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A Burning Concern: Family Forest Owner Wildfire Concerns Across Regions, Scales, and Owner Characteristics

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While there is a large literature on how individual homeowners perceive location-specific wildfire hazard, there is only one study specific to U.S. family forest owners. Using respondents from the United States Department of Agriculture (USDA) Forest Service's National Woodland Owner Survey of family forest ownerships in the United States, we investigate the relationship between landowners' wildfire concerns and biophysical wildfire hazard across the contiguous United States. As a measure of long-term conditions for high intensity wildfire, we use the USDA Forest Service's Wildfire Hazard Potential Index as our key variable of interest. We test six ways of aggregating Wildfire Hazard Potential using 1-, 10-, and 100-mile (1.6, 16, and 160 km) radii buffers with linear and logistic specifications for hazard potential. Results show the log of Wildfire Hazard Potential is the best fit for modeling wildfire hazard concerns. Respondents in the western United States have a higher baseline level of concern but are not necessarily more sensitive to the hazard spectrum compared to respondents in the north. Respondents in the southern United States have a lower sensitivity to the hazard spectrum compared to respondents in the north and west. Using predicted probabilities at the means, we also compute regional prevalence ratios to compare the impact of biophysical wildfire hazard to the relative impact of other important variables. Various property and owner characteristics not related to biophysical hazard potential, such as emotion, receiving information about wildfire, and the presence of a house on the property are determinants of wildfire concern in some, but not all regions of the United States.

KEY WORDS: Family forest owners; hazard perception; National Woodland Owner Survey; United States; wildfire

1. INTRODUCTION

Wildfires are an increasing problem and serious concern in many of the world's forested areas, and they are expected to further increase in their frequency, intensity, and negative impacts on surrounding human communities as a consequence of climate change (e.g., Liu et al., 2016; Lozano et al., 2017; Westerling, Hidalgo, Cayan, & Swetnam, 2006). Wildfires disrupt human life in and around the areas they burn, having negative economic and health impacts on communities directly affected by fire as well as those indirectly affected by resulting smoke (Fann et al., 2018; Richardson, Loomis, & Champ, 2013; Thom & Seidl, 2016). While wildfires can serve important ecological functions in various forest ecosystems (e.g., Benscoter, Greenacre, & Turetsky, 2015; Bergeron et al., 2017), high intensity and large-scale wildfires disrupt many of the important ecosystem services that forests provide to society (Thom & Seidl, 2016; Venn & Calkin, 2011). Despite the

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risks and costs, human development continues to expand into areas with fire prone conditions, even after destructive wildfires (Alexandre, Mockrin, Stewart, Hammer, & Radeloff, 2015). In the United States, the total area of transition between wildland and human development, the Wildland-Urban Interface, grew at a rate of 33% between 1990 and 2010, with the number of houses in previously burned areas increasing by more than 200% (Radeloff et al., 2018). With projections that people will continue moving into areas with high vulnerability to wildfires (Theobald & Romme, 2007), addressing wildfire hazard potential is an imperative for policymakers at all levels of government.

One difficult aspect of addressing wildfire hazard arises from the tendency of hazard potential, and wildfires themselves, to sprawl across boundaries of political administration as well as different types of landowners. Programs such as Community Wildfire Protection Planning recognize the multistakeholder involvement needed to create fire-resilient communities by integrating private lands along with federal, state, tribal, and municipal lands in management efforts (Ager, Kline, & Fischer, 2015). Since forests are typically the major fuel sources of destructive wildfires (Stevens-Rumann et al., 2018), owners of private forests are a key stakeholder group to better understand and incorporate into policy planning. Family forest ownerships (FFOs) control approximately 35% of all forestland in the United States (Butler et al., 2020), making them indispensable partners in tackling the challenges of wildfire hazard in an era of climate change. In contrast to federal, state, and municipal forest owners, FFOs can be relatively more challenging to incorporate into public policies because of their greater number and the diversity of individuals whose participation in management programs is similarly based on heterogeneous factors (e.g., Butler & Leatherberry, 2004; Floress et al., 2019). Acknowledging the critical role of private landowners, Smith et al. (2016) present a framework for approaching wildfire mitigation and adaptation in the United States and conclude, “we need to understand how the existing perceptions, abilities and capacities of local people can be leveraged to design unique strategies for living with wildfire” (p. 144).

While there is a large literature on how communities and individual homeowners perceive and respond to wildfire hazard (e.g., Champ & Brenkert-Smith, 2016; Dickinson, Brenkert-Smith, Champ, & Flores, 2015; Hamilton et al., 2016; Olsen, Kline, Ager, Olsen, & Short, 2017; Paveglio, Edgeley, & Stasiewicz, 2018), studies of how FFOs perceive wildfire hazard are relatively fewer (e.g., Fischer & Charnley, 2012; Jarrett, Gan, Johnson, & Munn, 2009; Wyman, Malone, Stein, & Johnson, 2012). Topics studied concerning FFOs and wildfire include actual and hypothetical forest fire insurance purchases (DENG, MUNN, COBLE, & YAO, 2015; Gan, Jarrett, & Gaither, 2014; Sauter, Möllmann, Anastassiadis, Mußhoff, & Möhring, 2016) and the management measures taken by FFOs to reduce fire hazard on their properties (Jarrett et al., 2009; Moorman, Bromley, Megalos, & Drake, 2004). Existing literature on FFOs and wildfire tends to study FFOs in areas of the United States with moderate to high wildfire potential, such as within certain states and ecoregions, but only some specifically account for the variation in location-specific wildfire hazard experienced by different owners, and most importantly, none are national in scope.

Only one study in the United States has used a measure of location-specific wildfire hazard to explore how FFO wildfire concerns correspond to biophysical wildfire conditions on and near FFO properties (Fischer, Kline, Ager, Charnley, & Olsen, 2014), with most studies on location-specific wildfire hazard and perceptions coming from the literature on homeowners. Fischer et al. (2014) find a positive and significant relationship between crown fire potential, a measure of likely burn intensity in the event of a wildfire, and FFO wildfire concerns in Oregon’s Ponderosa Pine ecoregion. The marginal effect of crown fire potential on wildfire concern from Fischer et al. (2014) is significant; however, they stop short of quantifying its effect in relation to the other variables in their model. To the extent that landowner perceptions of wildfire hazard tend to be associated with fire safety and mitigation actions (e.g., Blennow, Persson, Tomé, & Hanewinkel, 2012; Brenkert-Smith, Champ, & Flores, 2012; Champ, Donovan, & Barth, 2013; Dickinson et al., 2015; Eriksson, 2017; McCaffrey, Stidham, Toman, & Shindler, 2011), better understanding how FFOs think about wildfire with respect to location-specific biophysical wildfire hazard may produce policy-relevant insights.

