2. Risk-Related Property Attributes

The risk gap described above relates to overall wildfire risk on a parcel. However, risk is an aggregated concept that combines assessment of physical property characteristics and of the contribution of these attributes to overall risk; better understanding can come from deconstructing resident and professional ratings further. Specifically, comparison of resident survey responses and professional assessment ratings for individual property attributes associated with wildfire risk, shown in Table I, demonstrates substantial differences for most rated attributes. Wilcoxon matched-pairs signed-rank tests, for which p values are shown in the final column of Table I, strongly reject the null hypotheses of survey and assessment ratings following the same distribution for seven of 10 attributes assessed ($p < 0.001$ for all seven). For five of these attributes (*addressVisibility*, *deckType*, *sidingType*, *vegetationDistance*, and *combustiblesDistance*), the resident survey tended to report a less risky level than the professional assessment. For two attributes (*vegetationType* and *drivewayWidth*), the opposite was true. Only three of the 10 attributes (*numberOfRoads*, *topographyDistance*, and *roofType*) were statistically indistinguishable between the survey and the assessment. These results demonstrate that the disconnect between residents' and the professional's wildfire risk perceptions relates to differences not only in perceiving overall risk but also in assessing many of the individual factors associated with wildfire risk.

4.3. Aggregation of Risk-Related Property Attributes into Overall Risk Perception

Table V investigates another major component of resident risk perceptions: how individual risk-related attributes are aggregated into an overall risk perception. This table presents the results of regressing each resident's chosen risk level category (*surveyRiskRating*) on the weighted sum of his or her chosen risk-related attribute levels

Table V. OLS Model Results (Dependent Variable = *surveyRiskRating*[a], $n = 256$)

	Coefficient	StdErr	$(b-1)$/StdErr	p[b]
addressVisibilitySurvey	1.16	0.98	0.17	0.868
numberOfRoadsSurvey	1.65	0.82	0.80	0.425
drivewayWidthSurvey	−0.29	1.22	−1.05	0.293
topographyDistanceSurvey	0.29	0.18	−3.94	0.000
vegetationTypeSurvey	1.70	0.21	3.28	0.001
roofTypeSurvey	0.08	0.14	−6.49	0.000
sidingTypeSurvey	0.09	0.13	−6.73	0.000
deckTypeSurvey	1.21	0.49	0.42	0.671
vegetationDistanceSurvey	0.70	0.15	−2.04	0.042
combustiblesDistanceSurvey	1.24	0.42	0.58	0.566

[a]Specified as the midpoint of the range of point values pertaining to each overall risk category.
[b]p value corresponds to Wald test of coefficient equaling 1 (contrast with typical p values, which are tested against equaling 0).

([attribute]*Survey*), where the weighting corresponds to the point values assigned by the professional to attribute levels (shown in the fourth column of Table I). That is:

$$surveyRiskQuestion_i = \sum_j (\beta_j * \gamma_j * [attribute]\, Survey_{i,j}) + \varepsilon_i, \quad (1)$$

where $surveyRiskQuestion_i$ is the midpoint of the point value range associated with the overall risk perception rating chosen by respondent i, γ_j is the weighting value for attribute j assigned by the professional, β_j is the coefficient on the weighted response to be estimated, and ε is an assumed i.i.d. error term.[10] The coefficient of interest, β_j, corresponds to resident i's implicit adjustment of the professional-assigned weights when answering the *surveyRiskRating* question. In other words, any β_j significantly different from 1 signifies that respondents assigned more or less weight to the corresponding attribute when determining the overall risk level than the professional would have; the coefficient corresponds to the proportional under- or overweighting of the attribute relative to the professional's scale.

As Table V shows, β_j differs from 1 at a 5% significance level for five attributes. The coefficients of four of these (*vegetationDistanceSurvey*, *sidingTypeSurvey*, *roofTypeSurvey*, and *topographyDistanceSurvey*) are estimated as substantially lower than 1, signifying that respondents considered these four attributes less important for the overall risk rating, on average, than the wildfire professional did. Specifically, residents considered *vegetationDistanceSurvey* to contribute about 70% of the points to overall risk that the professional's weighting system would have assigned. Even more strikingly, residents underweighted *roofTypeSurvey* and *sidingTypeSurvey* to less than 10% of the contribution that the professional would have assigned, although the coefficient on *roofTypeSurvey* is only identified by the five respondents with a nonzero *roofTypeSurvey* rating. Only the coefficient on *vegetationTypeSurvey* is significantly greater than 1, showing that residents overweight the impacts of background fuels on overall risk by an additional 70% versus the professional's assigned ratings. Thus, the predominant background type of fuel in the neighborhood is the only factor that residents systematically put more emphasis on when constructing their overall risk rating than the professional would have. Combined with the preceding section, these results provide evidence in favor of alternative Hypothesis 2 that risk ratings by residents and the professional differ both at the detailed level of assessing individual risk-related attributes and at the point of aggregating these different attributes into an overall rating.

