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Exploring support and opposition to regulatory approaches for wildfire risk management: requirements, voluntary actions, and tailored local action

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Abstract
Formal requirements of wildfire mitigation on private properties are increasingly being considered as one avenue for "scaling up" wildfire management and voluntary mitigation actions to landscape scales. Likewise, enduring segments of wildfire research suggest that residents' perceptions about potential wildfire risk sources in their landscape, including ignition sources, are critical considerations related to support for mitigation efforts such as formal requirements or cross-boundary fuel reduction initiatives. The research presented in this article utilized mixed-method, residential surveys of property owners in Kittitas County, Washington, to explore influences on support for wildfire mitigation requirements and performance of voluntary mitigations on private lands. We found a high degree of variability in support for regulatory approaches, including relatively low levels of support for building or retrofitting regulations and a moderate level of support for vegetation management regulations. Perceptions about wildfire risk sources or public land management, past performance of wildfire mitigation actions, and support for shared, locally managed mitigations all correlated with support for differing regulatory approaches. We also found that performance of voluntary mitigation actions correlated with increasing wildfire program participation, differed among part-time or full- time residents, and were influenced by proximity to nearby property boundaries. Our results suggest that the most supported strategy in the study area may be the establishment of local, tax funded districts that encourage voluntary mitigation actions tailored to local circumstances. We conclude the paper by comparing our results to existing lessons from wildfire social science.

Keywords Wildfire · Mitigation · Regulation · Private property · Landscape

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1 Introduction

Wildfire science, management and policy are increasingly focused on more effectively addressing risk at landscape scales, including the design of collaborative and coordinated actions that land management agencies, private residents and local governments can contribute to strategies for "co-existing" with wildfire (Ager et al. 2019; Hamilton et al. 2021; Huber-Stearns et al. 2022). However, existing research and policy suggest that one enduring challenge of landscape level wildfire management concerns the need to more fully understand and incentivize private landowners whose mitigation action (e.g., wildland vegetation management practices, development patterns, willingness to collaborate, ignition of wildland fires) collectively exert significant influence on broader social-ecological systems (Paveglio et al. 2018a; Charnley et al. 2019; Brenkert-Smith et al. 2020). That work also suggests that private landowners' support or contribution to broader wildfire initiatives are not a given, and that addressing the somewhat lofty goals of coordinated wildfire management may mean 'scaling up" management at smaller initial scales where collective action is currently possible (Williams et al. 2012; Davis et al. 2021; Paveglio 2023). The research presented in this paper engages the above needs by exploring the relationships between private landowners' opposition or support of landscape-level wildfire management initiatives such as landowner vegetation mitigation requirements, residential building or retrofitting regulations, participation in collaborative wildfire management planning/programs and perceptions about the sources of wildfire in their landscape.

Among the most prominent strategies being advanced for addressing residential wildfire risk include: (1) voluntary or required wildfire mitigation actions performed by private landowners on their properties in high risk areas (e.g., fuels reduction around structures or use of flame-resistant building materials); (2) the regulation of future residential development in fire prone areas; and (3) the use of simulation modelling to designate focal landscapes where different actors can "transmit" fire across ownership boundaries and where collaboration on wildfire prevention may be of high importance (Schumann et al. 2020; USDA 2022; Paveglio et al. 2021; Ager et al. 2021a). Interest in the regulation of future residential development or requirement of mitigations among private landowners (what we refer to as regulatory approaches in this manuscript) reflect a long tradition of research indicating that actions taken by landowners at various residential densities (e.g., vegetation management, choice of building materials) can reduce the likelihood that their properties—and those nearby—are damaged during a wildfire (Cohen 2008; Hakes et al. 2017; Calkin et al. 2023). Likewise, the growth of wildfire risk modelling reflects an underlying desire to identify human populations whose actions are most likely to ignite, propagate, or spread fire across ownerships in a shared landscape. Risk transmission and associated wildfire modelling have recently been codified into policy at state and federal scales, including the designation of select landscapes where states or the U.S. Forest Service are vesting significant amounts of their efforts, including wildfire management prevention budgets (Ager et al. 2017; Palaiologou et al. 2019; USDA 2022; Wildland Fire Mitigation and Management Commission 2023).

Calls for more consistent regulation of private landowners in fire-prone lands, the use of risk transmission simulations to prioritize wildfire mitigation, and a focus on collaborative planning that crosses ownership boundaries are all advancements in fire management, but they also tend to assume that private populations will be willing to support or accept their utility in the places they live (Paveglio et al. 2016a; Evers et al. 2019; Leone et al. 2020). For instance, there is a tendency for increased calls about private property regulation or

risk transmission to be criticized as "top down" efforts—they propose aspirational "solutions" or priorities at scales that may not account for the complexity of working in specific landscapes, or that fail to reflect the understandings of people who live there (Buxton et al. 2011; Edgeley et al. 2020; Essen et al. 2023). Less research has explored how local people conceive of broad mitigation strategies increasingly being suggested as possible avenues for addressing increasing wildfire damage (e.g., regulatory approaches), including their support or opposition of such initiatives. Similarly, linkages between peoples' understanding about the sources of fire risk in their landscape and its potential influence on their actual or potential contributions to wildfire management are often hinted at, but rarely explored explicitly in terms of their influence on likelihood of engaging with emerging wildfire risk reduction initiatives. Such understandings seem increasingly important given the continued recognition that wildfire management responsibilities require "shared stewardship" among partners, and the careful negotiation about how different actors efforts influence a collective action problem that no one actor can fully control (Kelly et al. 2019; USDA Forest Service 2018; USDA 2022).

The research presented in this paper employed surveys among residential landowners in proximity to completed or proposed cross-boundary fuels reduction treatments in Kittitas County, Washington State, USA. The work is a partial replication and extension of existing research in another region of Washington that explored resident perceptions surrounding regulatory approaches for wildfire risk reduction, sources of risk, and mitigation actions (Paveglio et al. 2021). We selected residents in proximity to past or planned fuel reduction treatments to explore the perspectives of diverse residents grappling with wildfire risk in a landscape featuring diverse uses, perspectives, and residential densities (e.g., on the borders of municipal boundaries to remote properties). Survey results presented in this paper are designed to improve understanding of the needs identified in the literature above, including better understandings of: (1) influences on support or opposition to residential mitigation regulations in developing portions of the American West; (2) residential participation in collaborative wildfire mitigation programs, initiatives or programs that are often heralded as ways to encourage shared responsibility for wildfire management among private landowners; (3) residents' perceptions concerning cross-boundary wildfire risk, including how it influences or correlates with the performance of wildfire mitigations taken on their property; and (4) how any of the preceding actions or perceptions influence future intent of residential property owners to engage in shared mitigation actions with their neighbors or at landscape scales.

2 Literature

Increased interest in regulatory approaches for wildfire are a response to increased risk, losses and costs of suppressing fire. However, they are also indicative of a growing recognition that wildfire management is heavily influenced by human relationships and settlement patterns spanning broader landscapes where fire will inevitably occur (Paveglio et al. 2015; Kelly et al. 2019; Paveglio 2021; Canadas et al. 2023). The expanding Wildland Urban Interface (WUI)—areas where human settlement are in close proximity or interspersed with flammable vegetation—is perhaps the most well-known focus of efforts to engender collaborative responsibility for increasing wildfire risk (Radeloff et al. 2018; Carlson et al. 2022). Growth and change in the WUI at broad and fine scales is now readily accepted as a major contributor to the unsustainable system of wildfire suppression in the United States

in part because it has the potential to influence what "values-at-risk" (e.g., life, property, infrastructure, ecosystem services, etc.) are present in a fire-prone system (Paveglio et al. 2012, 2019a; Brenkert-Smith et al. 2017). In response, segments of policy, research and outreach struggling to alleviate the so-called "wildfire problem" have advocated for land-use planning and regulation foci that attempt to reduce the inherent risk posed to private structures in areas where wildfire is most likely (McWethy et al. 2019; Schumman et al. 2020; Wolters 2023). For instance, building standards such as the International Wildland Urban Interface Code are designed to be adopted by counties to help reduce future risk or ameliorate existing exposure through the requirement of residential building standards in high risk areas and the design of infrastructure in ways that improve fire response (International Code Council (ICC), 2024).

Empirically based recommendations about vegetation management and landscaping actions around private structures are one common foci of regulatory approaches for reducing wildfire risk at broader scales (Bond and Mercer 2014; Smith et al. 2016; Mockrin et al. 2023; Muffly and Birchall 2023). Vegetation management recommendations most frequently focus on what is called the "Home Ignition Zone"—an area 100–200 feet surrounding a residential structure that heavily influences whether that structure can survive a wildfire with minimal damage (Cohen et al. 2008; Calkin et al. 2014). Actions taken in the HIZ, including tree and shrub spacing, establishment of a "green space" surrounding structures, and use of nonflammable materials immediately adjacent to structures have been shown to reduce the potential for damage during the pass of fires (Hakes et al. 2017; Meldrum et al. 2022; Calkin et al. 2023). Similarly, a robust tradition of research on building materials have long been used to incentivize, or require, that homes be built or retrofitted with materials that make them more resistant to fires (e.g., metal roofs, brick or cement board siding, boxed eaves and vent screen requirements, etc.). (Syphard et al. 2017; Gonzalez-Mathiesen et al. 2021; Moritz et al. 2022).

Counties, cities and even statewide initiatives are beginning to codify building, retrofitting and HIZ mitigation requirements in fire prone areas as a means to explore consistent avenues for addressing broader wildfire risk. For instance, some counties and states have instituted ordinances or laws which require the "defensible space" that is commonly advocated in the HIZ. Other jurisdictions, including homeowners' or property owners' associations, have implemented monitoring of such requirements, complete with the option for citations, fines or liens on a property in cases on noncompliance (Intini et al. 2020; Kramer et al. 2021; Mowrey and Punchard 2021; Washington State RCW 19.27.560; Kolden and Henson 2019; California PRC 4291). However, select researchers, practitioners and policymakers suggest that interest and adoption of regulatory approaches has been inconsistent across locations, even after impactful fires (Paveglio et al. 2019a; Mockrin et al. 2018; 2022; Caroll and Paveglio 2019). Others caution that regulatory approaches are likely to be successful only in certain places, and that careful consideration of local perspectives, views about government influence, and relationships with the landscape might help better determine whether regulation or collaborative partnerships are best suited to reduce residential wildfire risk (Paveglio et al. 2018a; Mockrin et al. 2020; Edgeley et al. 2020). This is in part because adoption of any city, county or state ordinance for regulatory approaches pertaining to wildfire requires votes, referendums, or formal adoption by actors who are intended to represent their constituencies. Financial, organizational and human capacity also are needed to monitor, evaluate and enforce regulations. Such investments might not be possible for some jurisdictions, while in others the added tax burden imposed on residents could result in backlash or organized opposition (Buxton et al. 2011; Bardsley et al. 2015; Wilson et al. 2018).

An existing body of wildfire social science indicates that resident perspectives about regulatory approaches are a key differentiator of diverse residential populations who live in the WUI, and who often support very different strategies for risk reduction (Paveglio 2015, 2019b, 2023). For instance, existing research notes that segments of rural WUI populations, and those associated with current or past resource use (e.g., ranching, forestry, energy development) might actively resist or ignore regulatory approaches to residential wildfire risk management (Stasiewicz and Paveglio 2018; Rasch and McCaffrey 2019; Edgeley et al. 2020). Other literature notes how residents' desire to be independent of government influence, the belief that private property rights are a central component of shared identity, negative experiences with past wildfire response, or lack of trust in land or emergency management can also lead to opposition of formal regulatory approaches (Paveglio et al. 2018a, 2019b, 2021; Mockrin et al. 2020). Meanwhile, residents in more developed areas may come to expect that local professionals (i.e., fire districts, emergency services, conservation districts), and not homeowners, should be responsible for facilitating risk reduction efforts on private lands. The result of these unintended consequences can be populations who lack the skills or willingness to help reduce risk on their properties or in the larger landscape (Steelman and Burke 2007; Goldstein 2008; Carroll and Paveglio 2016; Stasiewicz and Paveglio 2022).

Support and enactment of regulatory approaches have been more successful among residential populations accustomed to or seeking the collective norms and standards that are commonly associated with regulations on private property. For instance, WUI residents living in formal subdivisions or exurbs may feature homeowners' or property owners' associations covenants requiring agreed upon building standards or arrangements for managing vegetation in common areas. Thus, acquiescence to shared action or requirements may be more ingrained (i.e., what some call 'normative') as part of choosing to live in those settings (Paveglio et al. 2016b; Mockrin et al. 2016; Wolters 2023). Similarly, developments and neighborhoods are more frequently targeted by wildfire programs, and thus may have a more robust history of working with landscape-level collaboratives or organizations (e.g., Forest Collaboratives, Fire Safe Councils, Resource Conservation and Development Councils) on cross-cutting projects for reducing wildfire risk (Abrams et al. 2015; Kocher and Bustic 2017). Existing research suggests that residents living or moving into the areas described above areas may be: (1) more supportive of shared standards for vegetation management on private properties if it can be proven to reduce overall risk; (2) more interested or trusting of professional input from wildfire managers and scientists about risk reduction; and (3) have local capacity to mobilize support or help enforce agreed upon regulations (Harris et al. 2011; Stidham et al. 2014; Olsen et al. 2017; Kolden and Henson 2019; Billings et al. 2021a). More broadly, such populations may feature a variety of professionals (e.g., fire managers, planners, lawyers, etc.) who can help navigate or negotiate the formal requirements associated with regulatory approaches due to their personal experience or expertise (Paveglio et al. 2015; 2018a).

Voluntary programs, educational initiatives, and community planning efforts designed to encourage personal responsibility for wildfire mitigation have a much longer history of implementation in the United States WUI and other countries (Olsen et al. 2017; Koksal et al. 2019; Cowan and Kennedy 2023). Such programs promote the benefits of reducing vegetation in the HIZ (e.g., Firewise Communities USA program, defensible space programs) or help organize resources and actions that can 'scale up' vegetation management across landownerships (e.g., chipping programs, fuels reduction agreements, Community Wildfire Protection Plan prioritization). Expanding voluntary mitigation programs might also provide information about "home hardening" practices (e.g., using proper screening

on vents, building material recommendations), connect landowners with contractors to perform structure renovations, or provide matching grants and resources that help residents bring additional resources to bear as they work to reduce risk across properties (e.g., shared fuel breaks, roadside clearing for evacuation planning, etc.) (Paveglio and Kelly 2018; Meldrum et al. 2018; Hilsenroth et al. 2023).