This study explores the relationship between FFO wildfire concerns and biophysical wildfire hazard across the contiguous United States using the United States Department of Agriculture (USDA) Forest Service’s 2018 National Woodland Owner Survey (NWOS) of family forest ownerships in the United States (Butler et al., 2020). In addition to its

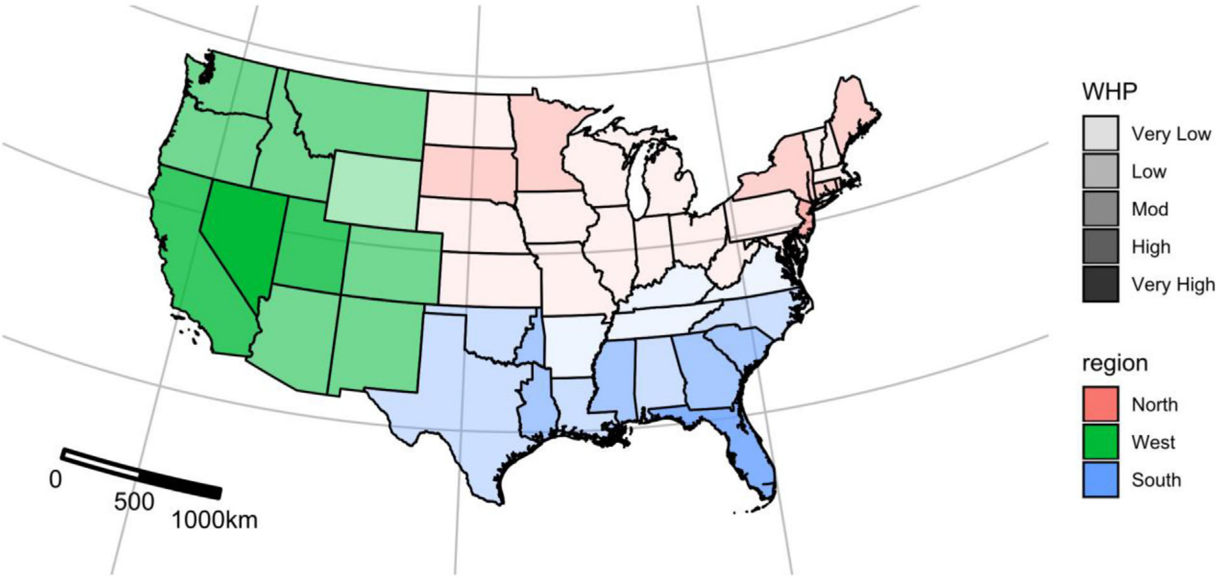

Fig 1. Mean log of Wildfire Hazard Potential (WHP, 1-mile radius) spectrum by state and region

broad geographical coverage, the NWOS also provides a sample of FFOs with forest properties existing across a broader spectrum of wildfire hazard potential than what has been previously studied. Our main dependent variable of interest is if survey respondents report they are "greatly concerned" about the topic of wildfire on their forestlands.[1] Our main independent variable is the 2018 USDA Forest Service Wildfire Hazard Potential (WHP) (Dillon, 2018) on and near respondent property locations. We selected WHP as our main independent variable since it has continuous coverage of the contiguous United States and it combines a host of prospective hazard factors as well as past wildfire occurrence data. Stated briefly, WHP is a measure of hazard that gives more weight to potential for fires of relatively high intensity in its estimation methodology, which are more difficult to contain and cause much more damage than lower intensity fires (Dillon, 2018).

We use a logit model to estimate the effect of location-specific wildfire hazard (as measured by WHP), along with a variety of other landowner attributes, on wildfire concern. Considering six ways of aggregating location-specific WHP, we employ a model selection approach (Burnham & Anderson, 2002) to determine how to specify WHP for a national model and three regional models. We use a pooled national model to test for differences in the level of wildfire concern in different regions of the United States as well as differences in sensitivity to the spectrum of WHP between regions. Using three regional logit models, we generate predicted probabilities at the means to further quantify and isolate the impact of WHP on wildfire concerns in the west, south, and north regions of the United States (see Fig. 1 for a description of the regions). We present the predicted probabilities at the means graphically and use the predicted probabilities to calculate regional prevalence ratios to compare the influence of WHP with the other determinants of FFO concerns.

The rest of this article is organized as follows: a background section reviews related literature on homeowners and specifies four aspects of the relationship between FFO wildfire concerns and biophysical wildfire hazard that we explore. A methods and materials section presents details about the survey data and WHP as a biophysical hazard measure along with specifications of the models we run. Results are presented followed by a discussion section putting the results into context. The conclusion presents our policy recommendations and suggestions for further research.

[1]Respondents could choose between five ordered response categories ranging from "no concern" to "great concern" about the topic of wildfire on their forestlands, with the option to also select "not applicable."

2. BACKGROUND

Most previous studies connecting wildfire perceptions with location-specific wildfire hazard comes from the homeowner literature. In general, the literature on homeowner wildfire perceptions and biophysical hazard or risk tends to confirm wildfire perceptions are related to measurable biophysical hazard factors on and near homeowner properties, but the connection between the two is often imprecise. For example, when asked to give a subjective percentage probability of the likelihood that a fire will occur on or around their properties, both Paveglio et al. (2018) and Olsen et al. (2017) find that survey respondents consistently overestimated such probabilities by multiple orders of magnitude. Olsen et al. (2017) finds homeowner perception of the chance of wildfire to be positively but weakly correlated with a measure of burn probability; however, a measure of likely fire intensity and trees per hectare had the largest influence of all the variables used to model perceptions of the damage a potential wildfire would cause. Meldrum et al. (2019) also confirm that homeowners were generally able to interpret fire ignition and intensity factors in the areas around their houses, but conclude more public outreach efforts are needed to educate homeowners about mitigation actions. Paveglio et al. (2018) find weak and mostly insignificant relationships between wildfire hazard perceptions and their models of social vulnerability to wildfire. Champ et al. (2013) found that homeowners' wildfire perceptions were positively and significantly correlated with physical hazard factors near their properties. Two earlier studies, Schulte and Miller (2010) and Collins (2008), found no significant relationships between hazard mitigation efforts and biophysical fire hazard factors.

While there is a broad consensus that individual hazard perceptions are important, there is no commensurate consensus on the best way to measure hazard perceptions (Wilson et al., 2019). Wildfire hazard is multiplicative of the probability of a fire event and the intensity of damage if a fire were to occur, and some studies explicitly measure respondent hazard perceptions along these two dimensions (Olsen et al., 2017; Renn, Burns, Kasperson, Kasperson, & Slovic, 1992). Another dimension of hazard perception is awareness of the hazard itself. Olofsson and Öhman (2007) and McGee, McFarlane, and Varghese (2009) found, however, that FFO awareness of various forest disturbances was not correlated to how concerned owners were about those hazards.

Concern is a measure of how much attention a person gives to something, and reflects both a cognitive and an affective component (Fischer, Morgan, Fischoff, Nair, & Lave, 1991). In a review of different measures of risk perception, Wilson et al. (2019) found the affective component of risk (including concern) to be the most powerful explanatory variable in predicting mitigation actions along with perception of the consequences of a hazard event. We do not argue that concern about wildfire hazard is a better measure of wildfire perceptions than alternative measures, but that concern is one of several useful measures of hazard perception.

Although the literature on homeowner wildfire perceptions and location-specific hazard potential can serve as a guide, the existence of only one study specific to U.S. FFOs on the topic calls for an exploration of several aspects of the relationship between FFO perceptions and biophysical hazard. With a sample of FFOs spanning substantially broader wildfire hazard conditions than what has been previously explored in the United States (i.e., Fischer et al., 2014), we are specifically interested in exploring four understudied aspects of the relationship between FFO wildfire concerns and location-specific biophysical wildfire hazard. The first aspect is how sensitive FFO wildfire concerns are across a broad spectrum of low to high biophysical hazard. As far as we are aware, every U.S. study that links location-specific measures of wildfire hazard with homeowner or landowner wildfire hazard or risk perceptions has been in the western United States (i.e., states situated in and west of the Rocky Mountains, Champ et al., 2013; Collins, 2008; Meldrum et al., 2019; Olsen et al., 2017; Paveglio et al., 2018; Schulte & Miller, 2010). Using data from FFOs across the contiguous United States, we can compare respondents with high wildfire hazard exposure (who are often studied) to those with relatively moderate and lower hazard exposures.

