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Understanding support for regulatory approaches to wildfire management and performance of property mitigations on private lands

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ABSTRACT

Formal regulation of private property and exploration of "risk transmission" across ownerships are two popular means for addressing wildfire management at landscape scales. However, existing studies also indicate that a number of barriers exist for implementing formal regulations surrounding wildfire risk, and that few efforts gauge influences on the resident support that serves as an important antecedent to implementation. Likewise, few studies of risk transmission incorporate social science literature to explore whether perceptions of wildfire sources influences support for regulatory approaches or performance of individual mitigations. The research presented here employed mixed-method, residential surveys of private property owners in Pend Oreille County, Washington, to explore potential influences on residents' support for regulatory approaches for wildfire management on private properties, including perceptions of risk sources across the landscape and whether wildfire is a healthy component of the landscape. We also explore how the above factors, and other correlates such as part-time residency or proximity to neighboring properties, might influence the performance of private property mitigations across a range of rural properties in a larger landscape. Results suggest a low level of support for private property regulation for wildfire risk management and reduced wildfire response on properties where fewer personal mitigations are taking place. Consideration of wildfire risk sources and participation in collaborative actions or programs all had mixed effects, with perceptions of human ignitions on private lands correlating with support for property regulation and perceptions of human ignitions on public lands interacting with collaborative actions to correlate with higher levels of mitigation performance on individual properties. Results indicate that participation in wildfire actions and existing outreach programs were both relatively low in the landscape, and that engagement with such efforts do not significantly correlate with support for regulatory efforts. We conclude by comparing our findings to existing wildfire social science and suggesting future efforts or interpretations designed to advance a more nuanced view of the tradeoffs that private residents engage in when considering how their actions support landscape level wildfire management.

1. Introduction

Discussions about wildland fire management increasingly revolve around collaborative strategies that reach across land ownerships to require varied management responsibilities among public land management agencies, local governments or private residents (Fischer et al., 2016; Steelman, 2016; Kelly et al., 2019). The evolution of these more holistic calls for wildfire management focus on the aggregation of existing actions, mitigations, or collaborations among different stakeholder groups at broader scales to promote "shared stewardship" of the increasing burdens wildfire creates across their common landscape (USDA Forest Service, 2018; Fischer et al., 2019). However, existing research also indicates that the promotion of shared stewardship requires a fuller understanding of the contributions private landowners are willing to make given their current understandings about wildfire risk, their participation in collaborative efforts related to its management, and the mitigation efforts they have already undertaken on their properties (Brenkert-Smith et al., 2006; Roos et al., 2016; Charnley et al., 2019; Paveglio et al., 2018a). The efforts outlined in this research respond to that lack of understanding by exploring the relationships between private landowners' support of land-use planning regulations, participation in various wildfire programs, and their perceptions about sources of wildfire risk where they live.

Two increasingly prominent approaches for landscape-level wildfire management include regulation of residential development or requirement of mitigation actions in fire-prone areas (National Fire

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Protection Association (NFPA), 2013; Syphard et al., 2013; Bustic et al., 2017; Mockrin et al., 2018) and simulation of wildfire "risk transmission" across ownerships (e.g. US Forest Service, private lands, Bureau of Land Management, state lands) to coordinate risk reduction across land ownership boundaries (Ager et al., 2017, 2018; Palaiologou et al., 2019). Increasing calls for formal requirement of mitigations such as fire-resistant building materials or vegetation management standards around private structures and government restriction of expanding residential development in particular areas of high fire risk are the extension of research implicating the significant impact that residential expansion has on the complexities of wildfire management, best practices for reducing losses or damages to private structures, and educational initiatives or mitigation programs focused on promoting resident responsibility for reducing wildfire risk on their properties (Cohen, 2008; Calkin et al., 2014; Syphard et al., 2017). We refer to these practices as regulatory approaches or formal regulations throughout the manuscript. Other segments of wildfire literature indicate that formal regulations for residential wildfire management may not be feasible in many areas at risk given that they require support, adoption and coordinated enforcement among residents and professionals (Winter and Fried, 2000; Buxton et al., 2011; Mockrin et al., 2020; Paveglio et al., 2018a, 2019b; Edgeley et al., 2020). The incompatibility of existing findings suggests there is a need to more comprehensively explore what influences residents' perspectives about land-use or property regulations regarding fire and their relationship with engagement in existing wildfire education or management initiatives.

The expanding focus on risk transmission or "transboundary wildfire risk" among landownerships reflects a growing desire to understand how wildfire management is shared by landowners in common regions and prioritize mitigation efforts that best reduce potential risk to different human actors (Alcasena et al., 2017; Ager et al., 2018; Palaiologou et al., 2019). Such studies also relate to broader findings implicating the importance of human attributions about the sources of their fire risk (e.g. ignition source, high fuel loadings) across different landownerships—and the ways those perceptions can influence their willingness to contribute toward collaborative efforts for managing wildfire in a shared locality (Prior and Eriksen, 2013; Fischer et al., 2014; Paveglio et al., 2018b; Schumman et al., 2020). Residents' perceptions of risk as stemming from neighboring landowners or agencies are often noted as an implicit influence on views of adaptation efficacy (Al Abri and Grogan, 2019; Warziniack et al., 2019), yet few research efforts explicitly correlate them with performance of wildfire mitigations on private properties, support for formal regulation of private residential development, or perceptions about the broader role of fire in a landscape. Exploration of these linkages is particularly salient given that one current focus of wildfire management policy is the performance of region-wide risk maps as a means to prioritize investments in fuels reduction or restoration activities through initiatives related to "shared stewardship" (Stephen Sepp Wildfire Suppression Funding and Forest Management Activities Act, 2018; USDA Forest Service, 2018).

The research presented here employed residential surveys with a geographically stratified sample of private residential landowners in Pend Oreille County, Washington. The geographically stratified nature of our sample was intended to capture a gradient of residential development conditions in the area ranging from dense lakeside properties to rural, remote parcels bordering public lands. Exploration of the topics implicated in this research responds to multiple calls for targeted exploration of: (1) the feasibility of or influences on support for land-use planning regulations in rural portions of the fire-prone American West; (2) empirical evidence pertaining to residential participation in wildfire mitigation initiatives, programs, or outreach opportunities; and (3) a better understanding of the ways that perceptions of cross-boundary wildfire risk influence adaptation actions among residential populations.

2. Components of a whole: Resident responsibility and regulation

2.1. Regulation and voluntary restrictions

Government regulation of ongoing residential development patterns and efforts to require mitigation actions among private landowners in fire-prone areas have long been considered potential strategies in a larger portfolio of actions designed to promote societies that can "better live with fire" (Haines et al., 2008; Bond and Mercer, 2014; Moritz et al., 2014; Smith et al., 2016; Kelly et al., 2019; Paveglio and Edgeley, 2020). Yet calls for stricter regulation of private residential property in fire-prone areas of the United States and elsewhere have grown following increases in fire-related deaths or injuries, suppression costs, and property damages. Existing research frequently indicates that continued residential development in and near wildland vegetation (what some call the Wildland Urban Interface or WUI) expose growing populations of residential homeowners to wildfire risk and has the potential to increase the number of human ignitions (Llausàs et al., 2016; Clark et al., 2016; Butsic et al., 2017; Nagy et al., 2018; Radeloff et al., 2018). As a result, a number of authors suggest that regulating future development in high fire risk areas (i.e. either restricting its occurrence in key places or dictating the density or construction materials of structures) can serve multiple goals, including coordination of landscape level management or reducing wildfire risk (Alexandre et al., 2015; Kocher and Butsic, 2017; Mockrin et al., 2018; McWethy et al., 2019). Likewise, programs such as the Community Planning Assistance for Wildfire (CPAW) or the development of specific land-use and building standards such as the International Wildland Urban Interface Code are intended to provide communities with the considerations necessary to help reduce wildfire (CPAW, 2020; International Code Council (ICC), 2018).

Efforts to require fire resistant building or vegetation management surrounding private properties in the WUI are often mentioned in concert with broader land use management as a way to address the growing "fire problem" that stems—at least in part—from the complexities of managing fire in a landscape with significant private property interests (Charnley et al., 2019; Cyphers and Schultz, 2019; Schumann et al., 2020; Carreiras et al., 2014). Collectively, these approaches constitute what we also refer to as regulatory approaches throughout the manuscript. Requirement of property mitigations is the extension of foundational research into the factors that increase the potential for structure damage during wildfire events. For instance, much of the outreach materials provided to private landowners about wildfire mitigation in the U.S. stems from work on the Home Ignition Zone (HIZ)—the 100- to 200-foot radius surrounding a structure whose composition has been demonstrated to significantly impact structure losses during wildfire (Cohen, 2008; Mell et al., 2010; Calkin et al., 2014). HIZ research and a larger body of work on material flammability both suggest that encouraging or requiring fire-resistant building materials (e.g. metal roofs, asphalt shingle siding, small vent screening, etc.) would decrease the potential for structure damage during prolonged episodes of ember showers, radiant heat or direct exposure to flames (Quarles et al., 2010; Syphard et al., 2017).