Lessons from the much deeper body of research exploring voluntary wildfire mitigation actions among private residents suggest that a complex array of influences and motivations underly residents' decisions about mitigation. For instance, some common factors noted as influencing resident mitigation actions include: (1) part-time or full-time residency; (2) trust in agency or wildfire professionals; (3) demographic characteristics such as age, income, education or retirement status; and (4) perceptions about the role of fire in the broader landscape (e.g., as a natural, healthy disturbance or a damaging hazard in need of suppression) (McCaffrey 2015; Hessln 2018; Billings et al. 2021b; Cowan and Kennedy 2023). However, those same factors also can be inconsistent across populations and regions, or in the case of demographics, display mixed utility as indicators of more elaborate and interacting influences that are contextually specific. For instance, those who see wildfire as a healthy, natural part of the landscape might be more inclined to see vegetation management on their properties as a responsible way to contribute to broader campaigns focused on ecosystem restoration (Paveglio et al. 2015; Wolters et al. 2017; Ribe et al. 2022). They might also have participated in various outreach or collaborative programs (e.g., community meetings, incentive programs, technical transfer workshops) that have long promoted a narrative of "living with fire," complete with evidence that private mitigations can help greatly reduce the potential for property damage during wildfires (Brenkert-Smith et al. 2013; Remenick 2018; Paveglio et al. 2021.

The complexity and variability of influences on individual action has led some researchers and policymakers to identify residential wildfire mitigation as a "last mile" problem—research and 'expert' assessment have resulted in recommendations that can reduce wildfire risk, but residents are not always inclined to perform them "en masse" on their private properties. In response, there has and continues to be significant effort surrounding the best ways to "convince" residents to perform voluntary mitigations, incentivize their adoption, or require their performance (National Academies of Sciences, Engineering and Medicine 2017; Hessln 2018; Sanchez et al. 2022; Calkin et al. 2023). Others note that the complexity of influences on residential mitigations decisions, and the continued "top down" approach to educating or convincing residents could in fact be a barrier to adoption, favoring instead the tailoring or co-designing of mitigation action in ways that fit local context (Paveglio et al. 2019a, b, 2023; USDA 2023a).

2.1 Attribution and the interconnectedness of fire risk

Select segments of wildfire social science have long acknowledged how residents' perceptions about their neighbors' action (or inaction) in the face of wildfire risk can influence subsequent mitigation behaviors. For instance, some traditions of wildfire science have noted how residents might justify a lack of mitigation action on their properties by claiming that such work will not be enough to reduce more systemic risk created in part by their proximity to public or private lands that they feel are poorly managed (Shafran 2008; Paveglio et al. 2016a; Gordon et al. 2018; Al Abri and Grogan 2021). Similar sentiments may also extend to residents consideration of other residential landowners, including the recognition that high density WUI areas would require a consistent level of vegetation

mitigation and home hardening that might not be possible to reduce potential losses during large fires (Busby et al. 2013; Brenkert Smith et al. 2006; Dickinson et al. 2020, Langpap and Wu 2021).

Awareness of wildfire management in a broader neighborhood, community, or landscape also can influence proactive behaviors in terms of mitigation—provided that the right combination of factors is present or interact to promote shared action (Busby et al. 2012; Fischer et al. 2019; Taylor et al. 2019). For instance, a number of authors have noted the potential for 'contagion effects' that occur when demonstration of fuels reduction efforts on select properties encourage subsequent mitigation performance by nearby residential landowners (Dickinson et al. 2015; Warziniack et al. 2019; Canadas and Novais 2019). Establishment of collaborative agreements among residents to better manage fire-prone areas in ways that promote ecosystem health can reinforce or encourage proactive behaviors across landowners who see their mitigation contributions as part of a shared commitment to broader initiatives (Stasiewicz and Paveglio 2022; Burnett and Edgeley 2023; Huff et al. 2022). And there is some evidence that highly visible efforts to mitigate fire risk on state and federal lands near private properties can motivate additional interest in the extension of fuels reduction or wildfire preparation efforts (i.e., evacuation planning, infrastructure or structure hardening) on nearby private lands (Charnley et al. 2019; Edgeley et al. 2020; Paveglio and Edgeley 2023).

Other threads of work contextualize the findings above by exploring how residents consider the ways their actions relate to others in a shared landscape. This includes how the occurrence of nearby mitigation efforts might allow individuals to maximize their personal risk reduction investments or allow them to 'freeride' in obtaining mitigation benefits from others. Such efforts are frequently hypothetical simulations of decision processes, while less work explores the way that perspectives surrounding personal mitigations relate to a broader suite of collaborative actions increasingly featured in the policies and programs of state and federal agencies (e.g., shared fuel breaks, ecosystem restoration spanning agencies, regulatory approaches to wildfire mitigations) (Talberth et al. 2006; Shafran 2008; Busby et al. 2013; Lanpap and Wu 2021; Al Abri 2022; Lauer et al. 2020).

Attribution of wildfire management outcomes—or the tendency of human actors to seek out the sources and potential reasons for impacts from wildfire—are another enduring feature of wildfire management that stems from individuals' consideration about human action in a shared landscape (Kumagai et al. 2004a, b; Charnley et al. 2017; Paveglio et al. 2021). For instance, impactful wildfires (including prominent recent examples such as the Maui wildfires or the Camp Fire) often feature efforts to better understand where the fire originated, what land use practices allowed the conditions that facilitated fire progression, and who is to "blame" for potential impacts (Daniels 2018; Morales 2023; Hals 2023; Montoya 2022). Perceptions about the potential sources of wildfire ignitions (i.e., private residential lands, public lands) including types of ignition (e.g., arson, power infrastructure failure, lightning) are also noted as important contributors to residents' conception of fire risk in their landscape because they have the potential to influence future collaborative relationships or willingness to engage in shared risk management (Carroll et al. 2006, 2007; Shindler et al. 2014; Edgeley and Paveglio 2017). Attribution of wildfire risk can extend to broader ecological conditions in the landscape, including action or lack of action among private and public actors that influence fire risk (Carroll et al. 2011; Paveglio and Edgeley 2017; Paveglio et al. 2018a).

Simulation research exploring the probabilistic occurrence of wildfire across landscapes are one increasingly popular way to attribute the potential sources of wildfire impact in a given landscape (see for example Ager et al. 2017; Palaiologou et al. 2019). Such efforts simulate

potential ignition and propagation of fire across landownerships based on historic and potential ignitions, weather conditions, fuel conditions or response efforts to better understand how different landowner classifications (e.g., residential lands, U.S. Forest Service lands, private timber lands, county lands, etc.) might "transmit" fire to others in a shared landscape (Ager 2019, 2021a). In that respect, risk simulations and related risk transmission research are being promoted as an effective way to prioritize areas where mitigation actions such as regulatory approaches might reduce negative consequences from increasingly destructive wildfires (Ager et al. 2021b; Alcasena et al. 2022). Risk transmission research efforts also are a partial response to prevailing notions that federal agency management of public land was to "blame" for increasing wildfire risk to communities, with findings indicating that private or public lands can both contribute to wildfire ignition or occurrence across landscapes (Nagy et al. 2018; Downing et al. 2022).

Despite the growing influence of wildfire risk mapping and risk transmission research, there has been little effort to understand how knowledge of wildfire risk sources influence private landowners' decisions about mitigations behaviors they might perform on their properties, or on their support for regulatory approaches (see Paveglio et al. 2021; Edgeley 2023). What little research has been conducted on these efforts suggests that continued narratives about who is most to "blame" for wildfire ignition or spread can engender some types of mitigations or collaborative planning, but it can also inhibit collaboration among partners who all contribute to overarching risk—and who might need to engage in different practices to reduce it (Carroll et al. 2011; Edgeley and Paveglio 2017).

In sum, the literature reviewed above suggests a need to better understand what influences support or opposition to the implementation of regulatory approaches among residential populations given that their continued contributions will be critical in perpetuating regulatory approaches beyond establishment. There also is a need to understand how increased participation in wildfire planning or outreach programming influences resident performance of wildfire mitigations on their properties or their support for regulatory approaches, including how their attribution of wildfire risk to different actors in a landscape correlates with their willingness to engage in collaborative action. Exploring these linkages is important given the more recent policy focus on landscape-level wildfire management initiatives and significant investments focused on the encouragement of voluntary residential wildfire mitigations that may serve as the foundation for any regulatory approaches. Accordingly, the following research questions guide our effort:

1. What are the relationships between perceptions of wildfire risk sources, participation in collaborative wildfire programs, future likelihood of engaging in collaborative wildfire management and support or opposition for formal regulations of private residential development for wildfire?
2. What are the relationships between support or opposition to formal regulation of private properties for wildfire, engagement in wildfire mitigation programs, future likelihood of engaging in collaborative wildfire initiatives and performance of personal wildfire mitigations?

3 Methods

North Central Washington State emerged as an initial study region during broader projects focused on in-depth social science research in high risk "firesheds"—large landscapes where a diverse mixture of landowners have the potential to transmit wildfire across boundaries. North Central Washington was selected as one foci for the larger project because it had been deemed a high priority for wildfire risk management nationally (see Ager et al. 2021a). The area later became known as the Central Washington Initiative (CWI) when it was selected for targeted landscape investment as part of the U.S. Forest Service Wildfire Crisis Strategy (WCS). The CWI extends across much of Chelan, Douglas, Kittitas, Yakima and Okanogan Counties (USDA 2022, 2024). Conducting research in a portion of a WCS priority landscape provided the opportunity to explore perspectives among residential populations who will be a significant focus of future fire adaptation efforts. Likewise, selection of the region provides the opportunity for potential comparison among populations across or within priority landscapes identified for investment as part of the WCS, which will be critical for monitoring large-scale investments in fire management.

Researchers selected Kittitas County as an initial study area because it features significant and ongoing amenity migration or second/vacation home development in high fire risk areas that feature prominently in literature on wildfire risk. Kittitas County also features a high proportion of state and federal lands in close proximity to private values-at-risk, which is one reason for significant investments in landscape level fuels treatments conducted by the U.S. Forest Service, Washington State Department of Natural Resources, Kittitas County Conservation District, and local fire departments. Portions of the county have been included in past Joint Chiefs projects aimed at cross-boundary fuels treatments to address wildfire risk (USDA 2023b) and the county contains multiple watersheds and communities listed as high risk from wildfire in the Washington State Department of Natural Resources (DNR) 20 Year Forest Health Strategic Plan (Washington DNR 2023).

Results from existing wildfire mitigation research in Kittitas County suggested a need to better understand residents' views about potential regulations or requirements being discussed among professionals representing a variety of landowners or managers (e.g., state and federal agencies, local governments, fire districts, residents, etc.) (see Edgeley and Paveglio 2024). Regulations being considered in Kittitas County included consideration of new Wildland Urban Interface designations and associated county planning ordinances that would regulate building standards and defensible space requirements in order to reduce wildfire risk. Thus, Kittitas County featured many of the key influences or contextual elements that our literature review suggests influence perspectives about risk transmission and wildfire regulation, while also fulfilling a local need for additional social science research to inform ongoing policy. That being said, lessons from existing research, including research in Kittitas County, suggested a need to narrow the final sample frame to achieve a rich coverage of diverse property owners at a smaller scale than a county (Paveglio et al. 2018a; 2019a; Edgeley and Paveglio 2024).

Researchers achieved a smaller, more focused sample frame through a series of empirically oriented choices aimed to diversify the range of potential survey respondents while still focusing on aspects of risk transmission, potential wildfire regulations, and the potential for cross-boundary mitigations. To begin, researchers worked with professionals from various agencies active in the area to compile spatial data of completed or planned fuels treatments in Kittitas County between the period of 2012–2020, with 2020 being the onset of the research project. Selection of the 2012–2020 time frame reflects an increased

interest in and funding to conduct fuels treatments across Kittitas County. It also corresponds with the time frame during which land clearing activities on private parcels are likely to retain effectiveness in reducing wildfire risk (see Stockmann et al. 2010, Paveglio et al. 2013 and Paveglio et al. 2018b). Researchers concurrently obtained private parcel data from the Kittitas County Assessor and created centroids for all parcel polygons. They created a buffer of 0.8 miles from every fuel reduction treatment in the aggregated dataset described above (approximately 2632 treatments) and selected any parcel centroid intersecting those buffers. The 0.8 mile buffer corresponds with common guidance from the National Wildfire Coordination Group concerning maximum crown fire spotting distance to ignite fires in WUI conditions, including fine moisture fuel content (FMC) and potential windspeeds matching the area as confirmed by local fire managers (NWCG 2021). Researchers excluded properties denoted as a land trust, undeveloped land, parcels associated with businesses or timber use, and any apartments or condominiums because questions about residential mitigations were likely far less applicable to those individuals or because those properties were unlikely to feature one set of owners who could comment on support for local initiatives. Omissions of such properties are similar to past wildfire studies exploring such topics, and thus also allow for comparability across studies (Paveglio et al. 2014; 2016a, b; Edgeley and Paveglio 2019).

Initial plotting of fuels treatments and consultation with local professionals indicated a primary focus on the northwestern portion of Kittitas County where there continues to be significant amenity migration, a high proportion of state, federal, and Nature Conservancy lands, small cities or towns, and the Highway 90 corridor that crosses the Cascade Mountains to connect with the Seattle metropolitan area (See Fig. 1). Local professionals indicated that a focus on the Cle Elum Priority Watershed, which is recognized as an area of high potential for wildfire risk in the DNR 20 Year Forest Health Strategic Plan, would be the best area for more in-depth study. The Cle Elum Priority watershed encompasses the municipalities of Cle Elum, Roslyn, Ronald and Teanaway. It extends in all directions from the aforementioned municipalities to encompass rural lands and features a large volume of fuels treatments occurring across the county. Thus, residential properties in the Cle Elum Priority Watershed boundary, and whose parcel centroids intersected any buffer of an existing or planned treatment, constituted the final sample frame for the survey.