[10]Although results are presented for an ordinary least squares (OLS) regression using the midpoint of each risk category for the sake of simplicity, coefficients and significance values are substantively the same as those estimated for the more properly specified interval regression (or "grouped data") model.

4.4. Determinants of the Risk Perception Gap

Our final set of analyses investigates whether the observed risk perception gap systematically relates to factors that have been found in other studies to relate to residents' risk perceptions. The resident survey collected information on numerous variables with a potential to explain the risk perception gap. Table VI shows descriptive statistics for these

Table VI. Descriptive Statistics for Individual-Level Variables with the Potential to Explain the Risk Perception Gap

Variable	Question or Description	Descriptive Statistics		
		N	Mean	*SD*
expertInfoSource	Have you received information about reducing the risk of wildfire from any of the following sources? (WRWC, local fire department, Colorado State Forest Service, U.S. Forest Service, Bureau of Land Management; 1 if yes, 0 if no)	256	0.80	0.40
mediaInfoSource	Have you received information about reducing the risk of wildfire from any of the following sources? (media, including newspaper, TV, radio, and Internet; 1 if yes, 0 if no)	256	0.37	0.48
closeFire	What is the closest distance (as a crow flies) a wildfire has come your current residence? (1 if within 2 miles or less, 0 otherwise)	256	0.28	0.45
knowEvacuated	Do you know anyone (in Colorado or elsewhere) who has been evacuated from his or her home due to a wildfire? (1 if yes, 0 if no)	254	0.30	0.46
talkFire	Have you ever talked about wildfire issues with a neighbor? (1 if yes, 0 if no)	256	0.57	0.50
neighborRisk	Do you have any neighbors who are not taking action to address what you would consider sources of wildfire risk in the event of a wildfire (e.g., dense vegetation) on their property? (1 if yes, 0 if no)	252	0.54	0.50
lotSize	Property size (from County Assessor data; reported in acres)	256	10.41	14.30
houseSize	Residential structure size (from County Assessor data; reported in 1,000 sq ft)	238	2.90	1.22
age	What is your age? (reported in years; centered at 0 for analysis)	237	62.32	10.98
landTenure	In what year did you move to your current residence? (reported as year of survey, 2012, minus response)	251	9.69	6.97
female	Are you? (0 if male, 1 if female)	235	0.36	0.48
college	What is the highest grade or year of school you completed? (1 if college graduate or beyond, 0 otherwise)	231	0.68	0.47
income	Which of the following categories describes your annual household income? (descriptive statistics omitted due to categorization; median bracket is $75,000–$99,999)	197	n/a	n/a

variables, which pertain to wildfire information sources (*expertInfoSource*, *mediaInfoSource*), experiences with wildfire (*closeFire*, *knowEvacuated*), social interactions (*talkFire*), perceived risk interdependency (*neighborRisk*), property characteristics (*lotSize* or *houseSize*), and demographic characteristics (*age*, *landTenure*, *female*, *college*, or *income*).

Table VII displays Spearman's rank correlation coefficients between these potential explanatory factors and measures of professional (*assessmentRiskCategory*) and resident (*surveyRiskRating*) wildfire risk ratings, indicator variables representing residents underestimating (*underRate*) or overestimating (*overRate*) their properties' overall risk level relative to the professional, and analogous measures relating only to the risk level associated with the amount of defensible space clearing of vegetation on the property (*vegetationDistanceAssessment*, *vegetationDistanceSurvey*, *underRateVegetationDistance*, and *overRateVegetationDistance*). In nearly all cases, correlations between potential explanatory variables and either risk ratings or gap measures are low, even when significant. Five of the 13 potential explanatory variables (*expertInfoSource*, *closeFire*, *talkFire*, *age*, and *landTenure*) correlate with one of the two overall risk gap measures (*underRate*, *overRate*) at a 5%

Table VII. Pair-Wise Spearman Rank Correlation Coefficients Between the Potential Explanatory Factors Shown in Table VI and Measures of Risk Ratings and Risk Perception Gaps