Second, FFOs' sensitivity to wildfire hazard has not been compared across regions of the United States characterized by different regional scale wildfire hazard, notwithstanding location-specific wildfire hazard. It is therefore possible that sensitivity to the spectrum of biophysical wildfire hazard may differ between areas where generally high wildfire hazard characterizes the landscape, and areas where more moderate wildfire hazard tends to cover much of the land area. Accordingly, we consider three different regions in the contiguous United States with one region being characterized by relatively high wildfire hazard (the Western United States), one area with somewhat moderate wildfire hazard (the Southern United States), and one area characterized by relatively low wildfire hazard (the Northern United States, including states in the north mid-west). Using interaction terms between regional indicator variables and WHP, we test for differences in sensitivity to the spectrum of WHP in the different regions. Sociodemographic and attitudinal determinants of wildfire concerns may also vary across different regions of the United States. To allow for regional differences in nonbiophysical determinants of wildfire concerns, we also generate separate models for the West, South, and North regions of the United States.

A third issue is the extent around FFO properties at which WHP is relevant for FFO wildfire concerns. Previous studies of landowner concerns tend to find wildfire concerns are related to wildfire potential at short distances (e.g., 1 km from property centroids in Fischer et al., 2014 and Olsen et al., 2017), while related literature shows responses to wildfire, such as changes in housing prices, may occur at somewhat longer distances (McCoy & Walsh, 2018). For example, one study finds a significantly negative price effect between houses 10 km from burned areas relative to houses 20 km away (Stetler, Venn, & Calkin, 2010). Given the lack of *a priori* guidance for how far away from FFO property locations biophysical hazard conditions may be relevant to owner concerns, we explore WHP at three different distance buffers/radii from forest ownership locations.

Next, homeowner and FFO wildfire perceptions are almost uniformly modeled as functions of raw wildfire hazard or risk measures; however, repeated findings from behavioral research show that people regularly misjudge uncertain quantities and probabilities (Kahneman, 2011; Kondolf & Podolak, 2014; Thaler & Sunstein, 2008). For this reason, our fourth issue of interest is if FFO wildfire perceptions exhibit a nonlinear relationship with biophysical wildfire factors across the hazard spectrum. One common tendency in human perceptions is for people to overestimate small quantities and low probabilities and underestimate large quantities and high probabilities, an observation first credited to Gustav Fechner (Fechner, 1860). The overestimation of small probabilities and underestimation of large probabilities implies human perceptions of some physical quantities and hazards are logarithmic (e.g., Elvik, 2015), and wildfire perceptions may display the same tendency. To explore the third and fourth issues, we create location-specific measures of WHP using 1-, 10-, and 100-mile (1.6-, 16-, and 160-km) radii buffers and both a linear measure as well as the natural log of WHP. This results in a set of six models. We then use a model selection approach to determine which of the candidate models best fit the data.

3. MATERIALS AND METHODS

The primary source of data for this analysis comes from the USDA Forest Service, Forest Inventory and Analysis (FIA), NWOS. The NWOS sample is based on the standard FIA sample (Bechtold & Patterson 2005), in which a semirandom distribution of points is established and forested status and broad ownership type is established for each point. The NWOS is administered to a subset of unique ownerships in each state, with each ownership owning land on which one or more FIA points fall (more on the NWOS sample can be found in Butler et al., 2020). For FFOs, most individual ownerships are represented by only a single sample point.[2] The most recent iteration of the NWOS was collected in 2017–2018. Nationwide, 9,518 complete FFO responses were returned, for a cooperation rate of 39.7% (Butler et al., 2020). Here, we use data from the 48 contiguous states from those respondents with 10 or more acres of forested land (n = 8,591). For our dependent variable, we use a question asking respondents to state their concern about the topic of wildfire for the forestland in terms of a five-point ordered Likert scale, from "no concern" to "great concern." We reframe this response as a binary variable, considering those who expressed "great concern" for wildfire on their forestland as $y_i = 1$, and those who expressed a level of concern for wildfire other than "great concern" as $y_i = 0$.[3] The distribution of answers to wildfire concern shows a clear spike in the frequency of respondents answering "great concern" relative to the other categories, suggesting a potential threshold between respondents stating the highest level of concern and those stating any lower level of concern. Models were also run grouping respondents who expressed the second-highest level of the dependent variable, "concern," with respondents expressing "great concern." All results from the models in which respondents who expressed the top two levels of concern are grouped together (i.e., "concern"

[2] Approximately 97.4% of the final sample used in this article.

[3] The National Woodland Owner Survey utilizes a multiple imputation technique for item nonresponse (Butler, Caputo, Robillard, Sass, & Sutherland, 2021).

or "great concern" are both modeled as $y_i = 1$) are qualitatively similar to the results presented below.[4]

We use the 2018 USDA Forest Service WHP (Dillon, 2018) as our main independent variable of interest. The Forest Service's WHP jointly considers ignition potential and expected burn intensity and has continuous coverage over all 48 contiguous states and ranges from 0 to approximately 98,000 (Dillon, 2018). The 2018 version of WHP uses data from the 2016 Large Fire Simulation system (Fsim), spatial fuels and vegetation data from LANDFIRE 2012, and point locations of fire occurrence from the Fire Program Analysis (FPA) from 1992 to 2013 (Short, 2015; Short, Finney, Scott, Gilbertson-Day, & Grenfell, 2016). The aim of the WHP measure is to help inform what areas of the United States should be prioritized for fuels treatments by identifying locations with long-term elevated hazard for destructive wildfires. While WHP is most suitable for the purposes of this study due to its continuous coverage of all land in the contiguous United States, our application of it to FFO survey data imposes the assumption that FFO concerns are driven by the prevailing long-term wildfire hazard conditions on and close to their properties. In addition to the continuous WHP measure, there are also discrete hazard categories that help facilitate interpretation of WHP, ranging from very low to very high. The amount of land in each discrete hazard category is intentionally unequal with very high WHP areas being in the top 95th percentile of wildfire hazard while the combined land with very low and low WHP represent the bottom 67th percentile of hazard.

To create respondent-specific measures of WHP, the sample points associated with each survey respondent were used to calculate a set of nested buffers (using 1-, 10-, and 100-mile radii) for each respondent. These buffers were overlaid on the WHP data (in raster format) and the mean value of WHP across all of the pixels contained within the buffer was calculated. Where a survey was linked to multiple sample points, the point-level values were averaged. Given the lack of *a priori* expectations for the relationship between FFO wildfire concerns and biophysical wildfire conditions across the contiguous United States, we tested six individual-specific WHP measures. The first three used the raw measures of WHP within each buffer to create three separate measures of location-specific WHP for each respondent ($WHP_{i,1}, WHP_{i,10}, WHP_{i,100}$). To test for a nonlinear relationship between wildfire concerns and WHP, we also generate the natural log of each measure ($\log(WHP_{i,1}), \log(WHP_{i,10}), \log(WHP_{i,100})$) for a total of six WHP measures for each respondent.