A group of researchers administered the survey to potential respondents in August 2021 using a mixed-mode approach that featured components of the Tailored Design Method (i.e., mail and online) (Dillman et al. 2009; 2014) and an initial experiment using a drop-off, pick-up method (DOPU) (Steele et al. 2001; Trentleman et al. 2016; Jackson-Smith 2016). Property owners were denoted as primary or secondary residents using their primary taxable residential address in the tax assessor data and subsequently assigned to different initial potential survey administration methods. A team of two researchers visited a random sample of primary residences (n = 195) using the DOPU method during the course of eight days to hand deliver surveys and explain the purpose of the research using a common protocol. They arranged to collect completed surveys within 24 h of drop off with an individual and left notes about the survey or additional collection times when potential respondents were not at the property. They also returned to each home in the initial random sample multiple times to ensure participation and placed fliers on the door of individuals not present during the time of implementation. Initial administration using the DOPU method was employed for a few reasons: (1) personally visiting the area to administer surveys has the potential to raise local awareness of the study among a broader set of potential respondents (Steele et al. 2001; Jackson-Smith et al. 2016), and was paired with promotion of the survey by local fire departments, conservation districts, KFACC, and in the

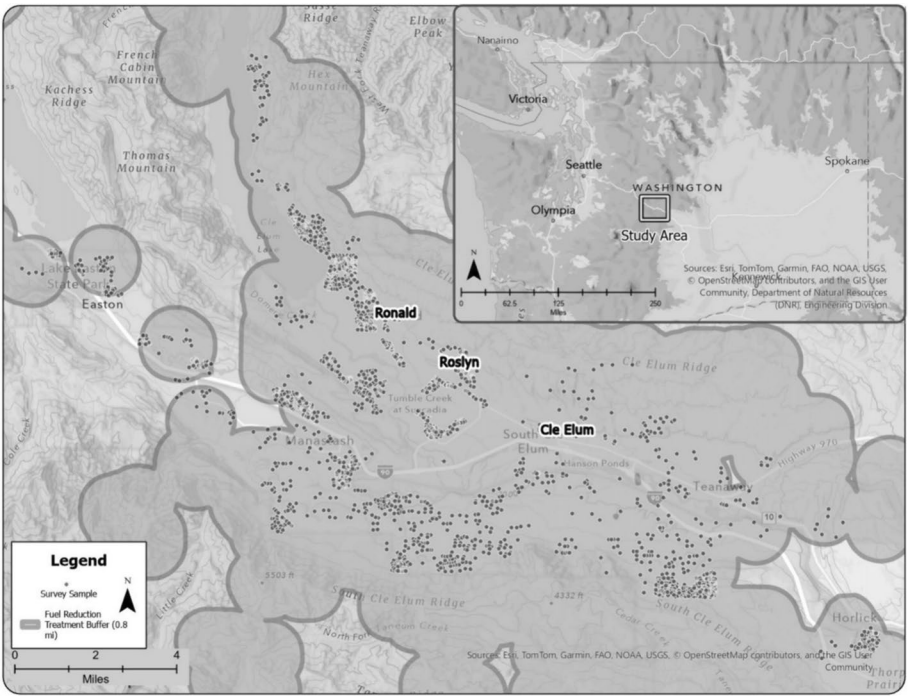

Fig. 1 Location of study area and landowners selected for the survey sample frame. Individual dots each correspond with a parcel centroid selected to receive the survey. The fuel reduction treatment buffer is an aggregate of buffers associated with all completed or planned treatments in the area between 2012–2020. See sect. "Methods" for a full description

local newspaper; (2) as a limited experiment to explore the cost effectiveness of the DOPU method against other mixed-mode methods of survey administration also employed in the study (i.e., mail and online). We do not report on the analysis of cost effectiveness related to survey administration modes in this paper because it is not the focus of the present study.

Researchers administered a concurrent mail survey to the primary tax address of second homeowners and primary landowners who were not contacted during the drop-off, pick up surveys described above. Primary residents who were not contacted using the DOPU method were later merged into the mail sample and sent materials using the mail administration procedures described below. Mail administration included the following mailings adapted from Dillman et al. (2009; 2014) Tailored Design Method: (1) an initial letter introducing the research and outlining the purpose of the study; (2) a paper copy of the survey and a prepaid return envelope, including a link to an online Qualtrics version of the survey; (3) a post card reminder and additional link to the online version of the survey; and (4) a final reminder letter include a second version of the survey and prepaid return envelope.

Researchers administered surveys to a total of 2311 residential property owners using the variety of methods described above. They received a total of 788 completed surveys for a combined response rate of 34%. That response rate is slightly higher than recent wildfire survey efforts, which have been steadily declining for many years. The response rate for the mail/online sample was 29% (622 responses from a sample of 2116). Response rates

using the DOPU method were higher than the mail and online effort (i.e., 85%), though the overall sample was small (165 responses from a sample of 195). Higher response rates for DOPU are consistent with previous work comparing that method to mail administration in rural areas (Brehm et al. 2006; Jackson-Smith et al. 2016; Paveglio et al. 2018b).

Researchers replicated and expanded a series of 5-point, Likert-scale, agree-disagree statements designed to assess residents support or opposition to property owner regulations for wildfire mitigations or broader land use planning to reduce wildfire risk. Those measures have been used in a range of past studies across the inland and intermountain U.S. West, including some of the few studies explicitly focused on resident support or opposition to regulatory approaches (see Paveglio et al. 2013; 2016a, b; 2018b; 2021; Stasiewicz and Paveglio 2022 and Table 1). Survey measures adapted from previous studies also included statements about reduced fire suppression response to private properties that are not in compliance with proposed regulations or planning codes for wildfire mitigation. We adapted Likert-scale, agree-disagree statements from the aforementioned studies gauging residents' perceptions about impact from wildfire, its role as natural landscape process, and its effect on the landscape or their property, including the addition of new measures implicating wildfire impacts to wildlife habitat or outdoor recreation opportunities (see Table 1).

One overarching question in the survey asked respondents about their participation in a variety of planning, education, incentive or mitigation programs designed to reduce wildfire risk. Some of these yes/no questions were replicated from the Paveglio et al. (2021) study for continuity. Researchers also included new prompts implicating cross-boundary and collaborative efforts or individual mitigations that have emerged as more recent foci of wildfire mitigation programs and policy as discussed in our literature review, including participation in community fire prevention events or receiving grant funding to retrofit homes or structures in ways that make them more fire resistant (see Table 2 for full list). Another overarching prompt expanded past work by asking respondents to indicate how likely or unlikely they would be to conduct wildfire mitigations in the future, including collaborative or cross-boundary efforts spanning scales of a broader landscape (see Table 1).

Respondents' perceptions about the perceived sources of wildfire risk or ignitions were derived and expanded from an existing series of Likert scale, agree-disagree statements piloted in other studies (Paveglio et al. 2021). Newly added for this study was an expanded series of statements assessing perceived performance of state, federal and community forest efforts to reduce wildfire risk as part of their management efforts, which is noted in our literature review as a potential correlate to support for regulatory approaches or performance of personal mitigations.

Another set of questions asked respondents about wildfire mitigations they or others have instituted on their property to reduce wildfire risk (see Table 3). These yes/no questions were replicated from a series of existing studies about resident performance of mitigations in the HIZ and the actions that they can take to reduce wildfire risk on their properties (Paveglio et al. 2013; 2016a, b, 2018, 2021). That also includes an expanded set of actions beyond the outer extent of the HIZ (200 feet) to better capture the mitigation actions of residents on larger properties, which is prevalent in the study area for this research. We grouped respondent answers about mitigations into six numerical categories based on methods employed in the studies described above, as follows: (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 correspond with a greater amount of activities performed within each zone of the HIZ or beyond the HIZ (if applicable).

Respondents needed to conduct at least two actions from block 1 of Table 3 mitigations to achieve light mitigation and at least three actions from block 1 to achieve heavy

Table 1 Descriptions of select dependent variables, composite variables and perceptual independent variables examined

Variable name	Variable definition		Descriptive statistics		
	Measures with a Cronbach's α are a summed, composite variable using a principle axis factor analysis. Missing values were not used in analyses		N	Range	Mean (SD)
Vegetation regulations		Homeowners in high fire risk areas should be required to reduce vegetation on their property to reduce their wildfire risk	704	−2=Strongly disagree −1=Moderately disagree 0=Neither agree nor disagree 1=Moderately agree 2=Strongly agree	.83 (1.15)
Building regulations		Homeowners in high fire risk areas should be required to build and retrofit their properties with fire resistant materials to reduce their wildfire risk	701	−2=Strongly disagree −1=Moderately disagree 0=Neither agree nor disagree 1=Moderately agree 2=Strongly agree	−.18 (1.30)
Support for restricted firefighting resources	α=.*916*	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	702	−2=Strongly disagree −1=Moderately disagree 0=Neither agree nor disagree 1=Moderately agree 2=Strongly agree	−1.00 (1.06)
Negative perceived impacts from wildfire	α=.*705*	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 Wildfire would negatively impact nearby outdoor recreation opportunities	685	−2=Strongly disagree −1=Moderately disagree 0=Neither agree nor disagree 1=Moderately agree 2=Strongly agree	.608 (.849)

Table 1 (continued)

Variable name	Variable definition		Descriptive statistics		
	Measures with a Cronbach's α are a summed, composite variable using a principle axis factor analysis. Missing values were not used in analyses		N	Range	Mean (SD)
Healthy wildfire	α=.*763*	Wildfire would improve the health of this landscape Wildfire is a natural and healthy part of this landscape Wildfire could improve wildlife habitat	684	−2=Strongly disagree −1=Moderately disagree 0=Neither agree nor disagree 1=Moderately agree 2=Strongly agree	.074 (1.01)
Public lands fire risk		Most of the fire risk in this area comes from public lands	704	−2=Strongly disagree −1=Moderately disagree 0=Neither agree nor disagree 1=Moderately agree 2=Strongly agree	.020 (1.28)
Private lands fire risk		Most of the fire risk in this area comes from private land	698	−2=Strongly disagree −1=Moderately disagree 0=Neither agree nor disagree 1=Moderately agree 2=Strongly agree	0.05 (1.16)
Human ignition private		Most of the fire risk in this area comes from human ignitions on private land	704	−2=Strongly disagree −1=Moderately disagree 0=Neither agree nor disagree 1=Moderately agree 2=Strongly agree	0.17 (1.08)

Table 1 (continued)

Variable name	Variable definition		Descriptive statistics		
	Measures with a Cronbach's α are a summed, composite variable using a principle axis factor analysis. Missing values were not used in analyses		N	Range	Mean (SD)
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	0.52 (1.05)
large landowner management	α=.*840*	The department of natural resources does a good job of managing lands for wildfire risk The Forest Service does a good job of managing lands for wildfire risk Nearby community forests are well managed to reduce wildfire risk Nearby public lands are well managed to reduce wildfire risk		−2=Strongly disagree −1=Moderately disagree 0=Neither agree nor disagree 1=Moderately agree 2=Strongly agree	−.437 (.933)
Trust fire suppression	α=.*824*	I trust the local fire department to put out fires on my property I trust state agencies to put out fires on my property I trust federal agencies to put out fires on my property I trust privately contracted firefighters to put out fires on my property	692	−2=Strongly disagree −1=Moderately disagree 0=Neither agree nor disagree 1=Moderately agree 2=Strongly agree	.296 (.939)

Table 1 (continued)

Variable name	Variable definition		Descriptive statistics		
	Measures with a Cronbach's α are a summed, composite variable using a principle axis factor analysis. Missing values were not used in analyses		N	Range	Mean (SD)
Collaborative vegetation mitigations	α=.*768*	Extend a fuels reduction project by allowing forest thinning on my land	664	−2=Very unlikely	−.032 (.871)
		Conduct pile burns to remove vegetation on my property		−1=Somewhat unlikely	
		Conduct prescribed fire on my land		0=Neither likely nor unlikely	
		Provide input on a shared fuel break established on public lands		1=Somewhat likely	
		Contribute money toward a shared fuel break with my neighbors		2=Very likely	
		Engage in an agreement with the Department of Natural Resources to have some of fuels reduction costs paid for			
Future shared mitigations	α=.*835*	Support an increase in my county taxes that local government organizations use to help offset risk near private lands	687	−2=Strongly disagree	.083 (1.10)
		Support and increase in my state taxes to help address wildfire risk across Kittitas County		−1=Moderately disagree	
		Support creation of neighborhood districts to help organize local wildfire mitigations		0=Neither agree nor disagree	
				1=Moderately agree	
				2=Strongly agree	

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

Variable name	Variable definition		Descriptive statistics		
	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.		N	Range	Mean (SD)
Wildfire program participation	α =*0.79*	Sum of participation in the following (yes=1, no=0):	646	1-10	2.05 (2.30)
		Received a risk assessment of your property from professionals (33.7%)			
		Obtained a cost-share grant to reduce wildland fuels on your property (13.7.%)			
		Attended a local fire department presentation about wildfire planning (27.5%)			
		Attended a public information meeting about a wildfire (32.0%)			
		Participated in a community fire prevention event (e.g., chipping event, neighborhood Firewise Day) (29.6%)			
		Received grant funding to retrofit your home or structures in a way that makes them more fire resistant (2.3%)			
		Participated in a coordinated effort among private landowners to reduce wildland fuels across properties (27.4%)			
		Participated in a coordinated effort among landowners to manage natural resources (e.g., weeds, streams, forests, etc.) across properties (19.8%)			
		Received grant funding to coordinate wildfire risk mitigation efforts across properties (7.5%)			

Table 3 Mitigation questions for evaluating level of HIZ 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

mitigation. Performance of all requirements for heavy mitigation and at least two actions from block 2 resulted in assignment to the full mitigation group. Residents needed to conduct the above requirements for full mitigation and at least one action from block 3 to achieve full mitigation extended, and all actions from block three and least two actions from block four to achieve full mitigation heavy. A separate question in the survey asked residents to identify the proximity of their nearest neighbor's property line to their residence as a means to better understand whether HIZ mitigation performance might be hampered by residential densities. That question included choices indicating whether the proximity of nearby property was equal to or less than common cutoffs of the HIZ (i.e., equal to or less than 30 feet, between 30 and 100 feet, between 100 and 200 feet, and more than 200 feet away).

Finally, the survey included broad demographic questions that have been consistently included in social science research on wildfire mitigation and resident perceptions of wildfire risk, and that appear in the literature about regulatory or voluntary mitigations discussed above, including: (1) level of education; (2) income (including applicable retirement income); (3) age; (4) full time or part time residency, where a part-time resident is any respondent who spends six months or less at the property that was the focus of the

survey; (5) retirement status; and (6) length of time living in the residence (i.e., tenure). Residency and retirement status were both recoded as binary values and dummy coded for further analysis described in the next section.

