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Estimating US federal wildland fire managers' preferences toward competing strategic suppression objectives

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Abstract. Wildfire management involves significant complexity and uncertainty, requiring simultaneous consideration of multiple, non-commensurate objectives. This paper investigates the tradeoffs fire managers are willing to make among these objectives using a choice experiment methodology that provides three key advancements relative to previous stated-preference studies directed at understanding fire manager preferences: (1) a more immediate relationship between the instrument employed in measuring preferences and current management practices and operational decision-support systems; (2) an explicit exploration of how sociopolitical expectations may influence decision-making and (3) consideration of fire managers' relative prioritisation of cost-containment objectives. Results indicate that in the current management environment, choices among potential suppression strategies are driven largely by consideration of risk to homes and high-value watersheds and potential fire duration, and are relatively insensitive to increases in cost and personnel exposure. Indeed, when asked to choose the strategy they would expect to choose under current social and political constraints, managers favoured higher-cost suppression strategies, ceteris paribus. However, managers indicated they would personally prefer to pursue strategies that were more cost-conscious and proportionate with values at risk. These results confirm earlier studies that highlight the challenges managerial incentives and sociopolitical pressures create in achieving cost-containment objectives.

Additional keywords: choice experiment, fire management, incentives, suppression cost.

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Introduction

Wildfire management involves significant complexity and uncertainty, requiring simultaneous consideration of multiple, non-commensurate objectives. The 2001 US Federal Wildland Fire Policy includes directives that firefighter and public safety should always be of highest priority, that natural and cultural resources should receive consideration equal to private property, that fire management should be founded in risk management, and that fire management activities should be economically viable – that is, commensurate in cost with the values they protect (Interagency Working Group 2001). The increasing emphasis on constraining costs in recent policy has been driven by substantial increases in wildfire activity and associated costs over the past several decades (Calkin *et al.* 2005; Abt *et al.* 2009). For instance, over the past decade, the US Forest Service (USFS), which is responsible for ~70% of all federal wildland fire expenditures in the USA, saw appropriation for wildfire management rise from 21% of its discretionary budget in 2000 to over 43% in 2008, when it spent almost US$1.5 billion on fire suppression (USDA Forest Service 2009).

Escaped large fires are jointly managed by local managers (agency administrators) and incident management teams. Agency administrators (AA) (a general term identifying the highest-ranking agency line officer with direct authority and responsibility within their administrative unit) develop suppression strategies and objectives consistent with existing fire- and land-management plans, and incident commanders implement operational tactics consistent with the overarching strategy. Members of incident management teams tend to have more experience managing large wildland fires than agency administrators. For the purposes of this paper, we will refer to those engaged specifically in fire management, including incident commanders, members of incident management teams and fire management officers, as 'fire and fuels management professionals', and we will refer to agency administrators and fire and fuels management professionals collectively as 'fire managers'.

In implementing risk-based management, fire managers rely on decision support systems such as the Wildland Fire Decision Support System (WFDSS) (Noonan-Wright *et al.* 2011). Decision analysis within WFDSS integrates a fire simulation model that provides spatially explicit burn probability maps (Finney *et al.* 2011), with locations of highly valued assets such as residential structures, critical infrastructure and natural resources, to give fire managers comprehensive assessments of fire risk (Calkin *et al.* 2011). However, despite the marked improvements in spatial risk-based decision support provided by tools such as WFDSS, wildfire management decision-making remains highly complex and affected by human factors.