Existing evidence suggests that formal land use regulations or mitigation requirements are being adopted inconsistently across many fire-prone areas (Buxton et al., 2011; Stidham et al., 2014; Paveglio et al., 2015; Mockrin et al., 2018; Edgeley et al., 2020). Moreover, recent research efforts in the U.S. have noted relatively high rebuilding rates in residential areas damaged by fires and a subsequent lack of changes to residential building or development codes in those same areas (Alexandre et al., 2015). The seeming inconsistency of support for formal regulation of private properties for wildfire indicates a need to more comprehensively explore what influences such outcomes among private citizens.

To begin, there is a large body of research demonstrating a desire for many rural residents to be independent or free of government

control on their private property (for wildfire-specific examples see Brenkert-Smith et al., 2005; Paveglio et al., 2016a; Stasiewicz and Paveglio, 2018; Rasch and McCaffrey, 2019). Such sentiments are particularly strong in select U.S. localities where private property rights can be integral parts of shared identity. Populations characterized by independence or distrust of the government may oppose, ignore or move away from locations where they perceive that government structures such as regulations are impinging on their private property rights, even if those actions might help reduce wildfire risk (Paveglio et al., 2019a, 2019b; Edgeley et al., 2020).

Efforts to regulate private property are reported as more successful in formal subdivisions that feature homeowners' associations, existing development codes or heavily managed landscapes with professional maintenance (McCaffrey et al., 2011; Stidham et al., 2014). Residents in these localities may be: (1) more supportive of shared standards and vegetation management that reduces their inherent risk (Harris et al., 2011; Olsen et al., 2017); (2) willing to concede some of their autonomy to larger governing bodies (Winter et al., 2009; Paveglio et al., 2016b); (3) more trusting of professional insight (Paveglio et al., 2019a); or (4) more comfortable with design standards that characterize the structure of their locality (Paveglio et al., 2015; Kolden and Henson, 2019).

City ordinances and the International WUI code provide avenues for "scaling up" land use planning or private property mitigations for wildfire across larger landscapes. A number of jurisdictions have adopted the International WUI code or other standards that provide guidance on building materials, ingress/egress requirements, and standards for residential sprinklers in high risk areas. However, counties, fire districts or other levels of government: (1) are not necessarily required to adopt all portions of existing codes; (2) may relax or remove certain restrictions that conflict with their priorities; or (3) might lack the human capacity, budget or resources necessary to enforce mitigation standards across large numbers of residential parcels (Brzuszek et al., 2010; Muller and Schulte, 2011; Bardsley et al., 2015; Mockrin et al., 2018, 2020; Paveglio et al., 2019b).

One common thread influencing the above results concerns the significant, but often implicit influence that private landowner support or acquiescence has on regulatory strategies for managing wildfire risk at broader scales. Failure to understand what influences resident support or opposition with regard to regulatory approaches for wildfire management, including how to work with private landowners in the design of such regulations or the factors that might encourage their adherence, will likely result in approaches that do not achieve their intended purposes (Paveglio et al., 2013; Mockrin et al., 2016; Edgeley et al., 2020; Carreiras et al., 2014). Likewise, the adoption of wildfire mitigation requirements at any of the scales discussed above often requires a vote or formal adoption by officials representing the broader constituencies that they serve. Elected representatives may be unwilling to support formal regulations for wildfire, or enforce them, if they feel that they lack constituent support (Muller and Schulte, 2011; Wilson et al., 2018). In sum, some recent studies calling for stricter land-use planning or requirement of residential mitigations lack discussion about the important need for regulatory approaches that resonate with or become part of the "culture" of a place. They seem to assume, through their focused discussions of alternative future scenarios or simulations, that individual actors will quickly forgo their autonomy to achieve a collective good that is contingent on the uncertain behaviors of many independent actors.

The vast majority of efforts designed to promote "smart" residential development or personal mitigations for wildfire have revolved around voluntary programs, homeowner education initiatives, and community planning efforts that have long grappled with the challenges of promoting individual action for the collective good (Jakes et al., 2011; McCaffrey, 2015; Koksal et al., 2019; Warziniack et al., 2019). Accordingly, a large body of research explores the factors that influence residents' decision to undertake mitigation actions recommended by existing outreach efforts, and which may have a bearing on support for regulatory approaches. Some common factors influencing performance of voluntary mitigations include: (1) availability of technical assistance or information about best practices; (2) perception of potential risk from wildfire; (2) demographic factors such as age, income and education; (3) perceptions about the role of fire in a landscape (e.g. as a healthy component of landscape processes or damaging to vegetation) and the types of human management that should occur in wildland areas; and (4) and whether residents are part-time or full time residents of the area, among others (Ojerio et al., 2011; Brenkert-Smith et al., 2012; Newman et al., 2013; Olsen et al., 2017; Meldrum et al., 2018, 2019; Paveglio and Kelly, 2018).

For instance, a number of studies have demonstrated that part-time residents may be less inclined or motivated to perform wildfire mitigation actions because they spend less time in those locations, feel that wildfire is less of a risk to their personal safety, consider insurance on the property to be a reasonable mitigation, or prefer the privacy afforded by dense vegetation (Absher et al., 2009; Eriksen and Gill, 2010; McCaffrey et al., 2011; Paveglio et al., 2016b).

Thus, there is ample indirect documentation that participation in wildfire outreach, collaborative planning, or incentive-based programs may increase voluntary completion of specific wildfire mitigations on private property. However, fewer research efforts focus explicitly on whether increased exposure to or participation in wildfire planning and outreach programming (e.g. Firewise, home assessments, Community Wildfire Protection Plans, wildfire briefings) correlates with mitigation action across the HIZ or support for broader initiatives to regulate residential property for wildfire. There also has been little exploration as to whether engagement in educational or collaborative programs surrounding wildfire management correlates with perceptions about the sources of wildfire risk, which we introduce in the next section, and their perspectives about the role of fire as a naturally occurring disturbance agent. Exploring such linkages is important given the large focus on private landowner assistance, education or engagement that has characterized wildfire management for the past 20 years, and because such programs are a primary way that many residents come to understand how they can contribute to societal goals of "living with fire."

2.2. Transmission, ignition and the science of blame

Research on "risk transmission" illuminates the risk contributions of public and private landowners whose fire-related actions are interdependent across landscapes. Researchers exploring the concept simulate past or future fire occurrence in a landscape to distinguish the potential for "transmission" of fire to and from various public lands (e.g. U.S. Forest Service, state department of lands, county lands) or private landowner classifications (e.g. private forest industrial, The Nature Conservancy, aggregated residential landowners) (Ager et al., 2016, 2017; Alcasena et al., 2017). Simulations of risk transmission result in metrics such as the number of fire ignitions in each land management class, the proportion of simulated fires that cross into or pass through other land management classes, and the number of fires originating in each land management class that expose different values-at-risk (e.g. forested public land, private structures) to potential fire damages (Ager et al., 2018; Palaiologou et al., 2019).

Risk transmission research and the broader science of wildfire risk simulation that it builds from continue to have a significant influence on policy approaches for managing wildfire at landscape scales (see Calkin et al., 2014; USDA Forest Service, 2018). Yet despite their growing popularity, there is less evidence that the understandings implicated in risk transmission studies (i.e. attribution of risk sources to various landowners) influences the ways that landowners address wildfire on their properties. More specifically, few studies directly explore how landowner perceptions about the sources of wildfire risk to their properties, or their contribution to broader wildfire risk in the landscape, might influence their willingness to support collective fire

management initiatives (Fischer et al., 2014; Charnley et al., 2017, 2019; Paveglio et al., 2018b).

Foundational concepts underlying risk transmission share much in common with ideas that have long been implicated in wildfire social science and hazard studies. For instance, early studies of wildfire hazard note the tendency for human actors to attribute wildfire risk to other actors in a landscape or blame them for impacts based on the source and type of a fire ignition (i.e. human caused or natural ignition, agency ignition on public lands). Other authors note how such attribution can extend to tactics taken to suppress the fire or to the ecological conditions surrounding increased wildfire risk (e.g. high fuel loadings, past forest management practices) (Kumagai et al., 2004a, b; Carroll et al., 2005; Edgeley and Paveglio, 2017). The result has been one source of longstanding disagreements about the management of wildland fuels and potential influence on landscape level coordination of wildfire management (Carroll et al., 2006, 2007; 2011; Shindler et al., 2014; Paveglio and Edgeley, 2017). Collectively, existing findings are a good reminder that while additional knowledge about the source of wildfire risk can be helpful, they also have the potential to reduce collaborative potential if they result in populations whose blaming behavior creates an inability to compromise on shared standards for taking collective responsibility.