3.1 Analysis

Researchers trained additional student coders to help enter all data collected from the survey into the quantitative software package SPSS 25. Coders used a consistent coding protocol, with senior researchers reviewing random samples of coder efforts to ensure consistency in data entry. The senior author conducted a series of factor analyses using the principle axis factoring method on measures related to perceptions about regulation, restricted firefighting resources, likely performance of future cross-boundary wildfire mitigations, wildfire as a healthy part of the landscape, negative impacts from fire, and efficacy of large landowner management using the principle axis factoring method with an oblique rotation. Factor analyses are frequently used to support the creation of composite measures from a series Likert-scale, agree-disagree statements, while oblique rotations are often used when individual measures are conceptually related (Stevens 2009). Measures suggested through factor analysis results are reported in Table 1, including subsequent reliability coefficients associated with constructs used as composite variables. Researchers retained only those factors with Eigenvalues exceeding 1 and individual items with factor loadings greater than 0.40, which is consistent with common methodological practice (Field 2018). Measures related to mitigation regulations were not combined into a composite measure as in previous studies (see Paveglio et al. 2021) for multiple reasons, including variance in average support or opposition to vegetation and building requirements among respondents, factor analysis results, and subsequent reliability coefficients indicating only moderate reliability as a composite measure. Instead, we treated measures about support or opposition to vegetation requirements around homes or building and retrofitting requirements as separate dependent variables in analyses described below.

SPSS is not immediately capable of factor analysis using polychoric or tetrachoric correlations, which are often advocated for use with binary variables such as those related to the program or incentive participation measures implicated in our survey (Green et al. 2016; Flora et al. 2021; Lorenzo-Seva and Ferrando 2021). Therefore, researchers used the FACTOR program (version 12.03.02) developed by Lorenzo-Seva and Ferrando (2022) to conduct factor analysis using polychoric/tetrachoric correlations. Experimentation with a variety of rotations and correlations all indicated a single factor for the actions included, indicating strong potential as a composite measure. The resulting composite variable of "wildfire program participation" also features a reliability coefficient (i.e., $\alpha = 0.79$) above cutoffs typically advocated in methods for creating composite variables (Stevens 2009; Field 2018).

Researchers conducted a series of regressions to replicate and expand previous work using similar measures, and to explore potential interactions or constructs that may be distinct to the study area. In particular, researchers began by running separate regressions for each independent variable and each dependent variable. Subsequent multivariate regressions combined sets of related independent variables (e.g., healthy wildfire and negative impacts) and each dependent variable to explore significant correlations. Variables included in later multivariate regressions were informed by multicollinearity diagnostic results of earlier regressions, correlation matrices and changes in significance of beta values or R^2 values when comparing across different regression models. A final multivariate

regression for each dependent variable retained significant correlates from previous rounds of regressions to explore how the combination of diverse variables influences the structure of correlations and the overall variance explained. The PROCESS v4.3 extension of SPSS (Hayes 2023) was used to conduct any moderation and mediation analysis reported, including post hoc analysis utilizing the Johnson and Neyman approach that allows for exploration of moderation relationships (Hayes 2017; Field 2018). Multiple stages of the regressions described above are presented in results tables.

4 Results

Respondents reported low levels of average support for vegetation regulations (M = 0.083, SD = 1.15) and slight opposition to building regulations (M = −0.18, SD = 1.30) (See Table 1). Respondents reported the highest average opposition toward restricting firefighting resources among private landowners who do not perform mitigation activities on their properties (M = −1.00, SD = 1.06). However, it is worth noting the high standard deviations associated with response to any regulations described above. These results provide initial indication that opinions about regulations differ across the targeted sample frame for the survey, and which covers a relatively small portion of a county.

There was high agreement among respondents that wildfire would result in negative impacts to the study area or private property (M = 0.608, SD = 0.849) and a related disagreement that wildfire is a healthy, necessary component of the landscape (M = −0.74, SD = 1.01) (See Table 1). Respondents also reported low to moderate engagement with participation actions comprising our composite variable of wildfire program participation (M = 2.05, SD = 2.30). Receiving a risk assessment of their property by professionals (33.7%), attending a public information meeting about a wildfire (32.0%) and participating in a community fire prevention event (29.6%) were the most commonly performed program activities. Participation in coordinated efforts among landowners to reduce wildland fuels (27.4%) or to manage natural resources (19.8%) were less common, while receiving cost share grants to reduce wildland fuels on properties (13.7%) or grant funding to coordinate wildfire risk mitigation efforts across properties (7.5%) were among the least performed activities.

Respondents indicated that the highest source of wildfire risk in their area stemmed from human ignitions on public lands (M = 0.52, SD = 1.05), followed by human ignition on private lands (M = 0.17, SD = 1.08). They indicated a higher overall perception that fire risk comes from public lands (M = 0.20, SD = 1.28) in the area when compared to private lands (M = 0.05, SD = 1.16), though high standard deviations for all these measures indicate disagreement among populations sharing the same risk. Respondents indicated relatively strong disagreement that public lands or community forests in the area were well managed for wildfire risk (M = −0.437, SD = 0.933). They also indicated a moderately strong agreement that they trusted local, state, federal and privately contracted firefighting agencies to put out fires on their properties (M = 0.296, SD = 0.939).

Approximately 27.01% of respondents indicated that they had performed none of the mitigation activities associated with the HIZ on their property. An additional 20.70% had performed actions associated with the light fuel reduction category, 26.88% had performed mitigations corresponding to the heavy mitigation category, and 6.72% had performed mitigations corresponding with the full mitigation category. Approximately 4.70% of respondents had performed sufficient mitigations to meet the full mitigation extended

category, and 13.98% had completed actions corresponding with the full mitigation heavy category. Finally, respondents indicated that they were somewhat unlikely to engage in future vegetation mitigations on their property, including cross-boundary fuels reduction efforts (M = − 0.032, SD = 0.871), and were moderately likely to support future shared mitigations such as increases in taxes for wildfire risk and creation of neighborhood districts to organize local wildfire mitigations (M = 0.083, SD = 1.10). Again, high standard deviations among these reliable composite variables indicate significant individual disagreement among populations in proximity to past or planned fuel treatments.

Select results from the multivariate models using support for vegetation management regulations on private property as a dependent variable are presented in Table 4. Initial regressions of conceptually related independent variables indicated that perception of wildfire risk as stemming from human ignition on private lands is significantly correlated with support for vegetation regulations (β = 0.095, $p = 0.029$). That is, as agreement that wildfire risk comes from human ignition on private lands increased, support for vegetation regulations also increased. Agreement that large landowners manage wildfire well (β = 0.098, $p = 0.015$) and performance of higher levels of HIZ mitigations (β = 0.126, $p = 0.001$) were both significantly and positively correlated with support for vegetation requirements on private properties. Likewise, higher likelihood of participating in future shared mitigation activities was positively correlated with support for vegetation requirements (β = 0.215, $p = < 0.001$). That is, as likelihood of supporting future increases in taxes or the establishment of neighborhood districts to organize wildfire mitigations increased, support for vegetation regulations also increased. Examination of initial collinearity diagnostics led us

Table 4 Results of regressions for support of vegetation management regulations

Independent variable	Model sets 1			Model sets 2		
	SE(b)	β[a]	p[b]	SE(b)	β[a]	p[b]
Program participation	.019	.052	.175			
Adjusted R^2			.001			
Human ignition private	.046	.095	.029*	.039	.078	.039*
Human ignition public	.046	.017	.710			
Human ignition private X Human ignition public	.031	− .106	.005**	.030	− .121	.001**
Adjusted R^2			.016			
Large landowner management	.049	.098	.015*	.048	.053	.199
Trust fire suppression	.049	.011	.785			
Adjusted R^2			.007			
Healthy wildfire	.048	.067	.115			
Negative wildfire impacts	.057	.036	.400			
Adjusted R^2			.001			
HIZ mitigation	.027	.126	.001**	.025	.140	.000***
Collaborative vegetation mitigations	.054	.039	.352			
Future shared mitigations	.038	.215	.000***	.038	.213	.000***
Adjusted R^2			.061			.084

*$p < .05$, **$p < .01$ and ***$p < .001$

[a]Standardized regression coefficient

[b]$p = p$-value

to introduce an interaction term for the human ignition private and human ignition public variables (i.e., moderation analysis) which was resulted in a significant, negative effect (β = −0.106, p = 0.005). More specifically, at low and mean levels of belief that risk comes from human ignition on public lands, there is a significant and negative interaction between belief that risk comes from private lands and support for vegetation management. None of the demographic indicators included in the models (i.e., age, income, education, part time/full time status or retirement status) were significant correlates with support for vegetation management requirements.

A final multivariate regression model retains and combines significant variables from previous regressions (see column 2 of Table 4). Perceptions about large landowner management for wildfire risk loses its significance in the model. Human ignition on private lands (β = 0.078, p = 0.039), the interaction between human ignition on private lands and human ignition on public lands (β = −0.121, p = 0.001), performance of HIZ mitigation (β = 0.140, p = < 0.001) and support for future shared mitigations (β = 0.213, p = < 0.001) all retained their significance. Analysis of multicollinearity statistics, potential conceptual relationships, and changes in the significance of variables across models led us to explore a potential mediation effect between perceptions of large landowner management and likelihood of support for shared mitigations. Results of the mediation analysis indicate there was a significant indirect effect of large landowner management on support for vegetation management requirements through support for future shared mitigation activities (β = 0.290, 95% BCa CI [−0.010, 0.05]). The final multivariate model explains a relatively moderate amount of variance in the data (R^2 = 0.084).

Select results from our multivariate regressions using support for requirements to build or retrofit homes to minimize wildfire risk are presented in Table 5. Initial regressions of conceptually related independent variables indicated a significant and positive relationship between performance of HIZ actions (β = 0.123, p = 0.002) and likelihood of support for future shared mitigations (β = 0.196, p = < 0.001) with support for building and retrofitting requirements. That is, as performance of HIZ mitigations or likelihood of support for future shared mitigations increased, support for building and retrofitting regulations also increased. Perception that risk comes from human ignition on public lands (β = 0.121, p = 0.005) and perception that large public landowners were doing a good job of managing for wildfire risk (β = 0.098, p = 0.015) were both significantly and positively correlated with support for building and retrofitting regulations. There was a significant and negative relationship between part time residency and support for building and retrofitting requirements (β = −0.103, p = 0.008). Put another way, part time residents were less likely than full time residents to support building and retrofitting wildfire mitigation requirements for private landowners. No other demographic variables tested were significant correlates (i.e., age, income, education, or retirement status).

A final multivariate regression model using support for building and retrofitting requirements is presented in column 2 of Table 5. Perception that risk comes from human ignition on public lands (β = 0.128, p = 0.001) performance of HIZ mitigations (β = 0.101, p = 0.008) and likelihood of support for future shared mitigations (β = 0.202, p = < 0.001) all retained their positive, significant relationships with support for building and retrofitting regulations. Likewise, the negative relationship between part time residency and support for building and retrofitting regulations retained significance (β = −0.112, p = 0.004). Perception that large landowners do a good job of managing for wildfire risk lost significance in the final model, though our review of multicollinearity statistics led us to explore a mediation effect between perceptions about large landowner management and likelihood of support for future shared mitigations. Results of the mediation test revealed that there

Table 5 Results of regressions for support of fire resistant building or retrofitting requirements

Independent variable	Model sets 1			Model sets 2		
	SE(b)	β[a]	p[b]	SE(b)	β[a]	p[b]
Program participation	.021	.004	.860			
Adjusted R^2			− .001			
Private lands fire risk	.045	.056	.161			
Human ignition private	.054	.015	.746			
Human ignition public	.053	.121	.005**	.046	.128	.001**
Adjusted R^2			.018			
Large landowner management	.056	.098	.015*	.054	.066	.088
Trust fire suppression	.056	.005	.905			
Adjusted R^2			.007			
Healthy wildfire	.065	.034	.419			
Negative wildfire impacts	.074	.055	.057			
Adjusted R^2			.000			
Part time	.101	− .103	.008**	.099	− .112	.004**
Adjusted R^2			.011			
HIZ mitigation	.031	.123	.002**	.030	.101	.008**
Collaborative vegetation mitigations	.062	− .043	.312			
Future shared mitigations	.047	.196	.000***	.045	.202	.000***
Adjusted R^2			.042			.087

*$p < .05$, **$p < .01$ and ***$p < .001$

[a]Standardized regression coefficient

[b]$p = p$-value

was a significant indirect effect of large landowner management on support for building regulations through support for future shared mitigations such as increased taxes and wildfire districts (b = 0.26, 95% BCa CI [− 0.83,0.47]). The final multivariate model explains a relatively modest amount of the total variance ($R^2 = 0.087$).

Select results for our multivariate regressions using support for restricted firefighting resources are presented in Table 6. Belief that wildfire is a healthy part of the landscape was significantly and positively correlated with support for restricted firefighting resources (β = 0.172, $p = < 0.001$). That is, as agreement that wildfire is a healthy part of the landscape increased, support for restricted firefighting resources also increased. Trust in fire suppression entities (β = − 0.089, $p = 0.021$) and retirement status (β = − 0.92, $p = 0.016$) were both positively and negatively correlated with support for restricted firefighting resources. In the case of the latter, non-retirees were less likely to support restricted firefighting resources when compared to retirees, while increased trust in firefighting entities correlated with less likelihood of support for restricted firefighting resources. Education (β = 0.92, $p = 0.017$), performance of HIZ mitigations (β = 0.093, $p = 0.014$) and program participation (β = 0.082, $p = 0.032$) were all significantly and positively correlated with support for restricted firefighting resources. Examination of multicollinearity statistics, results of initial regressions, and potential conceptual relationships led us to explore a potential moderation effect (i.e., interaction) between private lands fire risk and human ignition on private lands, which was positive

Table 6 Results of regressions for support of restricted firefighting resources

Independent variable	Model sets 1			Model sets 2		
	SE(b)	β[a]	p[b]	SE(b)	β[a]	p[b]
Program participation	.018	.082	.032*	.019	.012	.771
Adjusted R^2			.007			
Private lands fire risk	.038	.043	.273			
Human ignition public	.045	.085	.057			
Human ignition private	.046	.007	.864			
Trust fire suppression	.044	− .089	.021*	.046	− .081	.040*
Private lands fire risk x human ignition private	.031	.102	.009**	.019	.095	.014*
Adjusted R^2			.022			
Healthy wildfire	.040	.172	.000***	.043	.135	.001**
Negative wildfire impacts	.053	.055	.193			
Adjusted R^2			.030			
Education	.026	.092	.017*	.027	.090	.031*
Retired	.082	− .092	.016*	.085	− .076	.053
Adjusted R^2			.015			
HIZ mitigation	.024	.093	.014*	.027	.093	.024*
Adjusted R^2			.007			
Program participation x trust fire suppression				.019	− .091	.021*
Adjusted R^2				.074		

*$p < .05$, **$p < .01$ and ***$p < .001$

[a]Standardized regression coefficient

[b]$p = p$-value

and significant (β = 0.102, $p = 0.009$). More specifically, at moderate to high levels of perception that fire risk comes from human ignitions on private lands, there is a significant and positive correlation between perception that fire risk comes from private lands and increased support for restricted firefighting resources.