Studies of cost at the individual-wildfire level have generally shown that although fire size and the presence of structures can be significant determinants of suppression expenditures, physical factors alone do not fully explain observed variation in expenditures. Increasingly, this has led researchers to investigate several human factors that influence wildfire management decision-making and suppression costs. First, a significant body of research indicates that because fire managers may often fund suppression activities through emergency funds, they face no incentive to consider the opportunity costs of those expenditures, and so cost-containment objectives play a relatively minor role in their decision analyses (Donovan and Brown 2005; Canton-Thompson *et al.* 2008; Donovan *et al.* 2008; Bruins *et al.* 2010; Thompson *et al.* 2012). Second, through their role in formulating underlying suppression strategies, agency administrators' decisions often limit the decision space of incident commanders such that they are unable to choose the management strategy they believe will result in optimal fire-management outcomes (Canton-Thompson *et al.* 2008). Third, it is believed that sociopolitical pressure can occasionally lead to the deployment of resources that fire managers anticipate will be ineffective (Canton-Thompson *et al.* 2008); for example, Donovan *et al.* (2011) recently used an instrumental variables approach to demonstrate that newspaper coverage and congressional seniority positively influence suppression costs. Finally, Maguire and Albright (2005) identified a variety of decision biases and heuristics that may play a role in encouraging risk-averse manager behaviour, and Wilson *et al.* (2010) demonstrated that USFS fire managers exhibited three common risk-based biases: loss aversion (favouring safe options more often when consequences were framed as potential gains), discounting (favouring reduction of short-term risk over long-term risk), and status quo bias (favouring suppression when suppression was deemed the status quo option).

There is potential that fire manager decision-making and adherence to policy goals, such as firefighter and public safety, protection of natural and cultural resources and sound risk-based management, may be improved through explicit investigation of the factors that affect fire manager decision-making. Two previous studies in this area are of particular note. First, Rideout *et al.* (2008) used a hybrid stated-preference, multicriteria decision analysis exercise relying on ratio-scale pairwise comparisons, combined with the economic theory of substitution and search for consensus, to estimate marginal rates of substitution among fire protection attributes. Limitations relevant to their study included: (1) confounding fire managers' estimations of resource susceptibility with managerial preference through the implicit price elicitation exercise; (2) masking potentially important differences in preference structures across fire managers by searching for group consensus and (3) ignoring potentially beneficial effects of wildfire within the elicitation exercise. Second, Tutsch *et al.* (2010) applied maximum-difference conjoint analysis, a stated-preference choice-based approach, to better understand preferences among an interdisciplinary team of fire experts in Canada. It is important to note that Tutsch *et al.* did not include management cost as a tradeoff; thus measured preferences do not encompass attitudes regarding the economic efficiency of suppression expenditures. Further, neither study explicitly examined the external factors and sociopolitical pressures that can influence decision-making.

We apply the choice experiment method, which has been used extensively in environmental valuation to measure willingness to pay for improvements in environmental attributes (e.g. Adamowicz *et al.* 1994; Adamowicz *et al.* 1998; Brey *et al.* 2007; Czajkowski *et al.* 2009), to the fire-management context in order to quantitatively evaluate wildfire manager preferences and decision-making. In contrast to other common methods that facilitate decision analysis and articulation of preferences (e.g. the analytic hierarchy process; see Ananda and Herath 2009), the choice experiment method facilitates collection of preference data from a large number of decision-makers at relatively low cost. Our study uses a choice experiment questionnaire designed to reflect contemporary wildfire management protocols with its relation to spatial risk assessment to elicit preferences in a controlled environment, quantify marginal willingness to trade among attributes that influence suppression decision-making, and, importantly, query the differences between strategies managers prefer and those they expect they would choose given current sociopolitical constraints. Therefore, we provide three key advancements relative to earlier studies: (1) a more direct relationship between the instrument employed in measuring preferences and current management practices and operational decision support systems; (2) an explicit exploration of the role of sociopolitical expectation in decision-making and (3) consideration of fire managers' relative prioritisation of cost-containment objectives, in addition to consideration of tradeoffs managers are willing to make among other fire-management strategy attributes.

Methods

In this study, we used a choice experiment (CE) survey of federal fire managers to investigate preferences towards wildfire management strategies. CE uses respondents' stated preferences over alternatives offered in a series of choice sets to estimate the contributions of marginal increases in attributes to utility. As a generalised form of the contingent valuation method (CVM), CE methodology is founded on the assumptions of random utility theory (Louviere *et al.* 2000). Random utility theory proposes that the utility of a good – in this case an alternative within the choice experiment – can be expressed as the sum of a systematic component and a stochastic component. Therefore, the utility of alternative i to person n (U_{in}) is:

$$U_{in} = V_{in} + \varepsilon_{in} \qquad (1)$$

where V_{in} is the deterministic component of utility and ε_{in} is a randomly distributed error term. Utility-maximising individuals will choose alternative i if $U_i > U_j$ for all other available choices j in choice set C_n. Hence, the probability that person n will choose alternative i can be written as:

$$P(i) = P(V_{in} + \varepsilon_{in} \geq V_{jn} + \varepsilon_{jn};\ \forall j \in C_n) \tag{2}$$