	assessment RiskCategory	*survey RiskRating*	*under Rate*	*over Rate*	*vegetation DistanceAssessment*	*vegetation DistanceSurvey*	*underRate VegetationDistance*	*overRate VegetationDistance*
expertInfoSource	0.06	−0.07	0.05	−0.17**	0.04	−0.08	0.05	−0.09
mediaInfoSource	0.00	0.01	−0.03	0.04	−0.03	0.05	−0.08	0.00
closeFire	0.08	−0.01	0.05	−0.13*	0.15*	−0.09	0.19**	−0.18**
knowEvacuated	0.01	0.12	−0.10	0.05	−0.04	−0.04	0.00	0.06
talkFire	0.05	−0.04	0.06	−0.13*	0.05	−0.15*	0.14*	−0.11
neighborRisk	−0.04	0.03	0.04	−0.01	−0.05	−0.03	0.01	0.00
lotSize	−0.04	−0.17**	0.09	0.04	−0.14*	−0.24***	0.10	−0.05
houseSize	−0.15*	−0.19**	0.08	−0.03	−0.15*	−0.26***	0.04	−0.08
age	0.04	−0.06	0.16*	−0.03	−0.03	−0.06	0.04	0.05
landTenure	0.06	−0.05	0.14*	−0.02	0.04	−0.06	0.01	−0.06
female	0.08	0.16*	0.01	0.07	0.07	0.14*	−0.04	−0.03
college	−0.04	−0.01	0.03	−0.07	0.01	0.07	−0.05	0.08
income	−0.08	−0.02	−0.01	0.02	0.00	0.03	−0.05	−0.06

Notes: Missing observations deleted pairwise; *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

or stronger level of significance; an additional three (*lotSize*, *houseSize*, and *female*) correlate with either *assessmentRiskCategory* or *surveyRiskRating* significantly. However, with no coefficients greater in magnitude than 0.19, none of the measured correlations are very strong. Multivariate analysis (not shown) corroborates these conclusions, and it suggests that the majority of the results shown in Table VII are not confounded by other variables that could be easily controlled for. This implies that residents' and the professional's overall risk ratings and the associated gap measures are not well explained by the large number of potential explanatory variables.

Correlation coefficients (Table VII) do suggest some meaningful patterns, however. Residents of larger properties (*lotSize*), residents with larger houses (*houseSize*), and males (*female* = 0) all tend to rate their overall risk (*surveyRiskRating*) lower than other residents, but this does not translate into an observable risk perception gap (*underRate* or *overRate*) for any of these variables. In contrast, neither residents' *age* nor *landTenure*, which are significantly correlated with each other, systematically relate to either the professional's or their own perceptions of property risk levels, yet both are positively correlated with underestimating overall wildfire risk (*underRate*). Interestingly, residents who report receiving information from numerous possible expert sources (*expertInfoSource*), know that fire has come within two miles of their property (*closeFire*), or have talked about fire with neighbors (*talkFire*) are less likely to overestimate their risk but are no more or less likely to underestimate risk.

For ratings of the risk from vegetation within a structure's defensible space, to which the final four columns of Table VII pertain, a similar story holds; only two of the potential explanatory variables correlate with the gap measures, and those only do so weakly. Reporting a wildfire within two miles (*closeFire*) and talking with neighbors about wildfire (*talkFire*) are both weakly, positively correlated with overestimating one's amount of defensible space compared to the professional's assessment (*underRateVegetationDistance*). For those reporting *closeFire*, this appears to come from the professional observing less defensible space (*vegetationDistanceAssessment*) while the residents' ratings (*vegetationDistanceSurvey*) do not differ statistically from those of other residents. In contrast, residents reporting *talkFire* tend to report more defensible space than other residents, yet the professional observes no difference in defensible space levels associated with *talkFire*. The professional and residents agree that larger properties (in terms of either *lotSize* or *houseSize*) tend to have more defensible space (i.e., lower *vegetationDistanceAssessment* and *vegetationDistanceAssessment* ratings) than other properties. Overall, the potential explanatory variables do not correlate strongly with either the resident or professional ratings of defensible space, nor with the associated gap measures.

Therefore, we fail to reject the null hypotheses of independence of most pairings of risk gap measures with variables representing wildfire information sources, neighbor interactions, experience with wildfire, and demographics. We find weak evidence

for rejecting that null in the case of a few variables. Some demographics (age and property tenure) appear to increase the likelihood of underestimating risk, and consultation of expert information sources, discussion of fire with neighbors, and experience with nearby fire appear to decrease the likelihood of overestimating risk. However, other demographics (including education, gender, and income), measures of social interactions, and other information sources (media) do not systematically relate to the presence or direction of a wildfire risk perception gap. Overall, the alternative Hypothesis 3, which anticipated that observed risk gaps will correlate with factors previously found related to residents' risk perceptions, is only supported for a small subset of the potentially explanatory variables investigated. Thus, differences in risk perceptions between residents and professionals, particularly when carefully measured based on the same specific considerations, are perhaps best characterized by complexity and heterogeneity across individual circumstances.