Results from our final multivariate regression model using restricted firefighting resources as the dependent variable are provided in column 2 of Table 6. The final model explains a relatively moderate amount of variation in the data ($R^2 = 0.074$). Belief that wildfire is a healthy part of the landscape (β = 0.135, $p = 0.001$), performance of HIZ mitigations (β = 0.093, $p = 0.024$), education (β = 0.90, $p = 0.031$) and the interaction effect between private lands risk and human ignition on private lands (β = 0.095, $p = 0.014$) all retain their significant and positive correlations to restricted firefighting resources in the model. Trust in fire suppression entities retained its negative correlation to restricted firefighting resources (β = − 0.081, $p = 0.040$), while retirement status and program participation lost their significance in the model. Subsequent exploration of multicollinearity statistics and changes in the significance of variables between models led us to explore a potential moderation effect (i.e., interaction) between program participation and trust in fire suppression entities. Introduction of the interaction term revealed a significant and negative effect (β = − 0.91, $p = 0.21$). That is, at lower levels of trust in firefighting entities, there is a significant and negative interaction between program participation and support for restricted firefighting resources.

Select results for our multivariate regressions using performance of HIZ mitigation as the dependent variable are presented in Table 7. Increasing participation in wildfire programs (β = 0.277, $p = < 0.001$) and belief that wildfire is a healthy component of the landscape (β = 0.248, $p = 0.003$) were significantly and positively correlated with greater performance of HIZ mitigations. That is, higher levels of participation in wildfire related programs or greater belief that wildfire is a healthy part of the landscape are associated with increasing levels of HIZ mitigations performed by the respondent. There was a significant and negative correlation between part time residency and performance of HIZ mitigations (β = − 0.083, $p = 0.021$), indicating that part time landowners were less likely than full time landowners to perform increasing levels of HIZ mitigations. Belief that wildfire risk predominantly comes from private lands was significantly and positively correlated with HIZ mitigations (β = 0.080, $p = 0.045$). We also explored whether there was a potential moderation effect between belief that wildfire risk comes from private lands and belief that wildfire risk comes from human ignition on private lands, which was not significant (β = 0.116, $p = 0.874$). Support for collaborative vegetation mitigations (β = 0.306, $p = < 0.001$) was positively and significantly correlated with performance of HIZ mitigations, while future shared mitigations was significantly and negatively correlated with performance of HIZ mitigations (β = − 0.111, $p = 0.005$). Regarding the latter finding, those who indicated they were more likely to support shared mitigations such as increased taxes

Table 7 Results of regressions for HIZ mitigation performance

Independent variable	Model sets 1			Model sets 2		
	SE(b)	β[a]	p[b]	SE(b)	β[a]	p[b]
Program participation	.027	.277	.000***	.025	.230	.000***
Adjusted R^2			.095			
Private lands fire risk	.057	.080	.45*	.051	.035	.340
Human ignition private	.062	.062	.121			
Private lands fire risk X Human ignition private	.058	.116	.874			
Adjusted R^2			.013			
Healthy wildfire	.069	.248	.003***	.058	.130	.000***
Wildfire impact	.082	− .047	.570			
Healthy wildfire X Negative wildfire impact	.070	.117	.929			
Adjusted R^2			.030			
Part time	.119	− .083	.021*	.117	− .050	.165
Nearest neighbor	.466	.297	.000***	.079	.406	.000***
Adjusted R^2			.095			
Collaborative vegetation mitigations	.075	.306	.000***	.072	.202	.000***
Future shared mitigations	.059	− .111	.005**	.056	− .115	.002**
Adjusted R^2			.082			
Healthy*near				.054	.232	.000***
Adjusted R^2						.247

*$p < .05$, **$p < .01$ and ***$p < .001$

[a]Standardized regression coefficient

[b]$p = p$-value

and local neighborhood districts to organize mitigations were less likely to have conducted higher levels of HIZ mitigations on their properties. Again, no other demographic variables beyond residency (i.e., age, education, income, retirement status) were significant correlates with HIZ mitigation performance.

The final multivariate regression using performance of HIZ mitigations as the dependent variable are presented in column 2 of Table 7. We added the variable nearest neighbor in this final regression in an effort to better understand if proximity to property boundaries influenced performance of mitigations in the HIZ. Distance to nearest neighbor was positively and significantly correlated with greater levels of HIZ performance ($\beta = 0.406$, $p = < 0.001$) indicating that those respondents whose structures were further away from neighboring property lines were more likely to perform higher levels of HIZ mitigations. Support for collaborative vegetation mitigations ($\beta = 0.202$, $p = < 0.001$), belief that wildfire is a healthy part of the landscape ($\beta = 0.130$, $p = < 0.001$) and program participation ($\beta = 0.230$, $p = < 0.001$) retained their highly significant and positive correlations with performance of HIZ mitigations in the final model. Likewise, support for future shared mitigations retained its significant and negative correlation with performance of HIZ mitigation ($\beta = -0.115$, $p = 0.002$). Part time residency and belief that wildfire risk comes from private lands lost significance in the final model. These results and review of the multicollinearity statistics led us to test for additional mediation effects. Results of our mediation tests revealed a significant indirect effect of residency status on performance of HIZ mitigations through proximity to nearest neighbor ($\beta = -0.041$, 95% BC aCI [−0.092, 0.005]). This implies that part time residents are more likely to have neighboring property lines close to their structure, and are also less likely to perform HIZ mitigations. There also was a significant indirect effect of residency status on performance of HIZ mitigations through belief that fire risk comes from private lands ($\beta = -0.184$, 95% BCa CI [−0.045, 0.004]). Finally, we explored a moderation (i.e., interaction) effect between belief that wildfire is a healthy part of the landscape and the nearest neighbor variable, which was positive and significant ($\beta = 0.232$, $p = < 0.001$). More specifically, at mean and high levels of distance from their nearest neighbor, there is a significant and positive interaction between viewing wildfire as healthy and performance of greater HIZ mitigations.

5 Discussion

The purpose of this research was to explore relationships between residents' performance of wildfire mitigations on their properties, participation in wildfire mitigation programs or planning, and support for regulatory approaches to mitigation on private properties. We were also interested in whether and how perceived wildfire risk sources (e.g., public or private lands and human ignition), likelihood of future participation in collaborative vegetation management actions, support for shared mitigation efforts (e.g., taxes and local implementation districts), perceptions about the role of fire in the landscape, or perceptions about public land and firefighting management influenced support for regulatory or voluntary approaches to reducing wildfire risk among residential landowners.

Our results indicate variability in resident support for select elements of regulatory approaches, with relatively low levels of average support for building or retrofitting regulations and slight support for vegetation requirements on private properties. We found lower levels of support for restricted firefighting resources among those who do not mitigate risk on their lands, and a moderate level of participation in a variety of programs or actions

offered to engage landowners in mitigation of shared wildfire risk. We also found relatively low levels of study area resident support for engaging in future collaborative vegetation management actions, slight levels of overall support for shared mitigations that included taxes and local district management of risk, and a strong disagreement that public land agencies and community forests in the area are well managed for wildfire risk.

One overarching lesson from the summary findings above is the very high level of variability in individual residents' perspectives about nearly all of our measures, providing another example of diverse perspectives and support for fire management practices (what some call social diversity or social fragmentation) across relatively small geographic scales (Paveglio et al. 2015, 2018a, 2019a, b; Edgeley et al. 2020). Our results are one of the few to explicitly document such variability at specifically targeted scales—among residents in close proximity to past or planned fuels reduction treatments in the same small region of a county, and that span a gradient of more developed suburbs to rural properties. If such variability exists among the subset of populations implicated in this study, then it is likely that just as stark or even more divisive opinions may characterize other wildfire prone areas that have not yet received as much wildfire prevention attention. As such, our initial results corroborate growing concerns about wholesale efforts to generalize human populations at landscape, county or sub county scales (e.g., census block groups, tracts) when considering their support for wildfire mitigation initiatives or when attempting to gauge their perspectives about fire management (e.g., trust in fire managers, views about fire as a natural and healthy part of the landscape) (Buxton et al. 2011; Paveglio et al. 2021; Essen et al. 2023). While fire policy and planning increasingly focuses on "scaling up," our results and others in the literature suggest that resident agreement about the best ways to address shared risks may be increasingly divisive and detrimental to the shared agreements and mitigation contributions that are needed among individual landowners, governments, land management agencies, and other actors whose actions all co-create vulnerabilities in fire prone lands (Kelly et al. 2019; Billings et al. 2021a, Paveglio 2021; Mockrin et al. 2022). We return to this point in discussing additional nuance of our results below.

Results emerging across our regression efforts begin to contextualize the variable influences on differential resident support for regulatory approaches. To begin, our results support a long history of wildfire social science suggesting that attribution of human ignition as a source of wildfire risk or damages is likely an important influence on support for various regulatory approaches. They also suggest that consideration of human ignition may continue to be an important starting point when crafting dialogue about shared wildfire management initiatives, including efforts to minimize risk transmission across private and public lands (see Kumagai et al. 2004a, b; Carroll et al. 2006, Shindler et al. 2014; Nagy et al. 2018). However, our results also suggest that attribution of fire risk to human ignitions on private or public lands can be differentially correlated with support for what residents in this study appear to conceptualize as distinct regulatory actions (i.e., building requirements or vegetation requirements). That is, agreement that fire risk stems from *human ignition on public land* was correlated with support for building or retrofitting requirements, while agreement that fire risk stems from *human ignition on private land* was correlated with support for vegetative management regulations. Collectively, these findings may suggest that residents evaluate the need for regulatory approaches primarily as a *response or reaction* to perceived risk, and as a way to compensate for the system components (e.g., landownerships or people) they consider most responsible for that shared risk.

Take for instance the significant interaction effect we found between perceptions of risk as stemming from human ignition on private lands and human ignition on public lands when using vegetation management regulations as the dependent variable. This may imply,

as other research has suggested, that residents compare different sources of risk when determining which ones warrant the added level of burden that regulatory requirements may impose on private residents (e.g., vegetation requirements or building requirements) (Busby et al. 2012; Lanpap and Wu 2021; Al Abri and Grogon 2021). Our results also are contextualized by the indirect (i.e., mediating) effects that perceptions of large landowner management appears to have on support for either building or vegetation mitigation requirements. Those mediation effects, when paired with respondents' low overall evaluation of public lands management for wildfire, suggest that any support for regulatory efforts is in part a reaction to perceived wildfire conditions beyond individual control (see Talberth et al. 2006; Busby et al. 2013, Gordon et al 2018 or Dickinson et al. 2020 for supporting discussions).

The above findings provide nuance to ongoing research exploring the ways that residents living in fire-prone areas consider their potential liabilities or opportunities to reduce wildfire risk by demonstrating how their thinking might incorporate the actions of others operating in a broader landscape. However, those same findings could also be concerning in that motivation to implement regulations seems to be influenced, at least in part, by perspectives that land management agencies are not doing a good job managing wildfire risk or that private residents are not doing their part to reduce wildfire risk. Collaboration, coordination, and shared responsibility for addressing wildfire risk in shared landscapes are increasingly the overarching messages of much wildfire management policy and practice (Charnley et al. 2019; Hamilton et al. 2021; Huber-Stearns et al. 2022). And as much collaboration or risk communication literature demonstrates, motivating stakeholders to take action from a place of deficit, perceived risk, or "blame" can inhibit trust between parties sharing responsibility for management or dissuade mitigation action among some residents. This may also extend to the adoption of policy standards among governments without the funds, authority or constituent support to enforce regulations for wildfire on private lands (see Daniels and Walker 2001; Kumagai 2004a, b; Bardsley et al. 2015; Emborg et al. 2020; Paveglio et al. 2021; Byerly Flint et al. 2022 for supporting discussions).

Thus, our results suggest careful consideration when using risk transmission or other wildfire risk simulation outputs as a means to uniformly engage residential populations. Risk transmission and simulation efforts may be an effective way to conceptualize *initial* considerations about fuels treatment needs or responsibilities in a landscape, however, there is less understanding or utility regarding ways that residents might use or engage with them in producing the collective action needed to address wildfire risk. Future efforts may need to experiment with the best ways to make risk transmission or simulation efforts transparent, or to develop strategies for negotiating how results lead to a dialogue about what different landowners can contribute to mitigation efforts given results about risk sources or likely fire progression. Even better, these initial expectations and agreements about shared contribution should come *before* the development of risk transmission and simulation outputs that some users may misconstrue as "answers" rather than decision inputs created using a myriad of assumptions that may or may not conflict with stakeholder perceptions. Likewise, while attribution of fire ignition sources continues to be an important consideration, dwelling on this aspect of fire management, or using it as an overarching discussion point when negotiating how different landowners contribute mitigations to broader wildfire management could be detrimental to future collaborations. Instead, risk transmission efforts might do well to contextualize ignition sources as only one piece of a much larger set of conditions leading to wildfire propagation and spread, or co-develop scenario simulations of ignition potential with actors in landscapes that help illuminate targeted ways their behaviors could reduce potential exposure. This is especially true because

many wildfire risk simulations use historical ignitions or probabilistic random simulations of ignition as the source of their outputs (see Carroll et al. 2007; Wunder et al. 2021; Downing et al. 2022).