We created regional indicator variables (i.e., West, South, and North) based on general trends in landscape-scale hazard and corresponding to general notions of United States regional geography. Our choice of West, South, and North regions was guided by a combination of considerations. First, due to differences in ownership distribution, the number of respondents from the wildfire-prone Western United States in the NWOS is substantially lower compared to other regions (for example, the Western region contains less than one third as many respondents as the Northern region). To secure enough respondents for reliable estimates and produce regional analysis with somewhat comparable numbers of respondents, we pooled respondents in western states into one region. Accordingly, the North and South regions were created to be of comparable geographic size although they contain more respondents than the West. Second, these three regions have a high degree of overlap with U.S. Forest Service regions: the South exactly overlaps with region 8, the North mostly overlaps with region 9 (but also includes Kansas, Nebraska, and the Dakotas), and the West is comprised of regions 1–6 (but excluding the four states included in the North). Third, given the nation-wide coverage of the NWOS and relatively limited geographic scope of similar previous studies, we have a rare opportunity to compare landowners from the often, but separately studied western and southern U.S. states along with the rarely studied northern states. Finally, a visual inspection of the map of WHP from 2015 and 2018 suggests three contiguous areas of the continental United States where WHP tends to transition between the states (see Fig. 12 in Dillon et al. 2015), which happens to closely follow the historical north-south geographic divide east of the rocky mountain states.

Although wildfire tends to be a major topic in the western United States, there are some areas outside the west that have moderate and high WHP as well. Figs. 1 and 2 show how respondents to the NWOS are distributed across WHP in the three regions we consider. All regions have FFOs with forestlands in the "Very Low" and "Low" hazard categories, while the West has relatively more FFOs with forestlands in the "Very High" category. The South has a high

[4]Interested readers are directed to contact the authors for the RMarkdown document with results from the sensitivity analysis in which the top two levels of concern are grouped together.

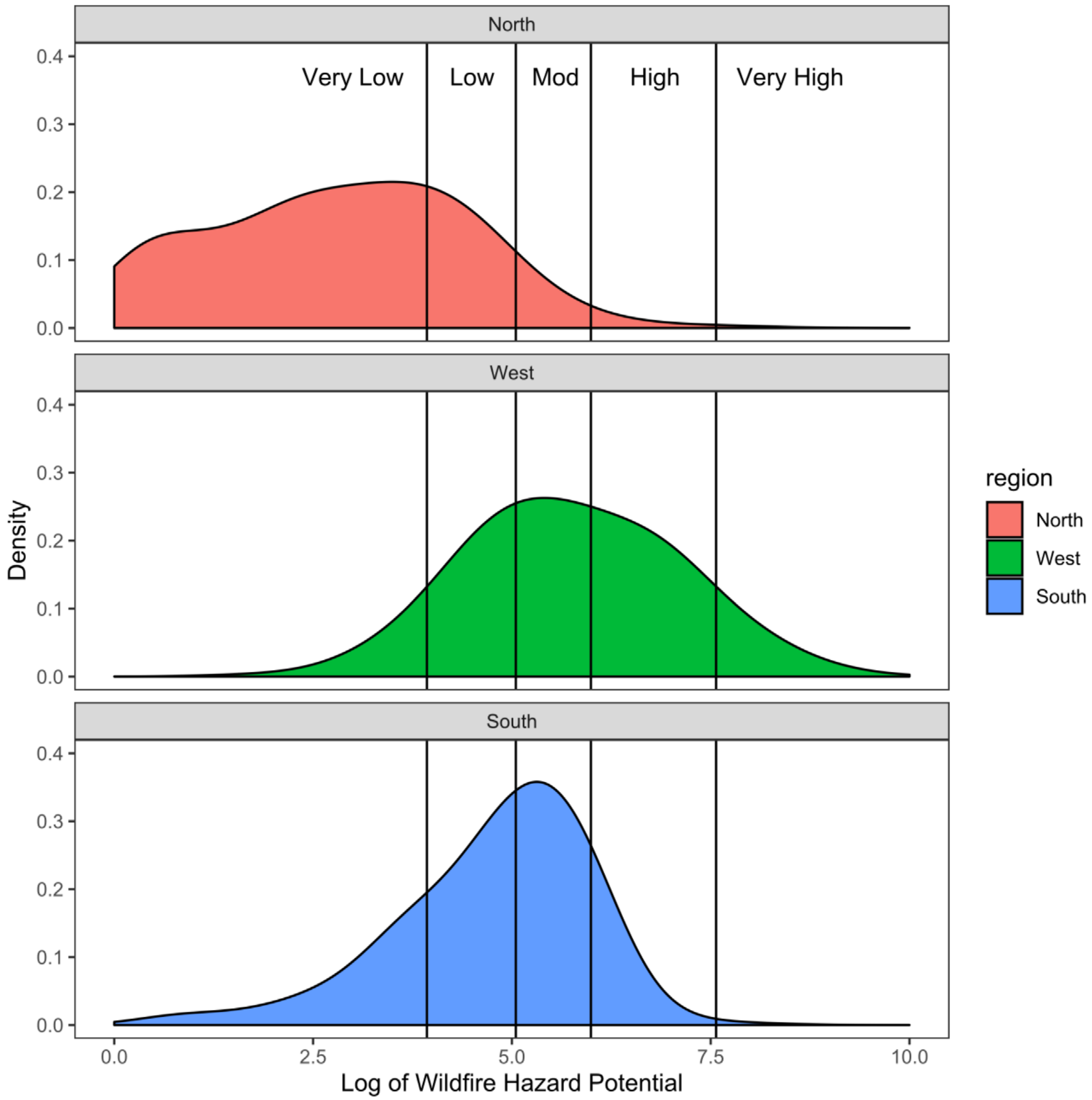

Fig 2. Density distribution of survey respondents across the log of Wildfire Hazard (1-mile) Potential spectrum. Vertical lines represent transition points between discrete hazard levels from Dillon (2018)

concentration of FFOs with lands in the "Moderate" hazard category while the North is characterized by many FFOs with lands in the "Very Low and "Low" category.

The non-WHP attributes in the models include binary variables for respondents who indicated the following: strong agreement they have a strong emotional attachment to their forestland (the highest level of agreement on a Likert scale), having received information or advice about fire safety on their forestland in the past 5 years, having a primary house or vacation house on the property, having a bachelor's degree or higher level of education, and if the respondent is female. Continuous non-WHP attributes include the natural log of total forestland acres owned by the respondent and the respondent's length of ownership tenure. These variables are all taken directly from the NWOS. A third continuous predictor variable, population density, comes from a standard U.S. census product (U.S. Census Bureau, 2010). Similar to the approach used for WHP, population density is defined as the population density of the census tract which contains the sample point associated with a survey. Where a survey is linked to two or more points, the mean population density was taken across the points (see Supporting Information 1).

The national and regional models are specified using a logit function. The probability that a given respondent will express great concern for wildfire (i.e., $y_i = 1$) in a logit model for all respondents at the national level is given by equation 1

$$P(1_i \mid \alpha, \gamma, z_i,\ \beta, x_i) = \frac{\exp\left[\alpha + \gamma \cdot z_i +\ \beta \cdot x_i\right]}{1 + \exp\left[\alpha + \gamma \cdot z_i +\ \beta \cdot x_i\right]}, \tag{1}$$

in which α is a constant to be estimated, z_i is a measure of respondent-specific WHP, x_i is a vector of non-WHP attributes for individual i, γ is a parameter to be estimated, and β is a vector of parameters to be estimated. The probability a respondent will not express great concern (i.e., $y_i = 0$) is $1 - \ P(1_i|\alpha, \gamma, z_i,\ \beta, x_i)$.