When it is assumed that errors are Gumbel-distributed, the probability of selecting alternative i becomes:

$$P(i) = \frac{e^{\mu V_{in}}}{\sum_{j \in C_n} e^{\mu V_{jn}}} \tag{3}$$

where C_n is the set of possible alternatives and μ is a scale parameter, which is typically assumed to equal 1 (Adamowicz *et al.* 1998). This is the equation for the conditional logit model, first suggested by McFadden (1973). Often the utility function embedded in Eqn 3 may simply assume that utility is a linear function of the quantities of the attributes of the good, $x_1 \ldots x_k$, and c (cost), and this utility function is fitted using a maximum-likelihood procedure:

$$V_{in} = \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_k x_{ink} + \beta_c c_{in} \tag{4}$$

where β_i is the coefficient for attribute x_i. For linear utility functions, the marginal rate of substitution (MRS) between any two attributes, for example x_l and x_k, can be calculated simply by comparing their linear contribution to utility:

$$\text{MRS}_{lk} = \frac{-\beta_l}{\beta_k} \tag{5}$$

CE has been useful in environmental valuation because when one sets $\beta_k = \beta_c$, MRS can generally be interpreted as willingness to pay (WTP) for marginal changes in attribute x_1. Other marginal rates of substitution indicate respondents' willingness to trade off among other pairs of attributes, and are relevant as well.

Data collection and experimental design

Early in the process of developing the CE questionnaire, we held a focus group in Missoula, Montana, to elicit opinions from fire managers regarding the factors they generally consider most important in selecting wildfire-management strategies. Based on the discussion at this focus group and ensuing communications with managers in attendance, we defined CE attributes and their levels, and devised the general organisation of the questionnaire. A detailed discussion of the survey instrument follows; however, interested readers are invited to contact the authors for the complete survey instrument.

The CE survey obtained wildfire management preference data using a two-tier structure consisting of wildfire scenarios and choice sets; respondents were asked to select from a series of choice sets the fire management strategy they would use in managing the wildfires described in accompanying wildfire scenarios. An example wildfire scenario and choice set are provided in Fig. 1. We carefully designed scenarios to mirror