Other segments of our results help advance literature on resident contributions to wildfire risk mitigation by more explicitly substantiating the link between increased participation in collaborative wildfire programs and the completion of HIZ mitigations that have been a primary focus of such efforts (see Paveglio et al. 2021). That being said, program participation had very little relationship with support for regulatory approaches, save for an interaction effect implying that residents seek out such programs when they have low trust in fire suppression agencies *and* are more likely to oppose restricted firefighting resources. We would suggest that these findings are a function of the historical focus guiding much wildfire outreach to residents. For instance, a focus on performance of HIZ mitigations has long been ingrained in resident outreach and programs surrounding wildfire, including the FireWise USA Communities Program, the International WUI code, and landscape-scale efforts such as the Joint Chiefs Landscape Restoration Partnership (McCaffrey 2015; Cowan and Kennedy 2023; International Code Council 2024).

Higher engagement with wildfire programs, which often focus on the ways that residents can perform mitigations that make their properties *easier to defend* during fire suppression, still tend to imply that firefighting resources will be employed during events that require the protection of values-at-risk. Nor do they often focus heavily on requirement of private property mitigations, instead focusing on incentivized, voluntary vegetation management or structure retrofitting actions that landowners can perform to reduce their risk (Hessln 2018; Koksal et al. 2019; Moritz et al. 2022; Wolters 2023). Therefore, it is not surprising that program participation was not related to support for regulatory approaches. However, those same results also imply caution in assuming that high levels of resident engagement in existing wildfire programs will translate to the broad support needed to impose regulatory requirements on private property through county ordinances, zoning requirements, and code adoption. Instead, our results and those of others (e.g., Paveglio et al. 2018a, 2019a, b; Mockrin et al. 2018, 2020; Paveglio 2021) suggest a potential need for new programs, initiatives, supporting information or locally led processes when making the case for regulatory efforts, which are likely to be first instituted in tailored ways at small scales (see Edgeley and Paveglio 2024 for empirically driven conclusions among professionals working in the study area). Therefore, an important next step for research may be to experiment with different messages, planning processes or supporting information necessary to institute regulatory approaches among various populations. It could also mean exploring what factors led to support and opposition where regulatory initiatives have been attempted.

Higher levels of voluntary HIZ mitigation performance were uniformly correlated with support for all forms of regulatory approaches explored in the research, and with future performance of collaborative vegetative mitigations. The former of these correlations, when considered in conjunction with earlier findings, may suggest that residents who have already taken responsibility to reduce risk on their properties are in support of regulating those that have not done the same. Likewise, those performing mitigations on their lands appear to be in support of contributing to cross boundary efforts in the future, providing further substantiation that individual mitigation action may be an important precursor or primer to the pursuit of coordinated mitigations across ownership boundaries (see Paveglio et al. 2016a, Meldrum et al. 2018, Paveglio and Kelly 2018, or Warziniack et al. 2019). Those motivated to perform HIZ efforts in greater amounts among our sample are more likely to consider wildfire as a healthy part of the landscape, which is another frequent focus of existing wildfire programming as discussed above. However, that consideration of

wildfire as a healthy part of the landscape was not a correlate in any consideration of regulations save for restricted firefighting response. These findings may further substantiate a conclusion that distinct options for addressing wildfire risk management may invoke different considerations or resonate with the beliefs of different population segments inhabiting larger landscapes (Brenkert-Smith et al. 2017; Edgeley et al. 2020; Paveglio 2023).

Our addition of property boundary characteristics suggests that those with larger properties are more likely to perform higher levels of HIZ mitigations, perhaps because they can more readily undertake mitigations that span the 100- or 200-foot focus of HIZ recommendations, or because they have the latitude to perform fuels reduction work beyond the 200 foot area surrounding their structures. The significant moderation effect we found between nearest neighbor and belief that wildfire is a healthy part of the landscape extends these findings to the perspectives, worldviews or beliefs underlying static indicators such as parcel size, and that larger segments of the literature indicate are less tangible, but enduring influences on human decision making about mitigation. Namely, our results suggest that those who own larger properties are more likely to view wildfire as a natural part of the landscape, and thus are more likely to perform HIZ treatments, including stewardship of land immediately beyond their homes (Paveglio et al. 2013, 2021; Olsen et al. 2017; Ribe et al. 2022). Such findings could be explored in the future through more explicit focus on how residents' lived experience or perceptions of amenities on different sized parcels, including those used for different purposes (e.g., recreational, investment property, agricultural), affect their views about wildfire.

Conversely, the highly significant correlation we found between property boundary characteristics and self-reported HIZ actions implies that smaller properties or dense residential development serve as potential barriers to the performance of perhaps the most commonly advocated private land fire mitigation in the United States. Many existing and ongoing research studies of resident mitigation performance do not take into account parcel size or boundaries during assessment of mitigation performance or exploration of what motivates mitigation action, which could bias mitigation monitoring or result in dedication of program resources toward actions that cannot be fully realized. For instance, residents performance of HIZ mitigations that extend onto their neighbors property are likely to require much more effort, or might not be possible due to an inability or unwillingness of neighbors to establish collective mitigations. We would suggest a few possible strategies to advance such considerations. To begin, our results and others have continued to suggest that self-reported data on resident mitigation efforts should also include data about parcel boundaries in order to better conceptualize whether HIZ actions are feasible and useful actions to use as benchmarks of adaptive behavior (see Paveglio et al. 2016a, 2021; Meldrum et al. 2022). HIZ mitigation messaging or actions could be expanded to incorporate different assistance, resources, or contributions for addressing defensible space in such conditions. For instance, targeting fuel breaks on the outskirts of densely populated areas may be attractive among homeowners in densely populated areas who cannot treat the full HIZ on their properties, as would the treatment of common areas through developments or neighborhoods (see Paveglio et al. 2018a, b, Schumann et al. 2020, Moritz et al. 2022; or Paveglio 2023 for related arguments). Those efforts might also ask different contributions from benefitting populations—a shared HOA fee to support fuel break creation (or contributed labor), agreements about retrofitting structures to be more fire resistant when properties are next sold, etc. Many of these activities already occur or are facilitated by managers at local scales, but less commonly are they conceived of as comparable actions to an overarching focus on the HIZ. However, a uniform view of the HIZ does not reflect the reality of diversifying settlements in the WUI and beyond.

Our findings about residency (full-time or part-time residents) and performance of HIZ mitigations provide further insight on the above considerations, and also help extend a longitudinal focus on the ways that "amenity migration" can influence strategies for reducing residential wildfire risk (see McCaffrey 2015 or Cowan and Kennedy 2023 for overviews). We found that second homeowners were less likely to perform HIZ mitigations on their properties when compared to full-time residents. However, the mediations and interactions we observed suggest that those results may be the product of both structural and attitudinal factors. For instance, the mediation we found between part-time residency and nearest neighbor suggests that lower performance of HIZ mitigations among part-time residents is at least partially related to the smaller parcels or high densities where those populations appear to own property in our study area. Other results do somewhat corroborate existing work indicating that part-time residents are less likely to believe risk comes from private lands (see Paveglio et al. 2021), however that belief does not appear to rise to the level of support for building and retrofitting requirements. These findings may be due to the fact that some second homeowners choosing to develop on the "eastside" of Washington do so to avoid the more restrictive residential requirements occurring west of the Cascades, and who can bring renewed expectations about the primacy of property rights in more rural areas. It could also suggest a desire for privacy, or perceptions of negative aesthetic impacts associated with vegetation removal, both of which might discourage mitigation action among some landowners (see Dickinson et al. 2015, or Paveglio et al. 2016b for examples). The lack of support for wildfire building regulations among part-time residents is particularly troubling given that home hardening among part-time homeowners living on small parcels are likely among the most salient contributions those landowners can contribute toward initiatives that reduce wildfire risk and unsustainable fire suppression efforts driven in part by protection of private property. It also suggests a key discussion point in negotiations about the targeting of regulatory approaches, especially as Kittitas County continues to see development of "bedroom" or "vacation" communities for individuals from the "westside" of Washington.

Comparing across our results suggests that the most supported strategy among residents in our sample may be to support the establishment of local, tax funded districts who help encourage *voluntary mitigations* and adapt additional wildfire mitigation programs that are tailored to smaller areas. However, that potential "pathway" for fire adaptation is a compromise between seemingly divergent views among population segments inhabiting the study area, and whose differences of opinion about future wildfire management may be the most complex barrier to overcome in the region (see Paveglio 2019b, Billings et al. 2021b or Paveglio 2021 for related discussions). Consider, for instance, the negative correlation we observed between support for future shared mitigations (i.e., taxes and local districts) and HIZ performance. This finding could implicate a population segment who value personal responsibility, voluntary actions, and personal property freedoms, which is common both in this region and other historically rural regions of the U.S. West (Paveglio and Edgeley 2017; Stasiewicz and Paveglio 2018; Mockrin et al. 2020). Another set of correlations between support for future shared mitigations, HIZ performance and regulatory approaches may implicate a different population segment who are taking personal responsibility on their properties, but see a need to more closely regulate other populations segments who have not done the same, and thus are not "pulling their weight" in contributing to fire management across the landscape. Our results suggest a desire for any such regulation to take place at local levels, and with local accountability that rural populations may prefer.

Thus, we would suggest that for the populations we studied in Kittitas County, residential mitigation efforts are likely more than just a 'last mile problem' (see National

Academies of Sciences, Engineering, and Medicine 2017). Residents have engaged in programs about HIZ mitigation, and some are taking mitigation action. Yet there also might be places where divergent perspectives or willingness to support broader initiatives among residents first necessitate working with changing "market segments" of the broader landscape when forging shared buy-in for mitigations that all actors feel are appropriate to reduce their shared risk. Establishing local districts who work to promote or encourage voluntary mitigations that might add up to broader cross-boundary projects has the potential to help achieve that buy-in, and might help to tease out the many nuanced, place-based elements of individual or collective action that surveys or distantly designed programs are not well designed address (see Edgeley 2023 or Paveglio 2023 for supporting discussions). Similarly, local districts would allow for a focus at smaller, community scales that professionals and practitioners in the region have identified as a more appropriate unit by which to address fire adaptation in their county (see Edgeley and Paveglio 2024).

6 Conclusions

Our results in this case suggest that neither regulatory nor voluntary approaches are likely to be a one-size-fits-all solution, even in a small segment of a broader landscape. A more actionable approach may be to first build up appropriate, supported actions among smaller segments of at-risk populations, and in ways that regularly consider how they perceive of wildfire risk sources or public lands management in the places where they live. Success in implementing initial mitigation actions (voluntary or regulatory) could eventually lead to broader actions by other agencies or local governments, and with an eye toward differential contribution by diverse population segments. Likewise, our exploration of perceived risk sources suggest that broader research or communication about "risk transmission" should be carefully contextualized and co-crafted to be one input in negotiations aimed to engender coordinated actions.

The relatively low amount of variance explained in our regressions suggest there is still much to understand when making the conceptual leap from promotion of personal responsibility for wildfire mitigations to shared actions or requirements for doing so among a broader segment of residential populations. For instance, while our results indicate that existing wildfire programs do correlate with *voluntary* landowner mitigation actions, separate programs are likely needed to develop the targeted support required to implement sustainable regulatory approaches for such mitigations (i.e., codes, ordinances, or laws). Similarly, those who are already conducting wildfire mitigations on their properties may be more supportive of regulatory approaches, but that correlation likely does less to stimulate the support needed among populations who are taking less mitigation action, and who might not adhere to any regulations that cannot be enforced. In any case, continued engagement with residential populations surrounding wildfire mitigation should be mindful that such efforts will look different among unique "market segments" that likely occupy each landscape. For instance, our results suggest that part-time residents continuing to purchase property in Kittitas County may not have properties large enough to conduct commonly advocated HIZ mitigations, while larger landowners may be motivated to conduct fuels reduction as a form of stewardship on lands beyond the HIZ where they have already taken mitigation action. More nuanced options for engagement, mitigation, or monitoring of progress in these and other emergent situations will be necessary to better plan the ongoing evolution of wildfire management recommendations for private property owners.

Future research could explore how additional influences on HIZ mitigation and private lands fuels reduction (i.e., risk perception, trust in collaborators, past wildfire experience, political beliefs) relate to support for a broader or more complex set of proposed regulatory approaches to wildfire mitigation. Perceptions and potential influences related to the provision of insurance, or the costs associated with regulatory requirements for residents are another avenue for study. Future explorations could evaluate how to more quickly understand the ways various influences promote shared action among diverse perspectives that already exist in those places. While these efforts could be useful in establishing a range of best practices to adaptively apply in different situations, it is unlikely that additional work will uncover a consistent "blueprint" for incentivizing uniform mitigation performance or regulatory support. Instead, there is a directed need to experiment with the co-design of information, inquiry, messages, or negotiated mitigation contributions that take into account the reality of risk that spans landscapes, and likely by engaging in ongoing negotiations that take place at local, practical scales.