To test for differences in sensitivity to the gradient of WHP between respondents with forest properties in the three different regions, r, that we consider (i.e., West, South, and North), each national candidate model includes interaction terms between regional indicator variables and WHP. A significant coefficient on the interaction term(s) indicates that respondent expressions of great concern about wildfire in a particular region are significantly more or less sensitive to WHP in that region compared to the baseline region. In addition to a national pooled model for all respondents, we run three separate regional logit models to which respondents are assigned based on the same regional indicator, r, from the pooled model. Each of the regional models contains the same independent variables as the other regional models and the national pooled model, with the exception of the regional indicator variables and interaction terms.

Following a model selection approach (Burnham & Anderson, 2002) we use the Akaike Information Criterion (AIC) to test which one of the six respondent-specific WHP measures is the most parsimonious fit to the national model and each regional model, respectively. In other words, six models were tested for each of the models we present, with each of the six containing only one of the candidate WHP measures, and we present the one with the highest AIC weight. As measures of model fit, we present McFadden's pseudo-R squared and Tjur's R squared (Tjur, 2009). To account for multicolinearity concerns among selected variables, we also calculate the Variance Inflation Factor (Akinwande, Dikko, & Samson, 2015) and present the results in Supporting Information 1.

After selecting the WHP measure of best fit for the national and regional models (in other words, the most plausable of the models tested), we further quantify the impact of biophysical wildfire hazard on wildfire concerns by exploring predicted probabilities from our regional models. As our main variable of interest is continuous, interpreting the effect of WHP on wildfire concerns relative to other relevant binary variables using odds ratios is cumbersome. Also, the distance between discrete hazard levels on the WHP scale vary for each discrete hazard category. For example, a 1-unit increase in the log scale of WHP represents different changes in hazard levels at different points along the hazard spectrum. To isolate the impact of the WHP measure of best fit and facilitate interpretation of its effect, we calculate predicted probabilities at the means for each respective region (Muller & Maclehose, 2014). In using predicted probabilities at the means for each regional model, we allow only the respondent-specific WHP measure of best fit from each regional model to vary and hold all other independent variables constant at their regional means as per Equation 2

$$\overline{\widehat{P_{i|r}}} = \frac{\exp[\hat{\alpha}_r + \widehat{\gamma_r} \cdot z^*_{i|r} + \widehat{\beta_r} \cdot \overline{x_r}]}{1 + \exp[\hat{\alpha}_r + \widehat{\gamma_r} \cdot z^*_{i|r} + \widehat{\beta_r} \cdot \overline{x_r}]}, \tag{2}$$

with $\hat{\alpha}_r$ representing estimated constants, $\widehat{\gamma_r}$ and $\widehat{\beta_r}$ representing estimated coefficients, $z^*_{i|r}$ representing the respondent-specific WHP measure of best fit in each regional model, and $\overline{x_r}$ representing the regional means of all other respondent-specific attributes for individuals conditional on regional assignment, r. We use the delta method (Jackson, 2011) to estimate standard errors for the predicted probabilities at the means from each respective regional model.

To compare the influence of WHP on stated wildfire concerns to the influence of discrete demographic and attitudinal characteristics, we use the regional predicted probabilities at the means to create regional prevalence ratios (Tamhane, Westfall, Burkholder, & Cutter, 2016). Regional prevalence ratios are calculated by dividing the predicted probability of being greatly concerned about wildfire at the highest regional WHP ($\widehat{\overline{P_{h|r}}}$) by the predicted probability of being greatly concerned about wildfire at the lowest regional WHP ($\widehat{\overline{P_{l|r}}}$) as per Equation 3.

$$\text{Prevalence Ratio}_r = \frac{\widehat{\overline{P_{h|r}}}}{\widehat{\overline{P_{l|r}}}} \tag{3}$$

In our case, the prevalence ratio represents the percentage increase in the probability of a regionally average respondent expressing great concern for wildfire by moving from the lowest to the highest regional WHP exposure as if it were a discrete difference. Like the odds ratio, a score of 1 shows no impact while scores below 1 show a negative impact of the variable on predicted probability. Scores above 1 show a positive impact on predicted probability. Regional prevalence ratios allow us to compare the influence of respondent characteristics, such as gender, to the greatest possible regional differences in long-term wildfire hazard conditions as measured by WHP. In other words, the prevalence ratio can be compared to the odds ratios of the discrete variables in the models, although the two measures represent different changes in the independent variables.

Spatial analyses were run using Python 2.7 (Python Software Foundation 2019) with the ArcPy module. All other analyses were run in R (R Core Team, 2019). Supporting Information 1 is an RMarkdown document containing the code base for all analyses.

4. RESULTS

Table I shows output from a logit model for all respondents, with dummy indicator variables for respondents in the West and the South regions. Using AIC tests to determine the most parsimonious fit of the national data, we select the natural log of the 10-mile (16 km) WHP buffer. AIC tests show that the worst-fitting specification with a log of WHP is a better fit to the data than the best fitting specification with a raw measure of WHP. The McFadden's pseudo R squared for the top-ranked model is 0.084 while the Tjur statistic is 0.109. The variance inflation factor for all non-WHP variables is below 1.5, while WHP, the West and South regions, and the interaction terms understandably range between 2.9 and 23.2 (see Supporting Information 1). The coefficient estimate for the log of WHP 10-mile buffer is significant and positive, meaning that great concern for wildfire is positively predicted by biophysical wildfire hazard potential. Positive and significant signs on the West and South indicator variables show respondents in these two regions are significantly more concerned about wildfire compared to respondents in the North, regardless of the location-specific hazard measure. The regional indicators show respondents owning a forest property in the West and South regions are 2.27 and 2.20 times more likely to express great concern about wildfire, respectively, compared to respondents in the North.

Table I. National Model

	Estimate	Pr (>|z|)	Odds ratio
Regional attributes			
West	0.820	0.001**	2.27
South	0.789	0.000***	2.20
WHP, 10 m (log)	0.172	0.000***	1.19
WHP in West, 10 m (log)	0.012	0.800	1.01
WHP in South, 10 m (log)	−0.100	0.011*	0.90
Population (km^2)	0.000	0.911	1.00
Forest owner attributes			
Attachment to land	0.676	0.000***	1.97
Wildfire information	0.527	0.000***	1.69
House on forest property	0.045	0.398	1.05
Acres (log)	−0.009	0.557	0.99
Forest tenure	0.000	0.827	1.00
University education	−0.399	0.000***	0.67
Female	0.255	0.000***	1.29
Intercept	−1.695	0.000***	0.18
Tjur's Statistic	0.109		
McFadden's pseudo R-squared	0.084		
n	9,230		

Note: Signifcant codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1 ($^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$?)

The interaction of the South and log of WHP 10 = mile buffer is negative and significant, meaning that wildfire concerns of respondents in the South are less sensitive to the broad range of biophysical WHP than respondents in the North. The interaction of the West and log of WHP 10 mile buffer is positive but not significant, meaning that we do not detect a significant difference in sensitivity to the biophysical WHP spectrum between respondents in the West and those in the North.