5. DISCUSSION AND CONCLUSION

Using a data set that pairs property-specific risk assessments completed by residents of Log Hill Mesa, Colorado with those by a wildfire professional, we find substantial evidence of a gap in wildfire risk perceptions. Comparison of responses to survey questions that pertain to different aspects of wildfire risk perceptions demonstrates that although different measures tend to be correlated, they vary independently and thus are not interchangeable measures of "risk perception" generically. For example, our binary measure of concern correlates only very weakly with most other measures, suggesting important differences between measures of concern and of risk perception, although some researchers use the terms synonymously. Most measures correlate more strongly with the conditional consequences of wildfire than with the unconditional probability of wildfire, suggesting that our respondents understand that individual risk levels relate to property-specific characteristics more than the baseline chances of wildfire reaching their property.

Despite these correlations, we observe substantial differences in risk perceptions of residents and the professional. Our results are consistent with standard results that the public tends to underweight overall risk relative to professionals. For example, more than half of respondents rated their property at lower risk than the professional did; the professional was more likely to rate a property as "high risk" than residents, who instead favored the "moderate risk" rating. More uniquely, we find that this gap extends to many individual property attributes related to wildfire risk, including the flammability of the home's exterior and deck, the distance to flammable vegetation and other combustibles, and the visibility of the property's address. However, differences in attribute ratings were nuanced, with the level of background fuels and width of driveway typically placed in more risky categories by residents than the professional.

These differences demonstrate that residents and the professional disagree on both subjective and objective aspects of risk even when considering seemingly straightforward, individual property attributes, but the direction of that disagreement is not consistent across measures. Assessing many of these attributes involves some level of judgment, and therefore subjectivity, such as what counts as "overgrown, dense, or unmaintained vegetation" or "dangerous topography." For such attributes, the professional can be expected to have a privileged perspective due to an advanced understanding of wildfire behavior and the vulnerabilities of a structure to wildfire, suggesting opportunities for education to improve residents' understanding of the details of factors that contribute to wildfire risks. For example, a resident might call a sign reflective if he used reflective paint on the sign, but a wildfire professional would only judge that sign as reflective if she expects it to be easily visible in heavy smoke conditions, which can be influenced by positioning, cleanliness, and obstructions. At the same time, differences in resident and professional risk assessments of more objective attributes such as the width of a driveway or the distance to combustible objects suggest that differences between residents and the professional's risk perceptions also stem—in part—from inaccuracies in judging distances.

In addition, our results suggest that residents and the professional differ in how they implicitly weight these attributes when assessing overall wildfire risk. These results demonstrate the complexity of the disconnect between residents' and the professional's wildfire risk perceptions, one grounded in perhaps differences in perspective and knowledge as well as expertise in relevant skills, such as judging distances. Corroborating the complexity story, many potentially explanatory variables do not help explain the presence or direction of the observed risk perception gap; exceptions include older residents and

those with longer property tenure being associated with a higher likelihood of underestimating a property's wildfire risk relative to the professional.

These results have many important implications for wildfire risk mitigation policy, programs, and research. First and foremost, they underscore the importance of careful articulation of what is meant by "risk." Wildfire risk refers to a combination of the unconditional probability of wildfire occurring and the conditional consequences of wildfire; we find that different ways of asking respondents about risk relate to these two aspects of risk differently. Relatedly, our results demonstrate that notions such as "people underestimate risk" are not as useful as "people underestimate this specific aspect of risk or how much this aspect impacts overall risk." Residents in this community view many specific property characteristics differently from how a professional does: taking the professional assessment as the baseline, residents overestimate the distances from their homes to dense or overgrown vegetation and to other combustible material. They also overestimate the visibility of their posted addresses. Residents tend to consider their driveways narrower, their vegetation generally denser, and their roofing and siding materials as more flame resistant than the professional does.

Residents in this community also place different emphases on the role of such characteristics in determining wildfire risk to the property. Specifically, we find that residents overweight the relative importance of background fuels, a wildfire risk factor largely outside their control, whereas they underweight the relative importance of numerous factors over which they do have control, including the amount of defensible space on their property, the structure's exterior material, and its roof type. This suggests that, despite substantial efforts by WRWC to provide guidance regarding actions that residents can take to affect wildfire risk levels on their properties, there remain opportunities to tailor education to focus on the specific aspects of wildfire risk mitigation that homeowners do not seem to fully understand.

This research, and its limitations, offers insight into needed further research. Our search for factors to help systematically explain the risk perception gap was limited to observable and collected variables; future work should investigate other potential explanatory factors, such as risk preferences. In addition, respondents were guided when assessing property risk to attend to the same factors as the professional did. This helped assure our observations of a risk gap were based on similar metrics but also might have led to conservative assessment of the extent to which risk perceptions diverge. Alternative approaches to measuring the gap could potentially find stronger systematic relationships with observable potential explanatory variables. More generally, next steps involve investigating the extent to which our substantive results generalize, both to other WUI communities and to other risk domains. Such further research will build on this article's contribution to improved understanding of the wildfire risk perceptions of residents in the WUI, with the promise of helping lower society's exposure to the hazards of wildfire.

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