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Declarations

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References

Abrams JM, Knapp M, Paveglio T, Ellison A, Moseley C, Nielsen-Pincus M, Carroll M (2015) Re-envisioning community-wildfire relations in the U.S. West as adaptive governance. Ecol Soc 20(3):34

Ager AA, Evers CR, Day MA, Preisler HK, Barros AMG, Nielsen-Pincus M (2017) Network analysis of wildfire transmission and implications for risk governance. PLoS ONE 12(3):1–28

Ager AA, Houtman RM, Day MA, Palaiologou P (2019) Tradeoffs between US national forest harvest targets and fuel management to reduce wildfire transmission to the wildland urban interface. For Ecol Manage 434:99–109

Ager AA, Day MA, Ringo C, Evers CR, Alcasena FJ, Houtman RM, Scanion M, Ellersick T (2021a) Development and application of the fireshed registry USDA forest service rocky mountain research station. Gen Tech Rep. https://doi.org/10.2737/RMRS-GTR-425

Ager AA, Day MA, Alcasena FJ, Evers CR, Short KC, Grenfell I (2021b) Predicting paradise: modeling future wildfire disasters in the western US. Sci Total Environ 784:147057

Al Abri I (2022) Evaluating incentive-driven policies to reduce social losses associated with wildfire risk misinformation. Forests 13:2071

Al Abri I, Grogan K (2021) The impact of heterogeneous management interests in reducing social losses from wildfire externalities. Forests 12:1326

Alcasena F, Ager AA, Belavenutti P, Krawchuk M, Day MA (2022) Contrasting the efficiency of landscape versus community protection fuel treatment strategies to reduce wildfire exposure and risk. J Environ Manag 309:114650
Bardsley DK, Weber D, Robinson GM, Moskwa E, Bardsley AM (2015) Wildfire risk, biodiversity and peri-urban planning in the Mt. Lofty Ranges. S Aust Appl Geogr 63:155–165
Billings MC, Carroll MS, Paveglio TB (2021a) The 'strings attached' to community difference and potential pathways to fire adaptiveness in the wildland urban interface. J Forest 119(1):13–27
Billings MC, Carroll MS, Paveglio TB, Whitman K (2021b) 'Us versus them;' local social fragmentation and its potential effects on building pathways to adapting to wildfire. Fire 4(4):96
Bond T, Mercer D (2014) Subdivision policy and planning for bushfire defense: a natural hazard mitigation strategy for residential peri-urban regions in Victoria. Aust Geogr Res 52(1):6–22
Brehm JM, Eisenhauer BW, Krannich RS (2006) Community attachments as predictors of local environmental concern. Am Behav Sci 50(2):142–165
Brenkert-Smith H, Champ PA, Flores N (2006) Insights into wildfire mitigation decisions among wildland-urban interface residents. Soc Nat Resour 19(8):759–768
Brenkert-Smith H, Dickinson KL, Champ PA, Flores N (2013) Social amplification of wildfire risk: the role of social interactions and information sources. Risk Anal 33:800–817
Brenkert-Smith HB, Meldrum JR, Champ PA, Barth CM (2017) Where you stand depends on where you sit: qualitative inquiry into notions of fire adaptation. Ecol Soc 22(3):7
Brenkert-Smith H, Jahn JLS, Vance EA, Ahumada J (2020) Resistance and representation in a wildland-Urban Interface fuels treatment conflict: the case of the Forsythe II project in the Arapaho-Roosevelt National Forest. Fire 3(2):1–18
Burnett JT, Edgeley CM (2023) Factors influencing flood risk mitigation after wildfire: insights for individual and collective action after the 2010 Schultz fire. Int J Disaster Risk Reduct 94:103791
Busby GM, Albers HJ, Montgomery CA (2012) Wildfire risk management in a landscape with fragmented ownership and spatial interactions. Land Econ 88(3):496–517
Busby G, Amacher GS, Haight RG (2013) The social costs of homeowner decisions in fire-prone communities: information, insurance, and amenities. Ecol Econ 92:104–113
Buxton M, Haynes R, Mercer D, Butt A (2011) Vulnerability to bushfire risk at Melbourne's urban fringe: the failure of regulatory land use planning. Geogr Res 49(1):1–12
Byerly Flint H, Champ PA, Meldrum JR, Brenkert-Smith H (2022) Wildfire imagery reduces risk information-seeking among homeowners as property wildfire risk increases. Commun Environ 3:229
Calkin DE, Cohen JD, Finney MA, Thompson MP (2014) How risk management can prevent future wildfire disasters in the wildland-urban interface. Proc Natl Acad Sci 111(2):746–751. https://doi.org/10.1073/pnas.1315088111
Calkin DE, Barrett K, Cohen JD, Finney MA, Pyne SJ, Quarles SL (2023) Widland-urban fire disasters aren't actually a wildfire problem. Proc Natl Acad Sci 120(51):e2315797120
Canadas J, Novais A (2019) Forest owners and fuels management coordination when neighbours' actions matter. Scand J for Res 34(3):67–77
Canadas MJ, Leal M, Soares F, Novais A, Ribeiro PF, Schmidt L, Delicado A et al (2023) Wildfire mitigation and adaptation: two locally independent actions supported by different policy domains. Land Use Policy 124:106444
Carlson AR, Helmers DP, Hawbaker TJ, Mockrin MH, Radeloff VC (2022) The wildland-urban interface in the United States based on 125 million building locations. Ecol Appl 32(5):e2597
Carroll MS, Paveglio T (2016) Using community archetypes to better understand differential community adaptation to wildfire risk. Philos Trans R Soc B 371(1696):20150344
Carroll MS, Paveglio T (2019) Local community agency and vulnerability influences on a Montana wildfire. J Forest 117(2):104–113
Carroll MS, Cohn PJ, Higgins LH, Burchfield J (2006) Community wildfire events as a source of social conflict. Rural Soc 71(2):261e280
Carroll MS, Blatner KA, Cohn PJ, Morgan TA (2007) Managing fire danger in the forests of the US Inland Northwest: a classic 'wicked problem' in public land policy. J Forest 105(5):239–244
Carroll MS, Paveglio T, Jakes PJ, Higgins LL (2011) Nontribal community recovery from wildfire five years later: the case of the Rodeo-Chediski Fire. Soc Nat Resour 24(7):672–687
Charnley S, Kelly E, Wendel KL (2017) All lands approaches to fire management in the pacific West: a typology. J Forest 11(1):16–25
Charnley S, Kelly EC, Fischer AP (2019) Fostering collective action to reduce wildfire risk across property boundaries in the American West. Environ Res Lett 15(2):025007
Cohen J (2008) The wildland-urban interface fire problem: a consequence of the fire exclusion paradigm. For Hist Today Fall 38(2):20–26

Cowan S, Kennedy EB (2023) Determinants of residential wildfire mitigation uptake: a scoping review, 2013–2022. Fire Saf J 140:103851
Daniels SE, Walker GB (2001) Working through environmental conflict: the collaborative learning approach. Praeger, Westport
Daniels J (2018) 'Pretty overwhelming' evidence against PG&E in deadly Paradise fire, says attorney suing CA utility. CNBC. https://www.cnbc.com/2018/11/14/overwhelming-evidence-against-pge-in-deadly-fire-says-lawyer-suing.html Accessed January 9 2024
Davis EJ, Huber-Stearns H, Cheng AS, Jacobson M (2021) Transcending parallel play: boundary spanning for collective action in wildfire management. Fire 4(3):41
Dickinson K, Brenkert-Smith H, Champ P, Flores N (2015) Catching fire? social interactions, beliefs, and wildfire risk mitigation behaviors. Soc Nat Resour 28:807–824
Dickinson KL, Brenkert-Smith H, Madonia G, Flores NE (2020) Risk interdependency, social norms, and wildfire mitigation: a choice experiment. Nat Hazards 103:1327–1354
Dillman DA, Smyth JD, Christian LM (2009) Internet, mail and mixed-mode surveys: the tailored design method, 3rd edn. Wiley, Hoboken
Dillman DA, Smyth JD, Christian LM (2014) Internet, mail and mixed-mode surveys: the tailored design method, 4th edn. Wiley, Hoboken
Downing WM, Dunn CJ, Thompson MP, Caggiano MD, Short KC (2022) Human ignitions on private lands drive USFS cross-boundary wildfire transmission and community impacts in the western US. Sci Rep. https://doi.org/10.1038/s41598-022-06002-3
Edgeley CM, Paveglio TB (2017) Community recovery and assistance following large wildfires: the case of the carlton complex Fire. Int J Disaster Risk Reduct 25:137–146
Edgeley CM, Paveglio TB (2019) Exploring influences on intended evacuation behaviors during wildfire: What roles for pre-fire actions and event-based cues? Int J Disaster Risk Reduct 37:101182
Edgeley CM, Paveglio TB, Williams DR (2020) Support for regulatory and voluntary approaches to wildfire adaptation among unincorporated wildland-urban interface communities. Land Use Policy 91:104394
Edgeley CM, Paveglio TB (2024) Bridging scales for landscape level wildfire adaptation: A case study of the Kittitas Fire Adapted Communities Coalition. Journal of Environmental Management https://www.sciencedirect.com/science/article/pii/S0301479723026063 Accessed 25 January 2024
Edgeley CM (2023) Social Science to advance wildfire adaptation in the southwestern United States: a review and future research directions. International Journal of Wildland Fire https://www.publish.csiro.au/wf/pdf/WF23102 Accessed 25 January 2024
Emborg J, Daniels SE, Walker GB (2020) A framework for exploring trust and distrust in natural resource management. Front Commun 5(13):1–14
Essen M, McCaffrey S, Abrams J, Paveglio T (2023) Improving wildfire management outcomes: shifting the paradigm of wildfire from simple to complex risk. J Environ Planning Manag 66(5):909–927
Evers CR, Ager AA, Nielsen-Pincus M, Palaiologou P, Bunzel K (2019) Archetypes of community wildfire exposure from national forests of the western U.S. Landsc Urban Plan 182:55–66
Field A (2018) Discovering statistics using IBM SPSS Statistics, 5th edn. Sage, Thousand Oaks, Calif
Fischer AP, Klooster A, Cirhigiri L (2019) Cross-boundary cooperation for landscape management: collective action and social exchange among individual private forest landowners. Landsc Urban Plan 188:151–162
Flora DB, Labrish C, Philip Chalmers R (2021) Old and new ideas for data screening and assumption testing for exploratory and confirmatory factor analysis. Front Psychol 3(55):1–21
Goldstein BE (2008) Skunkworks in the embers of the Cedar fire: enhancing resilience in the aftermath of disaster. Hum Ecol 36:15–28
Gonzalez-Mathiesen C, Ruane S, March A (2021) Integrating wildfire risk management and spatial planning—a historical review of two Australian planning systems. Int J Disaster Risk Reduct 53:101984
Gordon J, Wilcox AS, Luloff AE, Finley JC, Hodges DG (2018) Public perceptions of values associated with wildfire protection at the wildland-urban interface: a synthesis of national findings. In: Loures L (ed) Landscape Reclamation—Rising From What's Left. IntechOpen, London, pp 1–17
Green SB, Redell N, Thompson MS, Levy R (2016) Accuracy of revised and traditional parallel analysis for assessing dimensionality with binary data. Educ Psychol Measur 76(1):5–21
Hakes RS, Caton DJ, Gorham MJ, Gollner MJ (2017) A review of pathways for building fire spread in the wildland urban interface Part II: response of components and systems and mitigations strategies in the United States. Fire Technol 53:475–515
Hals T (2023) Maui fire lawsuit blames landowners for wild grass growth. Reuters. https://www.reuters.com/world/us/novel-lahaina-wildfire-lawsuit-asks-when-is-wild-grass-inherently-dangerous-2023-09-20/ Accessed 25 January 2024

Hamilton M, Fischer AP, Jasny L (2021) Bridging collaboration gaps in fragmented environmental governance systems. Environ Sci Policy 124:461–470
Harris LM, McGee TK, McFarlane BL (2011) Implementation of wildfire risk management by local governments in Alberta. Can J Environ Plan Manag 54(4):457–475
Hayes AF (2017) Introduction to mediation, moderation, and conditional process analysis: a regression-based approach, 2nd edn. The Gulliford Press, New York
Hayes, AF (2023) The PROCESS Macro for SPSS, SAS, and R. https://www.processmacro.org/index.html Accessed 25 January 2024
Hesseln H (2018) Wildland fire prevention: a review. Curr for Rep 4:178–190
Hilsenroth J, Grogan KA, Crandall RM, Bond L, Sharp M (2023) Non-industrial private forest owners' preferences for fuel reduction cost-share programs in the southeastern U.S. For Policy Econ 155:102994
Huber-Stearns HR, Davis EJ, Cheng AS, Deak A (2022) Collective action for managing wildfire risk across boundaries in forest and range landscapes: lessons from case studies in the western United States. Int J Wildland Fire 31(10):936–948
Huff ES, de Oliveria A, Markowitz EM, Guckian ML, Lomonoco L (2022) Family forest owner perceptions of wildfire and invasive pest risk: the role of interpersonally-produced risks. Int J Disaster Risk Reduct 83:103417
Initini P, Ronchi E, Gwyenne S, Benichou N (2020) Guidance on design and construction of the built environment against wildland urban interface fire hazard: a review. Fire Technol 56:1853–1883
International Code Council (ICC) (2024) International Wildland-Urban Interface Code. https://codes.iccsafe.org/content/IWUIC2024P1 Accessed 25 January 2024
Jackson-Smith D, Flint CG, Dolan M, Trentleman CK, Holyoak G, Thomas B (2016) Effectiveness of the drop-off/pick-up survey methodology in different neighborhood types. J Rural Soc Sci 31(3):35–67
Kelly EC, Charnley S, Pixley JT (2019) Polycentric systems for wildfire governance in the Western United States. Land Use Policy 89:104214
Kocher SD, Bustic V (2017a) Governance of land use planning to reduce fire risk to homes in Mediterranean France and California. Land 6(2):24
Koksal K, McLennan J, Every D, Bearman C (2019) Australian wildland-urban interface householders' wildfire safety preparations: "everyday life' project priorities and perceptions of wildfire risk. Int J Disaster Risk Reduct 33:142–154
Kolden CA, Henson C (2019) A socio-ecological approach to mitigating wildfire vulnerability in the wildland urban interface: a case study from the 2017 Thomas Fire. Fire 2(2):9
Kramer HA, Bustic V, Mockrin MH, Ramirez-Reyes C, Alexandre PM, Radeloff VC (2021) Post-wildfire rebuilding and new development in California indicates minimal adaptation to fire risk. Land Use Policy 107:105502
Kumagai Y, Bilss JC, Daniels SE (2004a) Research on causal attribution of wildfire: and exploratory multiple-methods approach. Soc Nat Resour 17(2):113–127
Kumagai Y, Daniels SE, Carroll MS, Bliss JC, Edwards JA (2004b) Causal reasoning processes of people affected by wildfire: Implications for agency-community interactions and communication strategies. West J Appl for 19(3):184–194
Langpap C, Wu J (2021) Preemptive incentives and liability rules for wildfire risk management. Am J Agr Econ 103(5):1783–1801
Lauer CJ, Montgomery CA, Dietterich TG (2020) Evaluating wildland fire liability standards—Does regulation incentivise good management? Int J Wildland Fire 29:572–580
Leone V, Tedim F, Xanthopoulos G (2020) Fire Smart Territory as an innovative approach to wildfire risk reduction. In: Tedim F, Leone V, McGee TK (eds) Extreme wildfire events and disasters: root causes and new management strategies. Elsevier, Amsterdam
Lorenzo-Seva U, Ferrando PJ (2022) FACTOR. Available at: https://psico.fcep.urv.cat/utilitats/factor/Download.html Accessed 20 November 2023
Lorenzo-Seva U, Ferrando PJ (2021) Not positive definite correlation matrices in exploratory item factor analysis: causes, consequences and a proposed solution. Struct Equ Modeling 28(1):138–147
McCaffrey S (2015) Community wildfire preparedness: a global state-of-the-knowledge summary for social science research. Curr for Rep 1(2):81–90
McWenthy DB, Schoennagel T, Higuera PE, Krawchuk M, Harvey BJ, Metcalf EC, Schultz C et al (2019) Rethinking resilience to wildfire. Nat Sustain 2:797–804
Meldrum JR, Brenkert-Smith H, Champ PA, Falk L, Wilson P, Barth CM (2018) Wildland-urban interface residents' relationships with wildfire: variation within and across communities. Soc Nat Resour 31(1):1132–1148