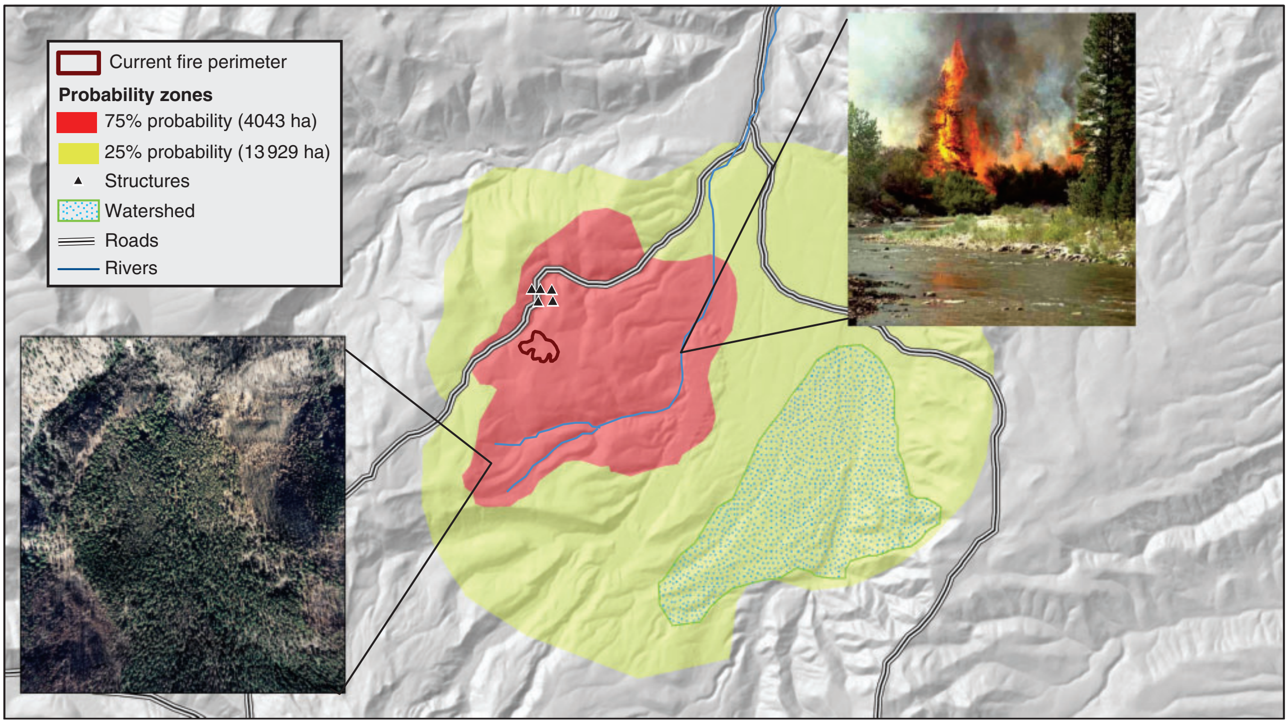

Fig. 1. Example wildfire scenario and choice set and accompanying text provided to respondents. Each scenario provided to respondents was accompanied by four choice sets.

Table 1. Attribute levels

Attribute	Definition	Levels
Scenario attributes		
hnumber	The number of residential homes (valued at US$200 000 on average) at risk	5 residential homes in 1 cluster; 30 residential homes in 5 clusters
hprob	Probability fire will reach homes in absence of suppression efforts	25%; 75%
mod[A]	The highly valued watershed has medium tree density, although the riparian zone along the river illustrated has high tree density. Mixed-severity in non-riparian areas and high-severity fire in the riparian area is projected	1 if yes; 0 if no. When the watershed is at risk for high-severity fire, it is not at risk for moderate-severity fire
high[A]	The highly valued watershed has high tree density throughout, including in the riparian zone. High-severity wildfire in non-riparian areas and in the riparian area is projected	1 if *mod* = 0; 0 if *mod* = 1. When the watershed is at risk for moderate-severity fire, it is not at risk for high-severity fire
wsprob	Probability fire will reach the watershed in absence of suppression efforts	25%; 75%
Strategy attributes		
hprotect	Protect residential homes	1 if yes; 0 if no
wsprotect	Protect watershed	1 if yes; 0 if no
avhours	Aviation person-hours	50[B]; 100; 1000
grounddays	Direct line person-days	0[B]; 100; 3000
duration	Wildfire duration	<14 days; >30 days
probsucc	Probability of success if a strategy that protects homes or the watershed is chosen	No containment effort[B]; 50%; 75%; 90%
cost	Wildfire management cost	US$0.2 million[B]; US$0.5 million; US$2 million; US$4 million; US$8 million; US$15 million

[A]Fire severity within the highly valued watershed is a single attribute within the scenario-level experimental design. Here, its two levels are given as separate variables, consistent with their use in Eqns 7 and 8.
[B]Denotes attribute levels given within non-suppression monitoring alternatives.