Select segments of wildfire social science implicate the ways that neighbors' actions might influence private landowners' willingness to conduct mitigations on their properties, though findings are mixed (Prante et al., 2011; Meldrum et al., 2018; Al Abri and Grogan, 2019). One emergent finding is the potential for positive mitigation action to spread among neighbors through the effective use of demonstration properties, collective peer pressure, or the development of shared values emphasizing shared risk (Charnley et al., 2017; Warziniack et al., 2019; Canadas and Novais, 2019). Such "contagion effects" can be codified into support for formal regulations provided they reflect the culture of the area (Dickinson et al., 2015; Fischer et al., 2019; Paveglio et al., 2019b).

Residents' consideration of neighboring properties may also extend to public lands, although studies explicitly focusing on this relationship are somewhat harder to find. For instance, a number of studies have demonstrated how overstocked fuels or high fire risk conditions on neighboring public lands may increase residents' desire to perform mitigations on their property. Other studies indicate that such conditions can make residents apathetic or fatalistic about their own mitigation actions because they do not feel as though their efforts are needed or have the efficacy to overcome potential risk (Prante et al., 2011; Busby et al., 2012; Fischer and Charnley, 2012; Paveglio et al., 2016c; Paveglio and Edgeley, 2017; Gordon et al., 2018). Meanwhile, there is some evidence that the performance of agency fuel treatments or commitment to risk reduction might spur private mitigation nearby (Brenkert–Smith et al., 2006; Schultz et al., 2018; Charnley et al., 2019).

The above literature suggests that a range of contextual factors have the potential to influence residents' support for regulatory approaches to wildfire management, including participation in a variety of collaborative programs or educational initiatives designed to increase residential responsibility for shared wildfire management challenges. Likewise, existing research indicates that residents' understanding about the source or transmission of wildfire risk among landowners in a shared landscape may influence their support for mitigation actions. However, there also appears to be a need to explore these linkages in a more direct way. Accordingly, the following research questions guide our effort:

1 What are the relationships between participation in collaborative wildfire actions or mitigation programs, perceptions of wildfire risk sources, and support or opposition to formal regulation of private properties for wildfire?
2 What are the relationships between participation in collaborative wildfire actions or mitigation programs, perceptions of wildfire risk sources, and performance of mitigations by residents on private properties?

3. Methods

Researchers selected Pend Oreille County, Washington, as an initial study location due to previous qualitative wildfire research indicating that the area featured a range of rural populations grappling with the challenges of landscape level wildfire management, the role of fire in the landscape, and views about private property rights (Paveglio et al., 2019b). More specifically, past research results indicated that distinct populations of residents in the WUI areas of Pend Oreille County might express differential support for land-use planning or private property mitigations and that development in the area was often concentrated in homeowners associations or neighborhoods near large lakes, with a gradient of more rural populations at farther distances from the lakes. The county features predominantly rural populations not associated with any census designated city, which are also understudied in terms of perspectives about land use planning or risk transmission (Edgeley et al., 2020). Finally, Pend Oreille County features a high proportion of public lands used for recreation or resource extraction, high levels of amenity migration or second homes due to its proximity to Spokane, WA, and was impacted by the Kanisku Complex fires in 2015, which burned approximately 26,124 acres and cost $26.3 million to suppress (Northwest Interagency Coordination Center, 2015). As such, the area features many of the key factors which our literature review suggests may influence perspectives about wildfire regulation or risk transmission.

The final sample frame for this research was drawn from GIS parcel data obtained from the Pend Oreille County Assessor's Office and the Washington National Hydrography Dataset (Washington State Department of Ecology, 2020). Fig. 1 provides a map of the study area, including land ownership patterns. Researchers chose to narrow the sample frame to multiple geographic areas smaller than the county because: (1) existing literature suggests that perspectives of populations in rural areas can be highly inconsistent at larger scales (see Paveglio et al., 2018b) and (2) to densely sample in representative gradients of development types that characterize the region. Accordingly, researchers selected four lakes in the county featuring dense residential development near shorelines and created a spatially stratified sample frame consisting of three distinct zones extending from each lake (i.e. a geographically stratified sample). More specifically, researchers: (1) selected parcels with a centroid within 500 feet of each of the 4 lakesides (Zone 1) to capture individuals with the highest lake access and who past research indicate may be socially distinct populations (see Winkler et al., 2013 for overview); (2) selected any parcel with its centroid within a 1.5-mile buffer extending from the border of Zone 1 to create Zone 2; and (3) buffered an additional 1.5 miles from the border of Zone 2 and selected any parcel with a centroid in that area (Zone 3). Researchers further restricted the primary sample to buffers surrounding Diamond and Sacheen lakes because they featured the densest development near lakes and captured the most representative gradient of development types in the county. The 1.5-mile cutoff for buffers is associated with the distance firebrands can travel to ignite new fires and has been used in mapping of the WUI (Stewart et al., 2009; Platt, 2010; Prato et al., 2014). The approximately 3-mile buffer extending from each lake also resulted in the selection of parcels directly adjacent to and within close proximity to public lands (e.g., U.S. Forest Service, state lands) or private industrial forest that are often the focus of risk transmission studies. Thus, the approach provides a representative sample of residents whose perceptions about the sources of wildfire risk are likely to be grounded in potential transmission of fire across ownerships. The geographically stratified sample also provides a representative range of resident views across the study area. Researchers removed from the sample frame any property that did not contain a

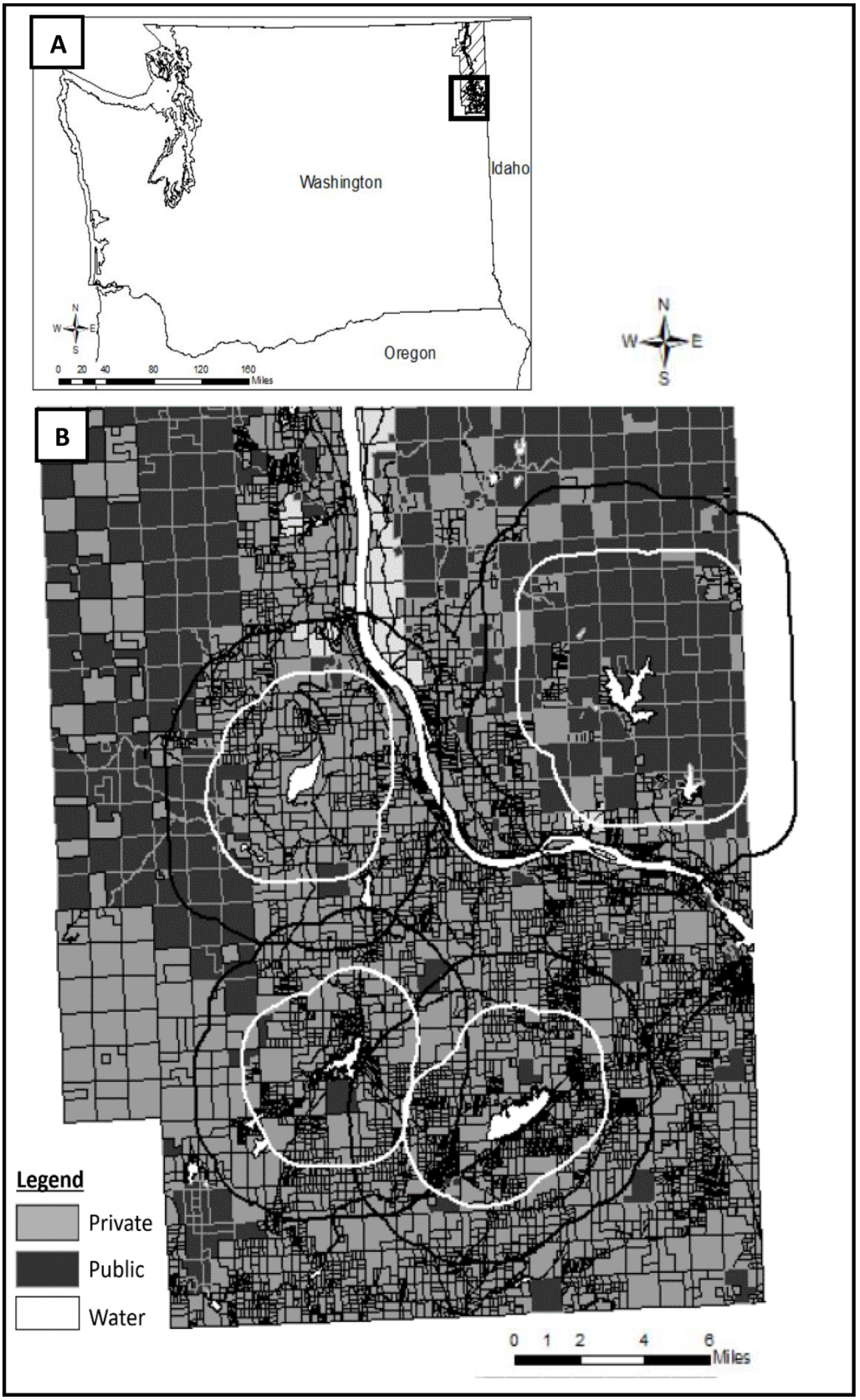

Fig. 1. (A) Location of study county and study area of Washington State, United States of America. (B) Public and private landownership within the study area. The white and black lines buffering the four lakes in B comprise the sample frame for the research.

residential structure, parcels associated with a land trust, parcels associated with businesses or timber use, and any apartments or condominiums. Owners with multiple residential parcels in the sample frame were restricted to inclusion through their primary taxable residential address in the region.