Meldrum JR, Barth CM, Goolsby JB, Olson SK, Gosey AC, White J, Brenkert-Smith H, Champ PA, Gomez J (2022) Parcel-level risk affects wildfire outcomes: insights from pre-fire rapid assessment data for homes destroyed in 2020 east troublesome fire. Fire 5(1):24

Mockrin MH, Fishler HK, Stewart SI (2018) Does wildfire open a policy window? Local government and community adaptation after fire in the United States. Environ Manag 62(2):210–228

Mockrin MH, Fishler HK, Stewart SI (2020) After the fire: perceptions of land use planning to reduce wildfire risk in eight communities across the United States. Int J Disaster Risk Reduct 45:101444

Mockrin MH, Fishler HK, Kramer HA, Radeloff VC, Stewart SI (2022) A tale of two fires: retreat and rebound a decade after wildfires in California and South Carolina. Soc Nat Resour 35(8):875–895

Mockrin MH, Schumann RL, Whittaker J, Gaither CJ, Brooks RA, Syphard AD, Price O, Emrich CT (2023) Creating fire-adapted communities through recovery: case studies from the United States and Australia. J Extrem Events. https://doi.org/10.1142/S2345737623500033

Mockrin MH, Stewart SI, Radeloff VC, Hammer RB (2016) Recovery and adaptation after wildfire on the colorado front range (2010–2012). Int J Wildland Fire 25:1144–1155

Montoya SB (2022) Miscalculations, errors blamed for massive New Mexico blaze. https://www.latimes.com/world-nation/story/2022-06-21/miscalculations-errors-blamed-for-massive-new-mexico-blaze Accessed January 2 2024

Morales M (2023) Lahaina fire lawsuit adds blame on state and Bishop Estate. Khon2. Available at: https://www.khon2.com/local-news/lahaina-fire-lawsuit-adds-blame-on-state-and-bishop-estate/#:~:text=HONOLULU%20(KHON2)%20%E2%80%94%20The%20latest,as%20fuel%20for%20the%20fire Accessed January 2 2024

Mortiz MA, Hazard R, Johnston K, Mayes M, Mowrey M, Oran K, Parkinson A, Schmidt DA, Wesolowski G (2022) Beyond a focus on fuels reduction in the WUI: The need for regional wildfire mitigation to address multiple risks. Front for Glob Change 5:848254

Mowrey M, Punchard D (2021) Land Use Planning approaches in the Wildland-Urban Interface: An analysis of four western states: California, Colorado, Montana and Washington. Community Wildfire Planning Center. https://www.communitywildfire.org/wpcontent/uploads/2021/02/CWPC_Land-Use-WUI Report_Final_2021.pdf Accessed January 2 2024

Muffly J, Brichhall SJ (2023) Key elements of defensible space land use bylaw provisions in wildland-urban interface municipalities of Alberta, Canada. Int J Disaster Risk Reduct 96:103988

Nagy R, Fusco E, Bradley B, Abatzoglou JT, Balch J (2018) Human-related ignitions increase the number of large wildfires across US ecoregions. Fire 1:4

National Academies of Sciences, Engineering, and Medicine (2017) A century of wildland fire research: contributions to long-term approaches for wildland fire management: proceedings of a workshop. The National Academies Press, Washington, DC. https://doi.org/10.17226/24792

National Wildfire Coordinating Group (NWCG) (2021) Spotting Fire Behavior. Available online at: https://www.nwcg.gov/publications/pms437/crown-fire/spotting-fire-behavior

Olsen CS, Kline JD, Ager AA, Olsen KA, Short KC (2017) Examining the influence of biophysical conditions on wildland-urban interface homeowners' wildfire risk mitigation activities in fire-prone landscapes. Ecol Soc 2(1):21

Palaiologou P, Ager AA, Evers CR, Nielsen-Pincus M, Day MA, Preisler HK (2019) Fine-scale assessment of cross-boundary wildfire events in the western United States. Nat Hazards Earth Syst Sci 19(8):1755–1777

Paveglio TB (2023) The interactional approach to adaptive capacity: researching adaptation in socially diverse, wildfire prone communities. Local Dev Soc 4(3):481–504

Paveglio T, Edgeley C (2017) Community diversity and hazard events: understanding the evolution of local approaches to wildfire. Nat Hazards 87(2):1083–1108

Paveglio TB, Kelly E (2018) Influences on the adoption and implementation of a wildfire mitigation program in an Idaho city. J Forest 116(1):47–54

Paveglio TB, Carroll MS, Jakes PJ, Prato T (2012) Exploring the social characteristics of adaptive capacity to wildfire: insights from Flathead County Montana. Hum Ecol Rev 19(2):110–124

Paveglio TB, Prato T, Hardy M (2013) Simulating effects of land use policies on extent of the wildland-urban interface and wildfire risk in Flathead County, Montana. J Environ Manag 130(3):20–31

Paveglio TB, Prato T, Dalenberg D, Venn T (2014) Understanding evacuation preferences and wildfire mitigations among Northwest Montana residents. Int J Wildland Fire 23(3):435–444

Paveglio TB, Moseley C, Carroll MS, Williams DR, Fischer AP, Davis EJ (2015) Categorizing the social context of the Wildland Urban Interface: adaptive capacity for wildfire and community "archetypes." For Sci 61(2):298–310

Paveglio TB, Prato T, Edgeley C, Nalle D (2016a) Evaluating the characteristics of social vulnerability to wildfire: Demographics, perceptions and parcel characteristics. Environ Manag 58(3):534–548

Paveglio TB, Abrams JB, Ellison A (2016b) Developing fire adapted communities: the importance of interactions among elements of local context. Soc Nat Resour 29:1246–1261
Paveglio TB, Carroll MS, Stasiewicz AM, Williams DR, Becker D (2018a) Incorporating social diversity into wildfire management: proposing 'pathways' for fire adaptation. For Sci 64(5):515–532
Paveglio TB, Edgeley C, Stasiewicz A (2018b) Assessing influences on social vulnerability to wildfire using surveys, spatial data and wildfire simulations. J Environ Manag 213:425–439
Paveglio TB, Edgeley CM, Carroll MS, Billings M, Stasiewicz A (2019a) Exploring the influence of local social context on strategies for achieving fire adapted communities. Fire 2(2):26
Paveglio TB, Carroll MS, Stasiewicz A, Edgeley C (2019b) Social fragmentation and wildfire management: exploring the scale of adaptive action. Int J Disaster Risk Reduct 33:131–141
Paveglio TB, Stasiewicz AM, Edgeley CM (2021) Understanding support for regulatory approaches to wildfire management and performance of property mitigations on private lands. Land Use Policy 100:104893
Paveglio TB, Schmidt A, Medley-Daniel M (2023) The fire adapted communities pathways tool: facilitating social learning and a science of practice. J Forest. https://doi.org/10.1093/jofore/fvad044AccessedJanuary42024
Paveglio TB, Edgeley CE (2023) Variable support and opposition to fuels treatments for wildfire risk reduction: melding frameworks for local context and collaborative potential. Journal of Forestry, *https://academic.oup.com/jof/advancearticle/doi/*https://doi.org/10.1093/jofore/fvad021/7193795 *Accessed January 2 2024*
Radeloff VC, Helmers DP, Kramer HA, Mockrin MH, Alexandre PM, Bar-Massada A, Bustic V, Hawbaker TJ, Marinuzzi S, Syphard AD, Stewart SI (2018) Rapid growth of the US wildland urban interface raises wildfire risk. Proc Natl Acad Sci 115(13):3314–3319
Rasch R, McCaffrey S (2019) Exploring wildfire-prone community tryst in wildfire management agencies. For Sci 65(5):652–663
Remenick L (2018) The role of communication in preparation for wildland fire: a literature review. Environ Commun 12(2):164–176
Ribe RG, Nielsen-Pincus M, Johnson BR, Enright C, Hulse D (2022) The consequential role of aesthetics in forest fuel reduction propensities: diverse landowners' attitudes and responses to project types, risks, costs and habitat benefits. Land 11(12):2151
Sanchez JJ, Holmes TP, Loomis J, Gonzalez-Caban A (2022) Homeowners willingness to pay to reduce wildfire risk in wildland urban interface areas: implications for targeting financial incentives. Int J Disaster Risk Reduct 68:102696
Schindler B, Olsen C, McCaffrey S, McFarlane B, Christianson A, McGee T, Curtis A, Sharp E (2014) A planning guide for wildfire agencies and practitioners—an international collaboration drawing on research and management experience in Australia, Canada and the United States a joint fire science program research publication. Oregon State University, Corvallis
Schumann RL, Mockrin M, Sphyard AD, Whittaker J, Price O, Gaither CJ, Emrich CT, Bustic V (2020) Wildfire recovery as a "hot moment" for creating fire adapted communities. Int J Disaster Risk Reduct 42:101354
Shafran AP (2008) Risk externalities and the problem of wildfire risk. J Urban Econ 64(2):488–495
Smith AM, Kolden CA, Paveglio TB, Cochrane MA, Bowman DM, Moritz MA, Kliskey AD, Alessa L, Hudak AT, Hoffman CM, Lutz JA, Queen LP et al (2016) The science of firescapes: achieving fire-resilient communities. Bioscience 66(2):130–146
Stasiewicz A, Paveglio TB (2018) Wildfire management across rangeland ownerships: factors influencing Rangeland Fire Protection Association establishment and functioning. Rangel Ecol Manag 71(6):727–736
Stasiewicz AM, Paveglio TB (2022) Exploring relationships between perceived suppression capabilities and resident performance of wildfire mitigations. J Environ Manage 316:115176
Steele J, Bourke L, Luloff AE, Liao P, Theodori GL, Krannich RS (2001) The drop-off/pick-up method for household survey research. J Community Dev Soc 32(2):238–250
Steelman TA, Burke C (2007) Is wildfire policy in the United States sustainable? J Forest 105(2):67–72
Stevens JP (2009) Applied Multivariate Statistics for the Social Sciences. Routledge, New York
Stidham M, McCaffrey S, Toman E, Shindler B (2014) Policy tools to encourage community-level defensible space in the United States: a tale of six communities. J Rural Stud 35:59–69
Stockmann K, Burchfield J, Calkin D, Venn T (2010) Guiding preventative wildland fire mitigation policy and decisions with an economic modelling system. Forest Policy Econ 12(2):147–154
Syphard AD, Brennan TJ, Keeley JE (2017) The importance of building construction materials relative to other factors affecting structure survival during wildfire. Int J Disaster Risk Reduct 21:140–147

Talberth J, Berrens RP, McKee M, Jones M (2006) Averting and insurance decisions in the wildland-urban interface: implications of survey and experimental data for wildfire risk reduction policy. Contemp Econ Policy 24(2):203–223

Taylor MH, Christman L, Rollins K (2019) Targeting policy to promote defensible space in the wildland-urban interface: evidence from homeowners in Nevada. Land Econ 95(4):531–556

Trentelman CK, Irwin J, Petersen KA, Ruiz N, Szalay CS (2016) The case for personal interaction: drop-off/pick-up methodology for survey research. J Rural Soc Sci 31(3):68–104

United State Department of Agriculture. (2024). Central Washington Initiative. https://experience.arcgis.com/experience/0fe032e92fad464fbcdc7faf12cd7928/page/Central-Washington-Initiative/. Accessed 5 May 2024.

United States Department of Agriculture. (2022). Confronting the Wildfire Crisis. https://www.fs.usda.gov/sites/default/files/Confronting-Wildfire-Crisis.pdf. Accessed 8 January 2024

United States Department of Agriculture (2023a) "Fire Adapted Communities." Available at: https://fireadapted.org/ Accessed 8 December 2023

United States Department of Agriculture (2023). Joint Chiefs Landscape Restoration Partnership. Available at: https://www.nrcs.usda.gov/programs-initiatives/joint-chiefs-landscape-restoration-partnership Accessed 8 December 202

USDA Forest Service, 2018. Toward Shared Stewardship Across Landscapes: an Outcome based Investment Strategy. FS-1118. https://www.fs.usda.gov/sites/default/files/toward-shared-stewardship.pdf Accessed 8 January 2024

Warziniack T, Champ P, Meldrum J, Brenkert-Smith H, Barth CM, Falk IC (2019) Responding to risky neighbors: testing for spatial spillover effects for defensible space in a fire-prone WUI community. Environ Resour Econ 73:1023–1047

Washington State Department of Natural Resources (DNR) (2023) 20-Year Forest Health Strategic Plan: Central and Eastern Washington. Available at: https://www.dnr.wa.gov/ForestHealthPlan Accessed 10 December 2023

Wildland Fire Mitigation and Management Commission. 2023. ON FIRE: The report of the Wildland Fire Mitigation and Management Commission: https://www.usda.gov/sites/default/files/documents/wfmmc-final-report-09-2023.pdf Accessed 10 January 2024

Williams DR, Jakes PJ, Burns S, Cheng AS, Nelson KC, Sturtevant V et al (2012) Community wildfire protection planning: the importance of framing, scale, and building sustainable capacity. J Forest 110:415–420

Wilson PI, Paveglio T, Becker D (2018) The politically possible and wildland fire. Fire 1(1):12

Wolters EA (2023) Homeowner firewise behaviors in fire-prone central Oregon: an exploration of the attitudinal, situational, and cultural worldviews impacting pre-fire mitigation actions. J Environ Manag 327:116811

Wolters EA, Steel BS, Weston D, Brunson M (2017) Determinants of residential firewise behaviors in central Oregon. Soc Sci J 54(2):168–178

Wunder S, Calkin DE, Charlton V, Feder S, de Arano I, Moore P, Silva F, Tacconi L, Vega-Garcia C (2021) Resilient landscapes to prevent catastrophic forest fires: Socioeconomic insights towards a new paradigm. Forest Policy Econ 128:102458