contemporary spatial risk assessment (as made possible by tools such as WFDSS), overlaying maps of likely fire behaviour with values at risk. The hypothetical wildfire scenarios assumed extreme fire weather conditions with two resources at risk: homes and a highly valued watershed. A wildfire probability contour map, which we described as having been developed through use of state-of-the-art wildfire simulation models, indicated the existing wildfire perimeter and 75 and 25% probability contours for potential fire spread projected over the next 14 days in the absence of suppression efforts. Wildfire probability contours were consistent across scenarios, but the locations of homes and the watershed relative to the contours and the number of homes and potential wildfire severity within the watershed (which is a function of its tree density) were varied. The number of homes at risk was indicated using markers placed within the appropriate probability contour, whereas the potential wildfire severity within the watershed was indicated using photographs that displayed the appearance of the watershed after wildfire of the given severity. Additionally, the levels of these attributes were stated explicitly in text that accompanied each wildfire scenario. Using a 2^4 experimental design, we generated 16 hypothetical wildfire risk scenarios by altering the levels of these scenario-specific variables, summarised in Table 1. Owing to concerns about receiving an adequate number of responses to estimate robust model coefficients (Louviere *et al.* 2000), we presented to respondents 12 wildfire scenarios with a relative D-efficiency of 0.9572 from the 16 scenarios in the full factorial design.

Choice sets presented respondents with three alternative wildfire-management strategies for each wildfire scenario. Strategies varied across the seven strategy attributes in Table 1. As wildfire scenarios described the risk to homes and the watershed in absence of suppression efforts, the choice sets included the attributes 'Protect residential homes' (*hprotect*) and 'Protect watershed' (*wsprotect*), consistent with the decision the wildfire manager makes: whether or not to protect the homes, the watershed, or both. If respondents selected a management option that included protection of one or both of those resources, that strategy would succeed in protecting those resources with a probability given by the attribute 'Probability of success' (*probsucc*). For strategies that did not include protection of homes, the survey informed respondents that no effort would be made to stop the fire before it reached homes, but reasonable levels of point protection (measures applied immediately adjacent to a structure to increase potential survival) would be implemented. The survey described homeowners as having been evacuated under all scenarios; therefore, risk to human life within the choice sets was entirely due to fire management personnel exposure.

Personnel exposure varied across alternative management strategies in two attributes, aviation person-hours and direct line person-days, which are proxies for risk in two of the most widely used wildland firefighting tactics: aerial suppression and implementation of control lines. Fatality statistics from 2000 to 2007 indicated to respondents that 153 US federal fire management personnel died while on duty, with 40 of those deaths due to aviation accidents, 47 due to ground vehicle accidents, 20 from burnovers or entrapments and 8 from snags or felling accidents (National Interagency Fire Center 2007). Given that aviation accident rates are considerably higher on a per-hour basis, the survey informed respondents that aviation entails greater risk to personnel than ground-based activities.

Finally, management strategies each differed in cost and resultant wildfire duration. The survey described cost as total suppression and post-fire emergency response cost to taxpayers, but it specified that cost did not include economic costs to the community or resource value losses (as these costs were described in potential losses to homes and the watershed). In addition, we reminded respondents that cost containment is a priority of federal wildland fire management. The survey described duration as the number of days a wildfire is likely to burn under a particular management strategy. It reminded respondents that duration is of concern because increased fire duration can result in prolonged periods of poor air quality, lost tourism revenue and recreation opportunities, and disruptions in local units' work plans. Although weather is a primary determinant of fire duration, the survey reminded respondents that fire management can affect fire duration by taking advantage of favourable weather to achieve containment.

We generated choice sets to accompany the fire scenarios in *SAS* (Statistical Analysis Software, SAS Institute Inc., Cary, NC) using a fractional factorial experimental design with 24 alternative management strategies. We grouped management strategies into eight choice sets of three alternatives, and the choice sets into two blocks of four choice sets based on the standard procedure described in Kuhfeld (2010). Many CE studies, especially in the consumer context, allow respondents to select 'none of these' if none of the alternatives offered in a choice set are acceptable. However, each wildfire necessitates some course of action. Some CE studies include a status quo alternative in each choice set to allow the respondent to 'opt out' of selecting an alternative strategy or good, but because each wildfire is unique, a status quo alternative did not make sense in this study. An argument could be made that an appropriate status quo is a non-suppression monitoring strategy, but in the fire scenarios described, with extreme fire weather and homes and a watershed at risk, monitoring did not represent realistic status quo management. To test this, we defined an alternative describing a non-suppression monitoring strategy, which protected neither homes nor the watershed, and which had other attribute levels as indicated in Table 1. We replicated the two choice-set blocks to create four blocks, and replaced a single alternative within the two replicate blocks with the monitoring alternative. Thus, 2 of 48 alternatives appearing within the design were replaced, with little loss in design efficiency. To complete the experimental design, we coupled every wildfire scenario with two choice-set blocks; every scenario was paired with either the first block or its corresponding monitoring block and either the second block or its monitoring block. Respondents were provided three wildfire scenarios, each accompanied by one of these two blocks; thus, because blocks contained four choice sets each, respondents were asked to complete 12 choice sets in response to three scenarios.