A group of researchers administered surveys to potential respondents in August 2018 using a mixed-mode approach featuring elements of a modified Tailored Design Method (Dillman et al., 2014) and the drop-off, pick-up method (Steele et al., 2001; Trentelman et al., 2016). Researchers used the aforementioned tax data to distinguish whether each residence in the sample was a primary or secondary residence and then assigned different administration methods for each category. A team of five researchers visited primary residences (n = 557) in person during the course of 15 days to hand-deliver surveys and inform residents about the purpose of the research using a shared protocol (i.e. drop-off, pick-up method). They arranged to collect completed surveys within 24 h of delivery and left notes about the survey or additional collection times when residents were not home. Researchers returned to each home in a systematic fashion multiple times to ensure adequate opportunities to participate or collect completed surveys.

Researchers administered a mail survey to the primary tax address of second homes in our sample frame. The sample frame for second homes was extended to all four lakes considered in the initial sample selection due to the propensity for lower response rates among second homeowners and when using mail survey administration (n = 956). Mail administration also took place in August 2018 and featured the following mailings adapted from Dillman et al.'s (2014) Tailored Design Method: (1) an introductory letter explaining the purpose of the study; (2) a paper copy of the survey with a prepaid return envelope and link to an online version of the survey; (3) a post card reminder with a link to an online version of the survey; and (4) a final reminder letter.

Researchers administered surveys to a total of 1513 residential landowners using the combination of the above approaches. They obtained a total of 744 completed surveys for a combined response rate of 49.2 %. Response rates for the drop-off, pick-up effort (445 completed surveys, 79.9 % response rate) were substantially higher than the mail/online effort (299 completed surveys, 31.3 % response rate) which is consistent with past research indicating lower response among second homeowners and when using mail administration.

The survey employed a series of 5-point, Likert-scale, agree-disagree statements that gauge residents support or opposition to land-use planning or property owner regulations surrounding wildfire mitigations (see Table 1 for a full list of statements). These measures are adapted from past surveys on perceptions of wildfire mitigation (see for instance Paveglio et al., 2018b). Select statements also implicated potential reduction in fire suppression resources for residents who do not perform mitigations. Perceptions about potential outcomes of wildfire and its role as a landscape process were also measured using a series of agree-disagree statements (see Table 1). These measures are adapted from past surveys on residents' perceptions of wildfire impacts (see Kooistra et al., 2018).

Two overarching questions asked respondents to indicate whether they had participated in a variety of planning, education, incentive or mitigation programs commonly used for wildfire management. The first of these questions asked residents to indicate whether they had participated in a series of wildfire mitigation programs or actions in Pend Oreille County, in another location, or not at all. Researchers collapsed "yes" answers for Pend Oreille County and in other locations to better implicate the influence of the programs regardless of location and to ensure a high enough number of responses for later statistical analysis. A full list of programs, incentives or actions are provided in Table 2. A second question asked whether respondents had participated in a series of collaborative local actions (i.e. anything in Pend Oreille County) related to reduction of wildfire risk.

A separate set of questions measured residents' perceived sources of wildfire risk to the area where they live. More specifically, the question employed a series of Likert-scale, agree-disagreement statements gauging whether respondents felt risk came from private lands, public lands, or commercial lands in the region. Also included in this series of questions were statements about whether fire risk stemmed from human ignition on either private lands or public lands (see Table 1). Both measures reflect lessons from the literature review above and help explore how fire origin or perceived "risk transmission" influence subsequent views about appropriate fire management.

Another set of questions asked residents about wildfire mitigation actions they might have undertaken to reduce wildfire risk on their property (see Table 3 for a full list). These questions are adapted from existing research on the HIZ and aggregate commonly advocated practices for achieving risk reduction (Paveglio et al., 2013, 2016c;National Fire Protection Association (NFPA), 2013). The work described here extends those past efforts by including a set of potential actions that residents may have taken beyond Zone 3 of the HIZ (greater than 200 feet) to capture activities that may be undertaken by rural residents with larger properties, which is the case for a portion of our sample. Researchers grouped respondent answers into six numerical categories based on past research (Stockmann et al., 2010; Prato and Paveglio, 2014; Paveglio et al., 2016c; 2018) and consultation with wildfire mitigation experts: (1) no mitigation; (2) light mitigation; (3) heavy mitigation; (4) full mitigation; (5) full mitigation extended; and (6) full mitigation heavy. Higher levels of mitigation denote a greater number of mitigation activities performed in different zones of the HIZ and would correspond with lower probability of potential wildfire losses. Residents had to perform at least two actions from block 1 mitigations outlined in Table 3 to achieve light mitigation and all four actions from block 1 to achieve heavy mitigation. They had to perform all the requirements for heavy mitigation and at least two actions from block 2 to achieve full mitigation. Residents had to perform all the requirements for full mitigation AND at least one action from block 3 to achieve full mitigation extended, and all actions for full mitigation extended and at least two actions from block 4 to achieve full mitigation heavy. A separate question asked residents to indicate how close their nearest neighbor's property line is to their residence, with choices implicating the different zones of the HIZ (i.e. equal to or less than 30 feet, between 30 feet and 100 feet, between 100 feet and 200 feet, more than 200 feet away) in order to evaluate whether property size or composition is a factor in performance of commonly suggested mitigations.

Finally, the survey included a series of demographic questions that are commonly included in social science research on performance of wildfire mitigation actions or perspectives about wildfire management, including: (1) full-time or part-time resident, where a part-time resident is anyone who spends six-months or less per year at the property; (2) level of education; (3) income (including retirement income); (4) age; (5) retirement status; and (6) length of time living in the residence (i.e. tenure). Researchers recoded both residency and retirement status as binary variables and dummy coded them for subsequent regression analysis.

3.1. Analysis

Trained coders entered all data collected from the survey into the quantitative software package SPSS 25 using a consistent protocol. Researchers conducted a series of factor analyses using the principle axis factoring method and an oblique rotation to inform the creation of composite measures related to perceptions about land-use and property regulation, restricted firefighting resources, negative impacts of wildfire and wildfire as a healthy landscape component (Stevens, 2009; Field, 2013). Interest in the creation of composite measures reflects lessons from the literature reviewed above. For instance, existing literature suggests how perspectives about the role of wildfire in the landscape (e.g. healthy or damaging) influence mitigation action and

Table 1
Descriptions of composite variables and perceptual independent variables examined.

Variable Name	Variable Definition *Measures with a Cronbach's α are a summed, composite variable using a principle axis factor analysis. Missing values were not used in analyses.*		Descriptive statistics		
			N	Range	Mean (SD)
Support for property owner regulations	*α =.70*	• Homeowners in high fire risk areas should be required to reduce vegetation on their property to reduce their wildfire risk • Regulations should prohibit building homes near wildland areas where they could be burned by fires • Homeowners in high fire risk areas should be required to build or retrofit their properties with fire resistant materials to reduce their wildfire risk	696	−2 = Strongly disagree −1 = Moderately disagree 0 = Neither agree nor disagree 1 = Moderately agree 2 = Strongly agree	−0.37 (0.97)
Support for restricted firefighting resources	*α = .92*	• Property owners who do not reduce fuel loadings on their private property should not receive firefighting resources during a wildfire event • Homeowners who do not build and landscape their homes to reduce wildfire risk should not receive firefighting resources in the event of a wildfire	693	−2 = Strongly disagree −1 = Moderately disagree 0 = Neither agree nor disagree 1 = Moderately agree 2 = Strongly agree	−1.22 (1.02)
Negative perceived impacts from wildfire	*α = .67*	• Wildfire would make this area less attractive • This area would not feel like home any more if a wildfire burned through it • I would consider moving away if a wildfire impacted this area	682	−2 = Strongly disagree −1 = Moderately disagree 0 = Neither agree nor disagree 1 = Moderately agree 2 = Strongly agree	0.55 (.93)
Healthy wildfire	*α = .74*	• Wildfire would improve the health of this landscape • Wildfire is a natural and healthy part of this landscape	678	−2 = Strongly disagree −1 = Moderately disagree 0 = Neither agree nor disagree 1 = Moderately agree 2 = Strongly agree	−0.23 (1.10)
Public lands fire risk		• Most of the fire risk in this area comes from public lands	706	−2 = Strongly disagree −1 = Moderately disagree 0 = Neither agree nor disagree 1 = Moderately agree 2 = Strongly agree	−.020 (1.25)
Private lands fire risk		• Most of the fire risk in this area comes from private land	705	−2 = Strongly disagree −1 = Moderately disagree 0 = Neither agree nor disagree 1 = Moderately agree 2 = Strongly agree	0.43 (1.21)
Human ignition private		• Most of the fire risk in this area comes from human ignitions on private land	703	−2 = Strongly disagree −1 = Moderately disagree 0 = Neither agree nor disagree 1 = Moderately agree 2 = Strongly agree	0.76 (1.02)
Human ignition public		• Most of the fire risk this area comes from human ignitions on public lands	700	−2 = Strongly disagree −1 = Moderately disagree 0 = Neither agree nor disagree 1 = Moderately agree 2 = Strongly agree	0.50 (1.06)