Nonbiophysical hazard factors are also significant in predicting wildfire concerns. Receiving information and advice about wildfire in the past

Table II. Regional Logit Models

	North (10-Mile WHP)			South (1-Mile WHP)			West (10-Mile WHP)		
	Coefficient	Pr (>|z|)	Odds Ratio	Coefficient	Pr (>|z|)	Odds Ratio	Coefficient	Pr (>|z|)	Odds Ratio
Geographic attributes									
WHP (log)	0.172	0.000***	1.188	0.079	0.01**	1.082	0.181	0.000***	1.199
Population (km^2)	0.000	0.954	1.000	0.000	0.97	1.000	0.000	0.631	1.000
Forest owner attributes									
Attachment to land	0.630	0.000***	1.878	0.711	0.00***	2.036	0.721	0.000***	2.056
Wildfire information	0.526	0.010**	1.693	0.348	0.00***	1.417	0.671	0.000***	1.975
House on land	-0.009	0.919	0.991	-0.117	0.15	0.889	0.427	0.000***	1.533
Acres (log)	-0.003	0.918	0.997	0.014	0.57	1.014	-0.040	0.194	0.961
Forest tenure	0.001	0.722	1.001	0.002	0.51	1.002	-0.007	0.034**	0.993
University education	-0.539	0.000***	0.584	-0.433	0.00***	0.648	-0.095	0.373	0.909
Female	0.257	0.006***	1.293	0.264	0.00***	1.302	0.224	0.089*	1.251
Intercept	-1.634	0.000***	0.195	-0.986	0.00***	0.373	-0.999	0.001***	0.368
Tjur's Statisistic	0.050			0.048			0.080		
McFadden's Pseudo R-Squared	0.043			0.035			0.062		
n	4,150			3,195			1,885		

Note: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

5 years is significantly positively associated with wildfire concern, as is having a strong emotional attachment to one's forest property. Female respondents are significantly more likely to express great concern about wildfire. Having a university education is negatively and significantly associated with wildfire concerns on FFO properties. The presence of a house as a primary or secondary residence on the property, the log of forested acres owned, population density where forestland properties are located, and ownership tenure are insignificant.

Next, we allow for all variables to be freely estimated within each of the three regions by running separate logit models for each region. Results of the regional logit models are presented in Table II. Comparing AIC tests for models with different buffer sizes, we select the natural log of the 10 mile (16 km) WHP buffer as the most parsimonious fit to the data in the North and West regional models; however, in the South regional model, the 1 mile (1.6 km) WHP buffer is the best fit. As in the national model, the worst fitting specification with the log of WHP is a better fit than the best fitting specification with raw WHP in the North and South regional models, according to the AIC. In the West regional model the pattern of all models with the natural log of WHP having a better AIC than raw WHP is also present; however, the specification with the raw 100 mile WHP buffer is better than the specification with the log of the 100 mile WHP buffer. McFadden's pseudo R-squared for the regional models range between 0.035 for the South to 0.062 for the West. Tjur's pseudo R-squared ranges between 0.048 for the South and 0.080 for the West. The highest variance inflation factor of any variable in the regional models is 1.205, with most being below 1.1 (see Supporting Information 1). Accordingly, the regional models display no signs to be concerned about multicolinearity between the independent variables. Coefficient estimates and subsequent odds ratio scores for the log of WHP in the North and West regions are more than twice the magnitude of those in the South, confirming results from the national model that wildfire concerns of FFOs in the South are less sensitive to the WHP spectrum.

Results of the remaining covariates in the regional models confirm some similarities between the regional determinants of wildfire concern as well as some important differences. In all regional models, the coefficients on having a strong emotional attachment to the property and receiving information about wildfire in the past 5 years are positive and significant. Furthermore, the odds ratio of both strong emotional attachment to the property and receiving information about wildfire in the last 5 years have the largest effect sizes relative to other binary variables in each respective regional model. Female FFOs are significantly more likely to express great concern about wildfire on their properties in all three regions.

Two variables have different signs in the West regional model compared to the North and South. The presence of a house (primary home, second home, or cabin) on one's forest property has a positive and significant effect on FFO concerns in the West, but the effect is negative and insignificant in the South and North. Ownership tenure is negative and significant in the West, but positive and insignificant in the South and North. The coefficient indicating if the respondent has a university education is a negative predictor of wildfire concerns in all regional models, although it is only significant in the North and South.

Finally, two variables are not significant in any regional model. The natural log of the total forestland acres a respondent owns is negative in all models, yet insignificant. Population density of the census tract where respondents' properties are located is also insignificant in all models.

To further explore the impact of WHP as a determinant of wildfire concern, we turn to regional predicted probabilities at the means and prevalence ratios. Fig. 3 visualizes predicted probabilities of great concern at the means from the regional models and accompanying 95% confidence intervals for the North, South, and West regional models. The endpoints of the hazard spectrum differ slightly in the three regions. The West lacks FFO respondents on the lowest end of the "Very Low" WHP category while there are respondents in the West with higher WHP on their forests than in the South and North.

Fig. 3 provides a visualization of the difference in levels of concern across regions (i.e., the different starting points of each regional predicted probability) and differences in the sensitivity to the log of WHP across regions (i.e., the slope of each line). The baseline level of concern about wildfire for the statistically average FFO within each region is highest in the West and lowest in the North, with the South being between the West and North. As expected from the results of the national model, the slope of predicted probabilities of the West and North models are similar while the slope of the predicted probabilities from the South model is relatively flatter. The predicted probability of an average FFO in the West being greatly concerned about wildfire is statistically significantly higher than the North and the South across the hazard spectrum, except for a portion of the "Very low" hazard spectrum. Wildfire concerns for the average FFO in the South are significantly higher than the average FFO in the North at "Very low" and "Low" hazard, but become statistically indifferentiable at the "Very high," "High," and part of the "Moderate" WHP categories.

Table III. Regional Predicted Probabilities at the Lowest Regional WHP (Lower bound p), Highest Regional WHP (Upper bound p), and Regional Prevalence Ratios

	Lower Bound p	Upper Bound p	Prevalence Ratio
North	17.45%	48.98%	2.807(**)
South	31.15%	47.26%	1.518(**)
West	40.32%	75.15%	1.864(**)

Note: $^{**}p < 0.05$.

Table III presents the prevalence ratios based on predicted probabilities at the means for the three regions. In the North and South regions, predicted probabilities imply the statistically average respondent with a property at the highest end of the WHP spectrum in those regions are almost 50% likely to express great concern about wildfire on their forests. FFOs with properties at the lowest end of the WHP spectrum in the North and South are about 17 and 31% likely to express great concern about wildfire, respectively. In the West, the statistically average respondent owning property with the highest WHP is about 75% likely to express great concern about wildfire while owning land with the lowest regional hazard exposure is associated with a roughly 40% probability of expressing great concern. The differences in predicted probabilities at the means at the highest and lowest regional WHP are significant using 95% confidence intervals (i.e., the delta method).