In each choice set, we asked respondents to indicate their expected response to the wildfire scenario and their preferred response. We defined the expected response as 'the strategy that you believe best meets community, agency leadership and political expectations, and conforms with federal fire and land management policies'. We defined the preferred response as 'the strategy you believe would result in the best long-term fire management outcomes, ignoring community, agency leadership and political expectations'. Therefore, we estimated models using two separate dependent variables. With respect to expected responses, we estimated managers' professional utility function, where professional utility may be affected by resource damage, personnel exposure and political considerations (Donovan and Brown 2005). With respect to their preferred responses, we estimated a personal utility function, where personal utility reflects the degree to which managers feel they have achieved optimal fire-management outcomes. Divergence between these models suggests areas where conflicts between professional incentives and mandated policy constrain managers from pursuing strategies they believe might lead to the best fire management outcomes.

Prior to release of the choice experiment survey, we conducted a pre-test with 17 fire managers at a December 2008 meeting of the National Incident Management Organisation in order to suggest final refinements to the survey instrument. In addition to the choice sets, the questionnaire provided respondents with detailed instructions and descriptions of each of the attributes of the wildfire scenarios and management strategies, and asked respondents to provide information about their employment, wildfire management experience and the community in which they work.

To identify potential respondents, we collected contact information for USFS Fire Management Officers (FMOs), Assistant Fire Management Officers (AFMOs) and agency administrators (District Rangers and Forest Supervisors) using agency distribution lists. In addition, we identified USFS personnel who had completed higher-level courses within the Incident Qualification Certification System, which provides training for federal land-management agency personnel in decision-making roles within wildfire management (including Department of Interior employees who participate in interagency fire teams). In March 2009, we asked a total of 2054 fire managers in the Forest Service, National Park Service, Bureau of Land Management and Bureau of Indian Affairs to participate in the survey via an email inviting them to follow an embedded link to the web-based survey.

Analysis of choice data

We estimated conditional logit models of expected and preferred management response within *Stata 10.1* (STATA Corp LP, College Station, TX) using utility functions of the form given by Eqn 4. All attributes given in Table 1 entered the models as explanatory variables; however, because several variables influence outcomes of fire-management strategies with respect to residential homes and watershed values, these variables entered the models as composite variables that describe the expected value change gained from each strategy:

$$homes = (hrisk) \times (\text{US\$0.2 million}) \times (hprob) \times (hprotect) \times (probsucc) \quad (6)$$

$$wsmod = (mod) \times (wsprob) \times (wsprotect) \times (probsucc) \quad (7)$$

$$wshigh = (high) \times (wsprob) \times (wsprotect) \times (probsucc) \quad (8)$$

For example, the variable *homes* equalled the number of homes at risk multiplied by the average value of those homes (which was provided to respondents in the questionnaire), the probability that the fire would reach the homes in absence of suppression efforts, a dummy indicating whether protection of home values would be pursued and the probability that those efforts, if undertaken, would be successful. The resulting variable provides the expected home value saved owing to the pursuit of any given suppression strategy.

The variables defined in Eqns 6, 7 and 8 are interaction terms whose effects on utility may not be strictly identifiable owing to the fractional factorial design and potential confounding effects with other interactions among attributes. This possibility is mitigated by the fact that main effects for the attributes included in the composite variables are not estimated. Additionally, we believe that although other attribute interactions may be confounded with the interactions that enter into our models, it is highly unlikely that there are behavioural reasons to believe these other undefined interactions affected choices among management strategies – in cases where interactions between attributes are not expected to affect utility *a priori*, interactions generally account for only 5 to 15% of variance in choices (Louviere *et al.* 2000). However, we anticipate that probabilistic expectations of loss will be a primary factor in determining managers' choices among strategies. Therefore, it is exceedingly likely that the effects we attribute to the interaction variables described in Eqns 6, 7 and 8 are in fact due to those variables and not due to other potentially confounding interactions.