the tendency for wildfire mitigation programs, initiatives and policies to associate vegetative or home construction regulations with larger land use development. The composition of measures that emerged from the factor analysis are reported in Table 1, along with reliability coefficients suggesting relatively reliable constructs. Researchers retained only those factors whose Eigenvalues exceeded 1 and individual items (i.e. measures) with factor loadings of at least 0.40 (Stevens, 2009; Field, 2013).

Creation of composite measures related to participation in wildfire programs, incentives or planning programs required a slightly different approach given that many authors advocate factor analysis using polychoric or tetrachoric correlations for binary variables (Holgado-Tello et al., 2010; Flora et al., 2012), which are not immediately possible using SPSS. As such, researchers conducted factor analysis for these variables using the FACTOR program developed by Lorenzo-Seva and Ferrando (2019) which uses polychoric/tetrachoric correlations. Experimentation with a variety correlations and rotations revealed that results from each question resulted in a single factor regardless of rotation or correlation matrix, providing a strong indication that each set of actions could be treated as a composite measure. Researchers created composite measures for each question by summing the binary measures in each question. The resultant measures are titled "collaborative wildfire actions" and "wildfire program actions" for simplicity.

Researchers conducted a series of multivariate regressions due to

Table 2
Composition of independent variables for participation used in the analysis.

Variable Name	*Variable Definition* Measures with an α (i.e. reliability statistic using a Kuder-Richardson 20 test) are a summed, composite variable using a principle axis factor analysis using polychoric/tetrachoric correlations. Missing values were not used in analyses. The percentage following each statement indicates the proportion of respondents who have participated in each action.		Descriptive statistics		
			N	Range	Mean (SD)
Collaborative wildfire actions	*α = 0.79*	*Sum of participation in the following (yes = 1, no = 0):* ● Attended or organized a wildfire information event (11.9 %) ● Contributed comments to a wildfire mitigation plan (5.6 %) ● Participated in a fuels reduction program (13.2 %) ● Participated in a wildfire planning meeting (4.8 %) ● Served on a local wildfire committee (2.3 %) ● Helped develop an evacuation or shelter plan (5%) ● Participated in an emergency management drill (5.9 %)	646	1 − 7	0.48 (1.17)
Wildfire program actions	*α = 0.71*	*Sum of participation in the following (yes = 1, no = 0):* ● Received a risk assessment of your property from professionals (15.9 %) ● Obtained a cost-share grant to reduce wildland fuels on your property (5.9 %) ● Received grant funding to retrofit your home or structures in a way that makes them more fire resistant (1.7 %) ● Participated in a coordinated effort among private landowners to reduce wildland fuels across properties (6.5 %) ● Participated in a coordinated effort among landowners to manage natural resources (e.g. weeds, streams, forests, etc.) across properties (6.5 %) ● Received grant funding to coordinate wildfire risk mitigation efforts across properties (12.1 %) ● Participated in a coordinated effort among private AND public landowners/managers to reduce wildland fuels (2.4 %)	695	1 − 7	0.49 (1.05)

Table 3
Mitigation questions for evaluating level of mitigation action.

Treatment area	Mitigation action[a]
Within 30 feet of the home (Block 1)	Removed trees less than 10 feet from your home Removed branches of trees lower than 10 feet from the ground Cleared or maintain a 30 ft "green space" around home Spaced trees or shrubs at least 10 feet apart
Between 30 feet and 100 feet of the home (Block 2)	Removed/thinned trees between 30 feet and 100 feet from the home Removed branches of trees lower than 10 feet from the ground Maintained thinning of trees and shrubs performed more than 10 years ago
Between 100 feet to 200 feet of the home (Block 3)	Removed/thinned trees and shrubs to reduce the density of vegetation Maintained thinning of trees and shrubs performed more than 10 years ago
Greater than 200 feet from the home (Block 4)	Removed/thinned trees and shrubs to reduce the density of vegetation Maintained thinning of trees and shrubs performed more than 10 years ago Used livestock grazing to reduce fuels Planted hay or other crops as a way to break up wildland vegetation Conducted a prescribed fire to reduce vegetation Established a fuel break to restrict fire spread Established a forest plan that includes periodic reduction of vegetation to reduce wildfire risk

[a] Performed during the past 10 years as reported by respondent.

the exploratory nature of the effort and interest in determining potential interactions between constructs across the entire study population. More specifically, researchers began by conducting separate regressions for each set of related independent variables (e.g. perceptions of risk from private and public sources) and a given dependent variable to explore significant correlations. Later multivariate regressions used results from initial outputs, including multicollinearity diagnostics, correlation matrices and changes in significance or beta values to explore the potential for moderation or mediation between select correlates from the first set of regressions (Field, 2013; Hayes, 2013). A final multivariate regression model for each dependent variable retains significant factors from earlier stages of the analysis to explore whether the addition of disparate constructs changed the structure of correlations and variance explained. Researchers used the PROCESS v3.4 extension to SPSS for moderation and mediation analyses (Hayes, 2019). Previous research used multinomial logistic regression in analysis of HIZ mitigation levels as a dependent variable (see for example Paveglio et al., 2013, 2016c). The effort described here deviates from that tradition for two reasons: (1) the mitigation actions included in this study create a larger number of mitigation levels resembling a Likert-scale graduation of effort and thus can be treated as ordinal data; and (2) because the research presented here focuses on understanding what influences greater levels of fuel reduction, not just the comparison of different levels of fuel reduction against a reference category, the latter of which is the purpose of multinomial logistic regression.

4. Results

Respondents across the study area reported a relatively low level of support for property owner regulations in the region (M = -0.37, SD = 0.97) and even less support for restricting firefighting resources to private landowners based on their mitigation activities (M = -1.22, SD = 1.02) (Table 1). There was moderate agreement among respondents that wildfire resulted in negative perceived impacts (M = 0.55, SD = 0.93) and a corresponding disagreement that wildfire was a healthy component of the landscape (M = -0.23, SD = 1.10).

However, the relatively high standard deviation for each of these measures provides a preliminary indication of variance in perspectives across residents in the sample frame.

Respondents reported relatively low levels of engagement with the actions constituting the collaborative wildfire actions variable (M = 0.48, SD = 1.17). Attending or organizing a wildfire information event and participating in a fuels reduction program were the most common actions respondents participated in. Participation in actions comprising the wildfire program actions variable (M = 0.49, SD = 1.05) also were relatively low, with receiving a risk assessment of the property from professionals and receiving grant funding to coordinate wildfire risk mitigation efforts across properties as the most common actions participated in by respondents.

Respondents perceived the highest source of fire risk as stemming from human ignition on private land (M = 0.76, SD = 1.02) followed by human ignitions on public lands (M = 0.50, SD = 1.06). Residents were more likely to agree that fire risk in the area came from private lands (M = 0.43, SD = 1.21), while on average they disagreed that public lands were the source of risk (M = -0.20, SD = 1.25). Standard deviations for these results indicate a high level of disagreement among respondents in the relatively small landscape selected for this sample frame and suggest a need to further evaluate the influence of individual values or perspectives associated with perceptions of fire risk source(s). This is one focus of the regression results presented below.

Approximately 32.1 % of respondents in the study area indicated that they had performed mitigations corresponding with the light mitigation category, 13.7 % performed mitigations consistent with heavy mitigation, and 5.8 % performed mitigations consistent with full mitigation. An additional 5.6 % of respondents indicated they had performed actions consistent with the full mitigation extended category and a final 7.9 % performed actions consistent with the full mitigation heavy category.