Recall, the prevalence ratio says how much more likely the average FFO is to express great concern at the lowest regional WHP compared to the highest regional WHP. The prevalence ratio can be compared to the odds ratio of the discrete variables in Table II. In the North, the change in predicted probability from the lowest to the highest WHP (i.e., the prevalence ratio) is larger than the odds ratio of all other discrete variables. In the South, the prevalence ratio is smaller than the odds ratio for having strong emotional attachment to one's property, but larger than the effect of receiving information about wildfire. The prevalence ratio in the West is smaller than the odds ratio for both a strong emotional attachment to the land and having received information about wildfires, but is larger than the odds ratio of having a house on one's forest property. In summary,

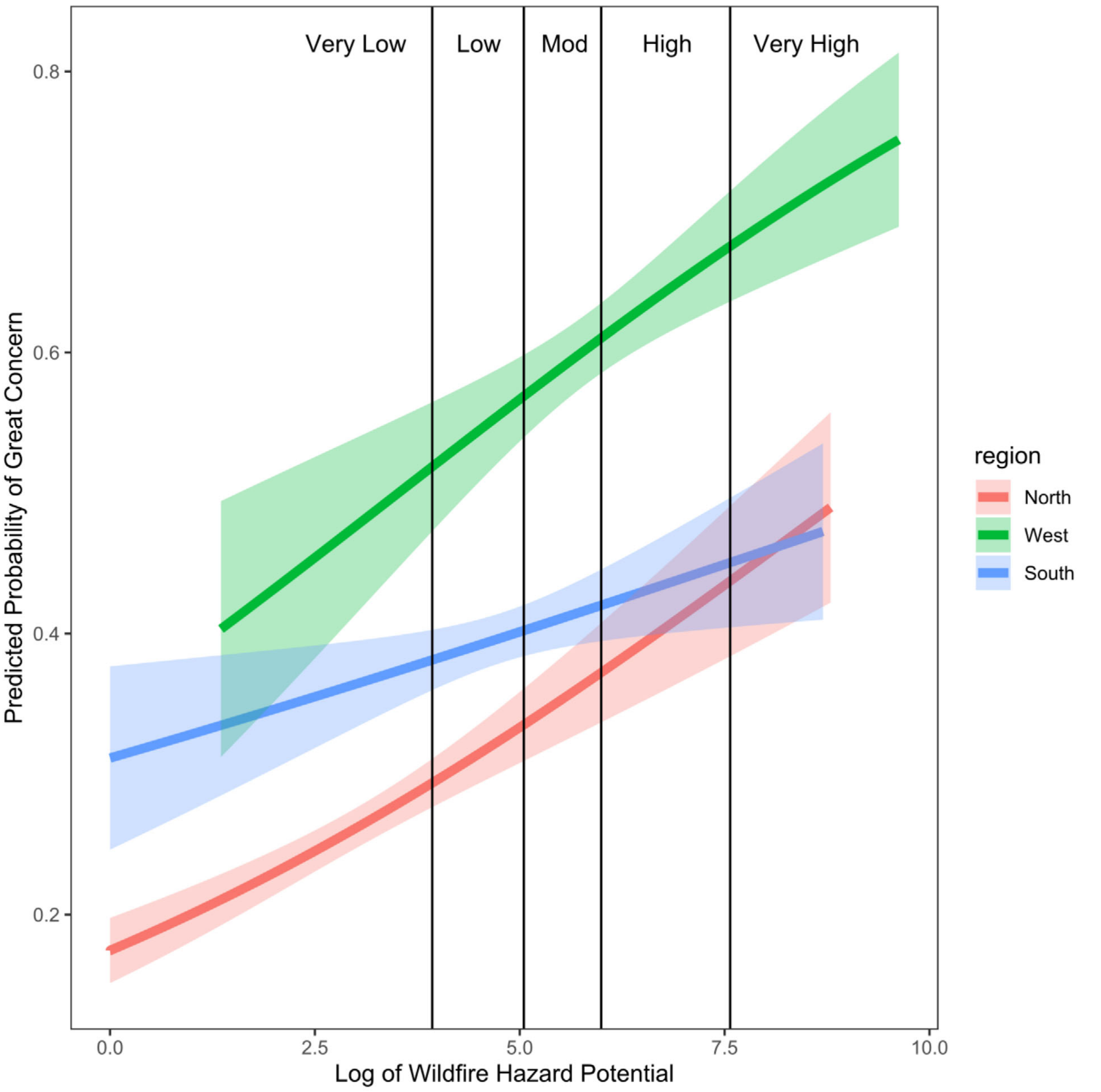

Fig 3. Predicted probability at the means of expressing great concern for wildfire for the North, West, and South regional models. Probabilities are calculated using the 10-mile radii buffers of the log of WHP for the West and North regions and a 1-mile buffer of the log of WHP for the South region

the prevalence ratio shows that the greatest possible regional difference in long-term hazard exposure has either the largest effect size on wildfire concerns (North) or among the largest effect sizes on wildfire concerns (South and West) as all other variables. It is important to note that in the South and West regions, having a strong emotional attachment to one's land actually has a stronger impact on wildfire concerns than the greatest possible regional difference in long-term biophysical wildfire hazard exposure.

One of the advantages of the model selection approach is that candidate models are not only ranked, the relative likelihood of each (given the data) is quantified via the likelihood weight. For the national model, the top-ranked model came as very substantially more likely than the other models (95.5% out of a total 100%). For the north and west models, the top-ranked model was relatively less likely compared to the second-ranked model, but still had a large majority of the likelihood (74.1 and 87.4%). In all three cases, the second-ranked model was the logit model with the 1-mile buffer. The 3rd–6th models in each set had only trivial weights (<5%). The south model was more complicated. In this case, the top-ranked model (logit, buffer = 1 mile) had less than half of the total weight (39.0%), and the second- (logit, buffer = 10 miles) and third-ranked models (logit, buffer = 100 miles) had substantial weights (25.0% and 23.4%, respectively). This suggests that buffer distance is less important in the south, and further justifies the use of the 10-mile buffer across the country.

5. DISCUSSION

We organize the discussion of results by this article's four main questions. Regarding the first question of how sensitive family forest owner wildfire concerns are to location-specific wildfire hazard, we find biophysical wildfire hazard has the expected effect of higher FFO wildfire concerns. Our findings confirm the positive relationship between location-specific wildfire hazard measures and FFO/homeowner wildfire hazard perceptions that has been shown to exist at the scale of ecoregions or states also exist at the broader scale of the continental United States.

Our second main question of inquiry was about regional differences in the level of concern for wildfire as well as differences in sensitivity to Wildfire Hazard Potential. The national model and predicted probabilities at the means for the three regional models show significant differences in the level of concern about wildfire between the West, South, and North regions. The level of wildfire concern tends to be highest in the West and lowest in the North with the South being somewhere in between, which confirms that baseline FFO concern for wildfire mirrors the broad regional trends of WHP.

Although we give consideration to regional tendencies in WHP in creating the North, South, and West regions, the significant level effects between the regions suggest an awareness of Wildfire Hazard Potential at a broad regional, or subcontinental, scale. In other words, FFOs seem to be sensitive to both localized Wildfire Hazard Potential as well as Wildfire Hazard Potential at distances far from their property locations. Most previous studies of FFOs and wildfire hazard tend to be geographically confined to areas where wildfire hazard is relatively higher than the surrounding landscape (e.g., DENG et al., 2015; Gan et al., 2014; Jarrett et al., 2009; Moorman et al., 2004). Our results indicate that fire-prone areas may put upward pressure on the wildfire concerns of property owners far away from such areas, even for landowners whose localized WHP is low. The awareness of hazard conditions at very long distances from FFO properties may be due to the far-reaching effects of wildfires that extend their impacts beyond likely burn areas, such as the long distances that wildfire smoke can travel. These results encourage additional research to explore how sensitivity to biophysical hazard may decay at different distances from landowner properties, as well as the multiple scales at which landowners think about biophysical hazard factors. While this study has considered three regions, future studies may employ different ways of geographically dividing respondents to check for consistency of results, perhaps sacrificing the number of respondents for finer geographic units.

Using regional predicted probabilities at the means, we isolate the impact of biophysical WHP on how likely the statistically average FFO in the North, South, and West regions are to express great concern about wildfire. Despite significantly different level effects, the predicted probability of great concern for wildfire at the means in the North and South converge to almost 50% for properties in the highest wildfire hazard areas in both regions. In the South, however, FFO concerns about wildfire are significantly less sensitive to the spectrum of WHP relative to FFOs in the West and North. Our approach also allows us to show that FFO sensitivity to the spectrum of WHP is similar between the West and the North, despite the level of concern being significantly higher in the West.