Results

Sample population

We received a total of 583 completed surveys, resulting in an overall response rate of 28.4%. Table 2 summarises characteristics of respondents. A total of 37.9% of respondents were managers working specifically in fuels management or fire suppression, whereas 37.7% of respondents identified themselves as agency administrators. Others represented in the sample likely include individuals who are not in one of the specified fire-management positions but have completed advanced fire-management training and likely maintain some role within fire and fuels management.

The response rate attained in this study was low relative to some other CE studies; however, it is not outside the range of expected response rates in web-based surveys (Cook *et al.* 2000). This is true despite the fact that methods for determining the sampling frame were imperfect; many managers solicited for survey responses no longer participated in fire management at the time they received the surveys and therefore did not complete the survey (though we did not observe the number of managers fitting this description).

Table 2. Respondent characteristics

	Count	%
Sex		
Male	451	77.40
Female	132	22.60
Total	583	100.00
Age (years)		
20–29	10	1.70
30–39	93	16.00
40–49	170	29.20
50–59	287	49.20
60+	23	3.90
Total	583	100.00
Agency		
Forest Service	495	84.90
Bureau of Indian Affairs	5	0.90
Bureau of Land Management	13	2.20
National Park Service	69	11.80
Interagency	1	0.20
Total	583	100.00
Current position		
Agency administrator	220	37.70
Fire manager (Fuels or fire use focus)	70	12.00
Fire manager (Suppression or operations focus)	151	25.90
Other	142	24.40
Total	583	100.00
Current grade level		
5–6	13	2.20
7–8	45	7.70
9–10	50	8.60
11–12	202	34.60
13–15	270	46.30
SES	1	0.20
Other	2	0.30
Total	583	100.00
Organisation of employment		
Washington Office	3	0.50
Washington Office: detached	22	3.80
Research	3	0.50
Field: Northern Rockies	48	8.20
Field: Rocky Mountain	39	6.70
Field: Eastern Great Basin	46	7.90
Field: Western Great Basin	26	4.50
Field: Northern California	35	6.00
Field: Southern California	40	6.90
Field: Southwest	69	11.80
Field: Pacific Northwest	98	16.80
Field: Alaska	8	1.40
Field: Eastern	56	9.60
Field: Southern	74	12.70
Other	16	2.70
Total	583	100.00

Table 3. Expected and preferred management response models
Probabilities are significant at: ***, $P < 0.01$. Standard errors are clustered by respondent

	Expected		Preferred		Chi-square
	β	s.e.	β	s.e.	
Homes	0.8810***	0.0635	0.4044***	0.0360	52.55***
wsmod	0.7827***	0.1166	0.0369	0.1253	26.39***
wshigh	1.2250***	0.1309	0.5695***	0.1329	17.92***
avhours	−0.0004***	0.0001	0.0001	0.0001	18.31***
grounddays	0.000047***	0.000015	−0.0000079	0.000015	9.58***
duration	−0.0264***	0.0025	−0.0073***	0.0021	44.74***
cost	0.0859***	0.0106	−0.1044***	0.0082	240.43***
Number of observations	19 575		19 578		
log-likelihood	−6122.64		−6860.45		
Pseudo-R^2	0.1459		0.0431		

Table 4. Marginal rates of substitution (MRS) calculated from the expected response model
Note: MRS values calculated from at least one coefficient having the unexpected sign are in parentheses

	homes	*wsmod*	*wshigh*	*avhours*	*grounddays*	*duration*	*cost*
homes	−1	−1.126	−0.7193	2343.1	(−18 784.8)	33.40	(−10.26)
wsmod	−0.8884	−1	−0.6391	2081.7	−(16 689.3)	29.68	(−9.118)
wshigh	−1.390	−1.565	−1	3257.4	(−26 114.9)	46.44	(−14.267)
avhours	0.0004	0.0005	0.0003	−1	(8.017)	−0.0143	(0.0044)
grounddays	(−0.000053)	(−0.00006)	(−0.000038)	(0.1247)	(−1)	(0.0018)	(−0.0005)
duration	0.0299	0.0337	0.0215	−70.1	(562.4)	−1	(0.3072)
cost	(−0.0974)	(−0.1097)	(−0.0701)	228.3	(−1830.4)	(3.255)	(−1)