Select results of our multivariate models using support for property owner regulations as a dependent variable are presented in Table 4. Initial regressions of conceptually related variables indicated that perceptions of wildfire risk as stemming from human ignitions on private lands is significantly correlated with support for property regulation (β = 0.134, p = 0.004). That is, as belief that most fire risk in the area comes from human ignitions on private lands increased, support for private property owner regulations also increased. Agreement that wildfire is a healthy component of landscapes (β = 0.093, p = 0.028) and agreement that wildfire would result in negative outcomes in the area (β = 0.090, p = 0.037) were both positively and significantly correlated with support for property owner regulations. Age was significantly correlated with support for property owner regulations, with older residents more likely to support property regulations (β = 0.156, p = 0.004). Finally, part-time residency status was positively and significantly correlated with support for property owner regulations (β = 0.094, p = 0.026), with part-time residents more likely to support such initiatives when compared to full-time residents. Neither participation in collaborative wildfire actions nor wildfire program actions were significantly correlated with support for regulatory approaches to wildfire management among property owners.

Table 4
Results of regressions for support for property regulation.

	Model sets 1			Model sets 2		
Independent variable	SE(b)	β[a]	p[b]	SE(b)	β[a]	p[b]
Collaborative wildfire actions	.039	.054	.224			
Wildfire program actions	.031	.013	.667			
Adjusted R^2			.004			
Public lands fire risk	.044	.084	.129			
Private lands fire risk	.035	.040	.346			
Human ignition private	.045	.134	.004**	.038	.108	.006*
Human ignition public	.041	.029	.618			
Adjusted R^2			.028			
Healthy wildfire	.037	.093	.028*	.037	.125	.004*
Wildfire impact	.090	.090	.037*	.044	.049	.252
Healthy*impact	.034	.007	.857			
Adjusted R^2			.007			
Age	.004	.156	.004**	.003	.128	.002**
Education	.033	.045	.279			
Retired	.105	−.027	.612			
Part time	.083	.094	.026*	.079	.118	.003*
Adjusted R^2			.030			.052

[a]Standardized regression coefficient b. p = p-value, *p < .05, **p < .01, and ***p < .001.

Examination of initial regressions and collinearly diagnostics prompted additional analysis of conceptually related variables. More specifically, we introduced an interaction term for the healthy wildfire and wildfire impact variables (i.e. moderation analysis), which did not result in a significant effect (β = 0.007, p = 0.857). We also explored a potential mediation effect between perceptions of risk as stemming from human ignitions on public land and human ignitions on private lands due to their conceptual relationship. Results of the mediation analysis indicate that there was a significant indirect effect of perceived risk from human-caused ignitions on public lands on support for property regulation though risk from human ignitions on private lands (β = 0.492 BCa CI [.0118, .863]). This represents a relative moderate effect (K^2 = 0.053, BCa CI 95 % [.0129, .0920]). A final multivariate regression model combines those variables that were significant in earlier models (see column 2 of Table 4). The amount of variance explained in this model is relatively small (R^2 = 0.052) and consideration of negative wildfire impacts loses its significance. Human ignition on private lands (β = 0.108, p = 0.006), wildfire as a healthy component of the landscape (β = 0.125, p = 0.004), age (β = 0.128, p = 0.002) and part time residency (β = 0.118, p = 0.003) all remain significant correlates with support for property regulation.

Select results of our multivariate regressions using support for restricted firefighting resources as a repercussion for not mitigating personal risk are presented in Table 5. Initial regressions of conceptually related variables indicate that participation in collaborative wildfire actions (β = 0.145, p = < 0.001) and support for property regulation (β = 0.350, p = < 0.001) were each positively and significantly correlated with support for restricted firefighting resources. That is, as participation in collaborative wildfire actions or support for property regulation increased, levels of support for restricted firefighting resources also increased. Agreement that wildfire is a healthy component of landscapes also was positively and significantly correlated with support for restricted firefighting resources (β = 0.092, p = 0.028), with increasing belief that wildfire is a healthy component of landscapes corresponding with increases in support for restricted firefighting resources among property owners who do not perform mitigations. None of the variables relating to the source of wildfire risk or demographics were significantly correlated with support for restricted firefighting resources.

Exploration of initial regression results for restricted firefighting resources, including collinearity diagnostics, suggested a need to test for interaction effects between the healthy wildfire and wildfire impact variables. Results of those interactions also are presented in column 1 of Table 5.

There was a significant and negative interaction effect for the healthy wildfire and wildfire impacts variables (β = -0.091, p = 0.021). More specifically, at the mean value of wildfire impact there is a significant positive interaction between consideration of wildfire as healthy and concern about wildfire impact on support for mitigation repercussions. The final multivariate regression model is presented in column 2 of Table 5 and accounts for a moderate amount of variance in support for mitigation repercussions (R^2 = 0.144). Belief that wildfire is a healthy component of landscapes (β = 0.100, p = 0.015),

Table 5
Results of regressions for support for restricted firefighting resources.

	Model sets 1			Model set 2		
Independent variable	SE(b)	β[a]	p[b]	SE(b)	β[a]	p[b]
Collaborative wildfire actions	.036	.145	.000***	.032	.111	.000***
Wildfire program actions	.033	−.034	.431			
Adjusted R^2			.019			
Regulation support	.037	.350	.000***	.039	.330	.000***
Adjusted R^2			.121			
Public lands fire risk	.034	.021	.620			
Private lands fire risk	.036	.005	.913			
Human ignition private	.047	.070	.128			
Human ignition public	.043	.011	.804			
Adjusted R^2			.001			
Healthy wildfire	.038	.092	.028*	.041	.100	.015*
Wildfire impact	.045	−.027	.552			
Healthy*impact	.035	−.091	.021*	.034	−.076	.024*
Adjusted R^2			.0185			
Education	.035	.019	.644			
Retired	.111	.012	.826			
Part-time	.088	.080	.059			
Age	.004	.040	.459			
Adjusted R^2			.005			.144

[a] Standardized regression coefficient.
[b] p = p-value, *p < .05, **p < .01, and ***p<.001.

collaborative wildfire planning (β = 0.111, p< = 0.001), regulation support (β = 0.330, p< = 0.001), and the interaction between healthy wildfire and wildfire impact (β=-0.076, p = 0.024) all retain correlations with the variable.

Select results from our multivariate regressions using HIZ mitigations as the dependent variable are provided in Table 6. Initial regressions using related variables indicate that both participation in collaborative wildfire actions (β = 0.121, p = 0.001) and wildfire program actions (β = 0.131, p = 0.010) are positively correlated with increasing levels of HIZ mitigation. That is, greater participation in the actions comprising either variable is correlated with increasing levels of mitigation actions performed on private properties. Belief that human ignitions on public lands were a source of risk in the area was positively and significantly correlated with performance of HIZ mitigations (β = 0.091, p = 0.036), with greater perception of risk from human ignition on public lands corresponding with performance of more mitigation actions. Age (β=-0.156, p = 0.006) and part-time residency (β=-0.264, p=<0.001) were both significantly and negatively correlated with performance of HIZ mitigation actions. Put another way, as age increased, likelihood of performing HIZ treatments decreased. Likewise, part-time residents were less likely than full-time residents to have performed higher levels of mitigation actions. Tenure also was positively correlated with performance of HIZ mitigations (β = 0.092, p = 0.038), with longer-term residents more likely to have performed mitigations.

Table 6
Results of regressions for performance of HIZ ignition levels.

	Model sets 1			Model sets 2		
Independent variable	SE(b)	β[a]	p[b]	SE(b)	β[a]	p[b]
Collaborative wildfire actions	.057	.121	.001**	.0567	.057	.315
Wildfire program actions	.047	.131	.010**	.062	.215	.000***
Adjusted R^2			.039			
Public lands fire risk	.51	−.073	.074			
Private lands fire risk	.054	.079	.060			
Public managed well	.057	−.037	.329			
Human ignition private	.070	−.026	.564			
Human ignition public	.064	.091	.036*	.061	−.035	.560
Adjusted R^2			.01			
Healthy wildfire	.037	.031	.465			
Wildfire impact	.044	−.012	.766			
Adjusted R^2			.000			
Age	.004	−.156	.006**	.005	−.013	.007**
Education	.057	−.028	.536			
Retired	.175	.018	.739			
Part time	.140	−.264	.000***	.134	−.563	.000***
Income	.035	−.011	.813			
Tenure	.004	.092	.038**	.003	.005	.156
Nearest neighbor				.053	.312	.000***
Human ignition public*collaborative wildfire actions				.038	.137	.000***
Adjusted R^2			.088			.216

[a] Standardized regression coefficient.
[b] p = p-value, *p < .05, **p < .01, and ***p<.001.