Our third issue of interest is at what distance from FFO properties biophysical wildfire hazard conditions become less relevant to owners' hazard concerns. Our results find that measures of WHP averaged over a 10-mile buffer from property locations tend to provide the best fit for modeling wildfire hazard concerns. The notable exception is in the South region, where averaging location-specific WHP at a 1-mile buffer provides the most parsimonious fit to the data. We note that the region where the relatively smaller buffer is the best fit to the data, the South, is also the region with the lowest sensitivity to the WHP spectrum of the three regional models. Our results suggest that FFOs may be aware of wildfire conditions at a broader geographic scale than the 1-km buffer used by Fischer et al. (2014).

The last aspect of wildfire concerns and biophysical wildfire hazard we explore is if FFO concerns and biophysical wildfire hazard show a nonlinear relationship. Our results show that the natural log of our biophysical hazard measure, WHP, is generally a better fit to FFO wildfire concerns than the untransformed measure for all models we run. In other words, FFOs tend to be disproportionately overconcerned about wildfires in areas with low hazard potential compared to FFOs who own properties with relatively high biophysical wildfire hazard potential. Even in the most fire-prone areas in the Western United States, the statistically average respondent still only has a 75% likelihood of expressing great concern about wildfire. We note the limitation that WHP includes both past actual wildfire as well as prospective wildfire conditions, and encourage additional research attempting to disentangle the impact of past experience and future expectations on FFO wildfire concerns. As a potential proxy for past experience with wildfire, the negative and significant sign on ownership tenure only in the Western regional model suggests a possible learning effect in which owners in the West may learn to accept wildfire as a part of natural landscape dynamics or, alternatively, become less concerned about wildfire the longer they own their properties.

Nonbiophysical determinants of FFO wildfire concerns are also critical to our results. In the West and South regional models, the full spectrum of WHP exposure has a similar impact on respondent wildfire concern as having a strong emotional attachment to the land and receiving information about wildfire within the past 5 years. Even in the North regional model, the odds ratios of having a strong emotional attachment to one's land (1.878) and having received information about wildfire in the past five years (1.693) are still substantial considering the prevalence ratio of WHP (2.807) shows the impact of the greatest possible difference in WHP exposure. Our results suggest that nonbiophysical factors are likely as important or more important to the formation of FFO wildfire concerns than biophysical wildfire hazard.

A strong emotional attachment to one's forestland consistently has the largest, or one of the largest, effect sizes in all models. Our findings suggest the topic of wildfire itself may be strongly emotional for many landowners. Accordingly, emphasizing ties to the land should be a strong component of the messaging for FFO wildfire education and outreach. Receiving information and advice about fire safety consistently has the second largest effect size on concerns, notwithstanding the prevalence ratio of WHP. It is important to note that while WHP can be considered exogenous to FFO wildfire concerns, there is likely a selection effect among owners who seek out information and advice about fire safety. Nevertheless, the significance of receiving information and advice on wildfire concerns further underscores the importance of education and outreach to FFOs about wildfire prevention and mitigation efforts.

University educated FFOs tend to be more aware of and concerned about environmental issues (Håbesland et al., 2016; LeVert, Stevens, & Kittredge, 2009; Nordlund & Westin, 2010); however FFOs with a university education tend to be less concerned about wildfire in the North and South regions. In the West regional model, the effect of education on concern is not significant. One possible interpretation of the negative and significant effect of university education on wildfire concerns among respondents in the South and North may be that these individuals are better able to interpret the lower overall landscape scale hazard in their regions. If this interpretation is valid, it may explain why university education is not significant in the West: wildfire hazard conditions in the West may be so salient that FFOs are aware of the higher regional-level hazard regardless of education. We acknowledge these results raise the question of why education has a seemingly opposite effect on concern than what is typically found in the FFO literature and encourage additional research to explain the link between education and FFO wildfire concerns.

The insignificance of population density in the census tract where FFO properties exist in all models is also important. Although areas with higher population densities may be prioritized by policymakers as more vulnerable to wildfire (such as areas of the Wildland-Urban Interface), policymakers need to be aware that owning a forest property in a more densely populated area does not increase FFO concern about wildfire on their properties. Conversely, FFOs in the western United States also tend to be more concerned about wildfire if they have a primary or secondary residence on their properties, while the presence of house on FFO properties is not associated with higher concern for FFOs in the northern or southern regions of the United States.

Policymakers in western U.S. states may therefore consider exploring different strategies in FFO wildfire education and recruitment into wildfire prevention programs for owners with houses on their forest properties compared to owners without houses on their properties.

Finally, we acknowledge the that while the variable inflation factor results show no substantial presence of multicollinearity in the regional models, McFadden's and Tjur's pseudo R-squared statistics show overall model fit is modest. Given that the main focus of this articles is testing the relationship between location-specific wildfire hazard potential and wildfire concerns, it seems unlikely that modest model fit is due to the absence of a relevant biophysical wildfire-related variable. The large effect sizes of emotional attachment and receiving information about wildfire on predicting wildfire concern suggest, however, that the inclusion of nonbiophysical wildfire characteristics may be important to improving models of wildfire concern.

6. CONCLUSIONS

This article investigated the relationship between FFO wildfire concerns and biophysical WHP using a sample of landowners across the contiguous United States using data from the USDA Forest Service's 2018 NWOS. Results show FFO wildfire concerns are sensitive to both broad regional-level hazard conditions as well as WHP in the specific locations where FFO properties exist. We find a tendency for FFOs to be disproportionately over-concerned about wildfires in locations with low hazard potential compared to FFOs who own properties with relatively high biophysical wildfire hazard potential. Practically, the allocation of public resources for wildfire prevention and adaptation may give consideration to FFO concerns, but should not be based too strongly on landowner hazard perceptions since such a strategy would divert needed resources to areas with relatively lower location-specific wildfire hazard conditions.

One unique aspect of this study is the broader geographical coverage of FFOs with forest properties existing across a greater spectrum of wildfire hazard exposure than existing studies. We find the level of wildfire concern is higher among FFOs in the fire-prone western United States; however, western FFOs have a similar sensitivity to the spectrum of WHP as FFOs in the northern United States. Furthermore, the sensitivity to location-specific hazard is lower in the South, and the plausibility of the Wildfire Hazard Potential buffer of best fit in the South regional model is substantially lower relative to the buffer measures of best fit in the North and West regional models. Among a host of potential explanations, it is possible that perceptions of prescribed burns in the South may be conflated with wildfires or that the Wildfire Hazard Potential measure itself does not capture the key biophysical drivers of wildfire concerns in the South region of the country as well as it does elsewhere. From a research standpoint, these results suggest an opportunity for further exploration into how and why wildfire perceptions in the United States southeast differ the rest of the continental United States.

Aside from biophysical WHP and regional location, landowners' emotional attachment to their forest properties and the information they have received about wildfire in the past five years consistently have the largest impact on FFO wildfire concerns. We also find that nonbiophysical factors are as important or more important to the formation of FFO wildfire concerns than the full spectrum of WHP exposure. Accordingly, although the main focus of this article is on location-specific wildfire hazard potential and FFO wildfire concerns, policymakers and service providers should understand that nonbiophysical factors, such as wildfire outreach and education efforts, are vital to the formation of forest owner hazard concerns.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Supplementary material