We introduced the nearest neighbor variable following the initial set of regressions because we were interested in whether property boundaries might influence HIZ performance or other variables in the model. Nearest neighbor was positively and significantly correlated with performance of HIZ (β = 0.312, p=<0.001), as noted in column 2 of Table 6. That is, as distance from nearest neighbor increased, so too did the likelihood of performing a greater number of mitigations in HIZ zones extending away from the house. Examination of the collinearity diagnostics in the full model also led us to include an interaction term between human ignition on public lands and collaborative wildfire actions. The interaction between these variables had a significant and positive relationship with increasing levels of HIZ mitigations (β = 0.137, p=<0.001). More specifically, at high levels of collaborative participation there is a significant positive interaction between perception of wildfire risk as stemming from human ignition on public lands and collaborative participation on performance of HIZ mitigations. Participation in collaborative wildfire actions, human ignition on public lands and tenure all lose significance in the final model, which explains a relatively high amount of variance in the sample (R^2 = 0.216). Wildfire program actions (β = 0.215, p=<0.001), age (β=-0.013, p = 0.007), and part-time residency (β=-0.563, p=<0.001) all retain significant correlations with performance of mitigations in the final model.

5. Discussion

The research presented here explored relationships between participation in wildfire planning or mitigation programs, support for regulation of private property, and residents' performance of wildfire mitigation actions on their properties. We also explored whether and how consideration of perceived wildfire risk sources (e.g. private or public lands, human ignition), the perceived role of fire in the landscape, and perceptions of potential negative impacts from wildfire influenced mitigation performance or support for regulation of residential development.

We found a low level of support for formal regulation of wildfire risk reduction on private lands and even less support for reduced wildfire response on properties that have not performed mitigations. Likewise, we found relatively low levels of participation in a variety of collaborative actions or programs designed to engage private landowners in reducing wildfire risk across broader landscapes. Regression results suggest that higher levels of participation in wildfire programs and performance of collaborative wildfire actions significantly correlate with greater performance of individual home mitigations, with the latter losing its significance when included with factors such as distance to nearest neighbor and part-time residency. Participation in either set

of actions has no relation with support or opposition to formal regulation of wildfire risk, while participation in collaborative wildfire actions and support for formal regulation do correlate with higher levels of agreement for reduced fire suppression response for populations who do not make efforts to mitigate their own risk.

Results suggest a number of nuanced findings related to perceptions of risk transmission across landownerships. We found that consideration of human ignitions on private lands significantly correlated with higher levels of support for land-use regulation, and results of our mediation analysis suggest residents consider how that risk compared to human ignitions on public lands when considering whether that risk was high enough to warrant support for uniform private property regulations. Likewise, residents' belief that there was a high level of risk from human ignitions on nearby public lands significantly correlated with greater performance of mitigation actions and interacted with participation in collaborative wildfire actions designed to reduce wildfire risk. Our results also suggest that perspectives of wildfire as a healthy component of landscapes are a significant influence on support for regulatory approaches or repercussions related to wildfire management, but that they can interact with tradeoffs about the potential for personal loss. Finally, our results suggest that select demographic factors such as age and part time residency may serve as useful *indicators* of potential relationships between support for regulatory wildfire approaches or performance of wildfire mitigations, and that a potentially overlooked source of variance in results from survey research on self-reported wildfire mitigations may include structural considerations about the proximity of property boundaries to primary structures. We expand on each of these points in the paragraphs below.

To begin, this study provides further quantitative evidence that regulatory approaches to wildfire risk management may not be supported by all populations, and especially rural populations such as the sample used in this study (see Muller and Schulte et al., 2011; Mockrin et al., 2016; Paveglio et al., 2018b). While many case study efforts hint at such findings, our results make it clear that populations in the sample frame may actually oppose such regulations. That opposition has the potential to influence elected officials or professionals who might introduce, adopt or attempt to enforce such standards, and may serve as a potential indicator that formal regulation of wildfire risk on private properties in not possible at this time in our study area (see Prior and Eriksen, 2013; Paveglio et al., 2019b; Edgeley et al., 2020 or Mockrin et al., 2020 for related discussions). However, the relatively high level of residents performing some form of voluntary mitigations on their properties provides initial indication that segments of the population are willing to address wildfire management in some way.

Our results are a good reminder that growing calls for regulation of land-use requirements for property-level wildfire mitigations should consider resident support as an important factor in the feasibility or applicability of such recommendations. Residents in our study area—and potentially others—will likely need to help develop or be convinced of the need for formal regulations if researchers and policymakers hope to reap their potential benefits (Harris et al., 2011; Paveglio et al., 2013, 2016b; Mockrin et al., 2018). Existing research indicates that regulations for wildfire risk reduction will endure when they become a normative aspect of many rural places and emerge from a shared recognition of need. They must be reinforced by agreement among residents in places such as the rural areas of Pend Oreille County because enforcement of regulations may not be feasible given local government budgets and the number of staff needed to monitor such arrangements (Jakes et al., 2011; Wilson et al., 2018; Edgeley et al., 2020). Future efforts to extend our work could explore individual requirements associated with formal regulations (e.g. building material requirements, vegetation management ordinances) as dependent variables to determine thresholds for linked actions. They also could expand the requirements suggested in our survey by incorporating other fire mitigations commonly discussed in the literature (e.g. adequate road and driveway widths, visible signage, development of individual or collective water sources, etc.).

This study helps advance literature surrounding resident responsibility for wildfire risk by providing a direct and quantitative link between increasing participation in outreach or collaborative wildfire programs and the performance of HIZ mitigations they often advocate. While that recognition is useful, it also needs to be tempered by the realization that increasing amounts of individual participation in the many outreach programs captured as part of this study appears to have no relationship with support for formal requirements of risk reduction on private lands and that overall participation in programs is relatively low. One possible explanation for our results is a potential decoupling of risk reduction strategies outlined in common wildfire mitigation programs or collaborative efforts and initiatives to foster landscape-level norms for wildfire mitigation among private residences. That interpretation is plausible given that a significant focus of existing wildfire mitigation programs and research focuses on *individual* property owner responsibilities leading to the adoption of wildfire mitigations that reduce *personal losses* on private parcels (see McCaffrey, 2015; Olsen et al., 2017 or Meldrum et al., 2018 overviews). Future work could explore these ideas in-depth by analyzing the type, frequency and content of wildfire mitigation programs targeted to residents in particular study areas and explore how participation in those programs correlate with perspectives about collective standards. This could include data collection regarding the budgets, frequency and type of advertisements associated with outreach or collaborative programs, the number of organizations, meetings or outreach efforts conducted by various professionals in the area, and metrics about the composition of attendees at such events. Alternatively, it would be interesting to ascertain whether residents view increasing voluntary mitigations as a means to achieve the "contagion effect" necessary to implement more consistent standards or whether they see them as a means to stave off government control. Both motivations are noted in select studies of existing wildfire social science, and in-depth examination among residents might help explain the dynamics we observed here (Fischer et al., 2019; Paveglio et al., 2019b; Warziniack et al., 2019).

The positive relationship we found between participation in collaborative wildfire actions and support for restricted firefighting resources among those who do not mitigate their personal risk suggests an interesting potential caveat to the above points. One possible explanation for these results is that participation in collaborative wildfire actions or outreach programs helps residents better understand the complexities and limitations of providing suppression resources (see also Absher et al., 2009; Jakes et al., 2011; McCaffrey et al., 2011; Stasiewicz and Paveglio, 2018; Charnley et al., 2019), which makes them more likely to advocate for placing finite resources in places where people are also taking personal responsibility. These tactics could be considered a "disincentive approach" because it focuses on reduced fire suppression response if residents do not perform voluntary mitigations. Future research could better explore the parameters of such approaches among both residents and professionals in rural regions, including under what circumstances residents would support disincentive approaches, at what scales, and the legal requirements needed from government agencies.

Collectively, our results suggest that only a few key factors in the data set correlate with formal land use regulation for wildfire, but the combination of those factors do suggest some potential pathways for introducing regulation in our study area. For instance, older, part-time residents who characterize segments of the study area appear to be more supportive of property regulations. The county or fire districts could introduce regulatory ordinances specifically targeting those segments of the growing residential population in the area through building code restrictions or the concentration of part-time dwellings in certain area that can support added wildfire response. Introduction of such ordinances on new or existing properties could be risky in terms of its repercussions on future development and the potential tax base for the region. They likely would require some sort of corresponding

(though distinct) requirement of actions among full-time residents, perhaps using the disincentive approach described above, because existing work suggests that equitable performance of wildfire planning actions among diverse actors is necessary to implement collective mitigation actions.

Results from our exploration of residents' perceptions about the sources of wildfire risk suggest that risk transmission studies may have some potential to influence support for landscape-level regulations or mitigations. However, they also indicate that those considerations can be complex or contingent on the mitigation strategy discussed and at least partially explained by existing studies about the "attribution" of blame for wildfire hazards (see for instance Kumagai et al., 2004a, b; Carroll et al., 2007 or Paveglio et al., 2016a). Support for the latter statement begins when recognizing that the only significant attribution factors in our analysis concerned human ignitions. Those results extend existing research discussing how negative reactions or retroactive calls for mitigation action are often tied to hazards that can be attributed to past human action (Carroll et al., 2011; Mockrin et al., 2018; Schumann et al., 2020).

We found that increasing perception of human ignitions on private lands correlated with increasing support for regulatory approaches to wildfire mitigation on private properties. One plausible interpretation for this finding is that many respondents see a need to regulate a human population they consider to be their primary source of risk and whose behaviors are a plausible source of change. The significant mediation effect we observed between attribution of wildfire risk to human ignitions on private lands and human ignitions on public lands deepens that understanding by demonstrating how residents consider the contributions of different landowners or actors in their landscape when determining which landowners should be most responsible for additional reduction of risk that they share. However, consideration of human ignitions on private lands was not a significant correlate for performance of HIZ mitigations, while human ignitions on public lands was. There are a few potential interpretations for such findings, and future studies could explore both their occurrence in other locations and their antecedents in more depth. One potential explanation is that residents consider wildfires stemming from public lands as those with the highest potential for widespread threat to private property. Thus, risk from large wildfires starting on public lands are those which cross a high enough "risk threshold" to prompt preemptive mitigation action. Another plausible explanation, and one grounded in our results, is that increasing participation in collaborative wildfire mitigation programs is one source of residents' perception that human ignitions on public lands are a primary source of fires that go on to damage private property. The in-depth studies we suggested earlier in this section could help explore these potential linkages in more depth.

The overall variance explained by residents' consideration of risk sources is relatively low or interacted with other variables in our analysis. These findings suggest a need to better explore the links between such attributions and support for landscape level management that risk transmission studies seek to inform. Additional work could engage the results of risk transmission analysis specific to a region to discuss with a variety of stakeholders how such information supports or contradicts their existing conceptions. It could also be used experimentally to structure negotiation of the "social contracts" that might be necessary to forge buy-in from disparate landowners who contribute different resources or actions toward managing wildfire at larger scales (see also Paveglio et al., 2018b, 2019b; Charnley et al., 2017, 2019; Schultz et al., 2018). Exploration of resident reactions to risk transmission research or results is particularly relevant right now given national directorates to create consistent risk maps (see USDA Forest Service, 2018) and the relative lack of evidence suggesting whether the significant investments in the such work have the capability to produce local actions. Our results suggest that risk transmission studies may be somewhat useful, but that more social science is necessary to better conceptualize, refine, and understand how the information they seek to provide might structure ongoing dialogue or individual considerations about residents' role in larger landscape management.

Regardless of risk attribution, residents' perspectives surrounding the broader role of fire in the landscape do appear to correlate with their consideration of regulatory approaches for wildfire management among private properties. More specifically, we found that greater perceptions of wildfire as a healthy component of the local landscape correlated with increased support for regulatory approaches. However, those same considerations appear to be at least partially contingent on tradeoffs with the potential for personal impacts and do not appear to influence individual level mitigation action. For instance, our results demonstrate how positive views of fire can influence support for landscape-level regulatory approaches—but that such views are highly significant when perceived impacts are also at moderate or neutral levels. The nuance in these tradeoffs, and their potential for different expressions among diverse populations at risk from wildfire are not well captured in existing research on wildfire dynamics. Thus our results, when compared with the ever-deepening literature on residential mitigations for wildfire, suggest that the field needs to explore more detailed analyses of resident tradeoffs in a way that can aggregate to a more comprehensive theory of wildfire adaptation behavior. Future studies could integrate more nuanced measures related to residents' perceptions of wildfire as a natural disturbance process in landscapes, including understanding of current fuel levels or the introduction of prescribed and controlled fires as a positive force on the landscape. Likewise, it would be interesting to explore how past experience with wildfires, including knowledge of impactful wildfires across the larger region, might correlate with support for a variety of regulatory approaches.

Our results extend and add nuance to a longstanding debate about the appropriateness of demographic variables as indicators of mitigation action or support for wildfire mitigation actions (see McCaffrey, 2015; Paveglio et al., 2016c, 2018b). As mentioned above, part-time residents were those most supportive of property regulations, while no demographic variables correlated with support for mitigation repercussions. We suggest that the former findings extend existing research suggesting how part-time owners or amenity migrants to rural areas may bring with them an expectation of increased government regulation or management they have come to expect in the other locations where they previously resided (Eriksen and Gill, 2010; McCaffrey et al., 2011). Support for regulation among such populations is just one of the many reasons for "culture clash" that many segments of research have documented among more rural populations who prefer normative or common standards and value self-reliance (see Smith and Krannich, 2000; Ulrich-Schad and Quin, 2018). Our results support and add nuance to these existing understandings when one considers the inverse relationships we observed among part-time residency and performance of HIZ mitigations. That is, part-time residents were less likely to perform personal, voluntary mitigations on their properties, but appear in support of regulatory approaches that require such actions among all residents.

Collectively, we would suggest that these findings are another example in a long line of research suggesting that a primary challenge of fire management is the ever-changing patchwork of human cultures that influence a landscape—and thus the conceptual "landscape" of fire risk (Jakes et al., 2011; Paveglio et al., 2015). It also suggests the potential for a shift in study area WUI resident support for regulatory approaches, provided that part-time residents continue to increase in the area. Both components can lead to higher levels of "social fragmentation" or the proliferation of diverse values, perspectives, and connections with the landscape that lead to a myriad of communities or interest groups that may be at odds in a landscape. The high level of disagreement among our respondents about regulatory approaches to wildfire in the region and the influence of the above demographic characteristics both suggest that there is high "social fragmentation" even in the small geographic region studied, which corroborates earlier

work in the region (Paveglio et al., 2019b). It may also help to explain the relatively low level of variance explained in some of our regression models given that the factors influencing perspectives on regulation or performance of mitigations may differ across diverse populations. Our findings and other research indicate that future work needs to move beyond merely identifying which populations will or will not contribute to wildfire risk initiatives and experiment with the compromises or tradeoffs that can bridge significant differences in values or perceptions. It is likely through those shared negotiations that recognize difference—and not a quest for universally generalizable results—that individual actions might begin to aggregate up as part of a collective whole.

Finally, our addition of property boundary characteristics as a potential correlate with performance of mitigations extends the literature by demonstrating how existing development patterns may be a significant explanation for some past results. They also have the potential to inform potential risk transmission at smaller scales. More specifically, we found that the distance respondents reported between their property and neighboring properties was a significant correlate with performance of mitigations in broader "zones" of the HIZ. These results suggest that pre-existing development patterns can be one important explanation for self-reported mitigation results that characterize ongoing research on adoption of mitigations among private residences (see Busby et al., 2012; Newman et al., 2013; Paveglio et al., 2016b, for examples). For instance, our findings also suggest that larger, rural properties are more likely to be owned by residents who are performing high levels of mitigations on their properties and which extend beyond the typical 100- or 200-foot HIZ. Many existing studies do not explicitly include consideration of structure proximity to property boundaries as an influence on or barrier to mitigation action, but our results suggest that they should. Future research could expand our preliminary findings by stratifying their samples by ownership type, proximity of structures to neighboring properties, or across a gradient of development types to better understand if such measures can serve as potential correlates with difference in rates of mitigation performance.

6. Conclusion

Emerging wildfire science and policy continue to place significant focus on collective approaches for managing wildfire at landscape scales. Yet it also is important to remember that promotion of regulatory or voluntary strategies for achieving coordinated wildfire management still require understanding how individual or local considerations will influence their application in practice. We found that regulatory approaches may not currently be supported in sections of Pend Oreille County, that collaborative wildfire programs designed to help mitigate wildfire risk had no relationship to support for broader regulation of such risk across private properties, and that perspectives about the sources of wildfire risk have selective influence on mitigation action. Collectively, our findings suggest that existing influences and correlates for wildfire mitigation action may be poor predictors of the important support that is necessary to make regulatory approaches a reality in portions of the rural U.S. West, and that targeted social science research, experimentation or collaborative dialogue likely needs to be a focus of ongoing wildfire management planning. Likewise, our findings suggest that the expanding focus on risk simulation or transmission across landscapes may have limited utility until such studies are informed by or applied in ways that reflect residents existing notions about wildfire management in the places where they live. Landscape-level approaches cannot necessarily be forced on private residents or dictated by approaches that oversimplify the complex and multi-scalar considerations that influence human agency surrounding collective standards. The research presented here attempts to alleviate that current gap in the literature by pointing out how much work may still be necessary to engage private residents in considerations of shared responsibility at landscape scales.

CRediT authorship contribution statement

Travis B. Paveglio: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Resources, Data curation, Writing - original draft, Writing - review & editing, Visualization, Supervision, Project administration, Funding acquisition. **Amanda M. Stasiewicz:** Conceptualization, Methodology, Investigation, Writing - review & editing, Data curation, Project administration, Visualization. **Catrin M. Edgeley:** Conceptualization, Methodology, Investigation, Project administration, Writing - review & editing.

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