Choice model results

Table 3 provides base conditional logit models of fire managers' preferred and expected strategies. With the exception of the coefficients on *grounddays* and *cost*, which are not of expected sign, each of the coefficients in the expected response model is statistically significant and of the expected sign. For example, *homes* is expected to be positive because each added unit of the variable indicates that a strategy could be expected to preserve an additional US$1 million in home values. In the preferred response model, coefficients on each of the variables but *avhours* are of the expected sign, though the coefficient on *avhours* is insignificant. Chi-square tests across the two models indicate that each coefficient in the expected response model is significantly different from the corresponding coefficient in the preferred model. Interestingly, although managers favoured lower cost-suppression strategies when choosing their preferred strategies, they preferred more expensive strategies to less expensive ones when choosing their expected strategies, all other factors equal. Managers also tended to select expected strategies with higher levels of personnel exposure in the form of direct line person-days, holding other attribute levels constant.

To examine the effect of omitting a status quo alternative in nearly all choice sets, we assessed the incidence of item non-response and the frequency of selection of monitoring alternatives. Prevalence of item non-response would indicate that respondents were often unable to locate a suitable alternative within choice sets and may be more likely to have provided protest responses, but 90.4% of respondents selected a preferred and an expected strategy from each of the 12 choice sets they were offered. Therefore, protest behaviour is likely not a major concern in this study and it is likely that the majority of respondents were at least able to locate a 'least worst' alternative within each choice set. Respondents indicated that they preferred the monitoring alternatives in 33.9% of the choice sets in which they appeared. However, monitoring alternatives were selected by respondents as the strategy they expected they would adopt in only 6.4% of the choice sets in which they appeared. Therefore, managers appear to have agreed that, in the scenarios described, monitoring was not a realistic management response.

Tables 4 and 5 provide matrices of MRS values calculated from the respective expected and preferred response models using Eqn 5. Usually, environmental CE studies are primarily concerned with the final columns of these tables, which provide willingness to trade increases in cost for increases in levels of the other attributes. However, because the expected response model yielded a positive cost coefficient, values from this model indicating willingness to trade off against cost are nonsensical; for instance, Table 4 implies that fire managers would be willing to spend US$10.3 million for a US$1 million decrease in the expected home values preserved by a suppression strategy. Because of this, MRS values that are calculated from at least one coefficient without the expected sign should be ignored and are only included here for the sake of completeness.

Nevertheless, Tables 4 and 5 yield several interesting insights about the tradeoffs respondents were willing to make in choosing fire-management strategies. Fire managers were

Table 5. Marginal rates of substitution (MRS) calculated from the preferred response model
Note: MRS values calculated from at least one coefficient having the unexpected sign are in parentheses

	homes	*wsmod*	*wshigh*	*avhours*	*grounddays*	*duration*	*cost*
homes	−1	−10.95	−0.7101	(−4165.1)	51 200	55.20	3.874
wsmod	−0.0913	−1	−0.0648	(−380.3)	4670	5.040	0.3537
wshigh	−1.408	−15.42	−1	(−5865.2)	72 100	77.73	5.456
avhours	(−0.0002)	(−0.0026)	(−0.0002)	(−1)	(12.3)	(0.0133)	(0.0009)
grounddays	0.0000195	0.0002	0.0000139	(0.0814)	−1	−0.0011	−0.000076
duration	0.0181	0.1984	0.0129	(75.46)	−0.0927	−1	−0.0702
cost	0.2581	2.827	0.1833	(1075.1)	−0.000132	−14.25	−1

Table 6. Agency administrator-only models
Probabilities are significant at: *, $P < 0.10$; **, $P < 0.05$; ***, $P < 0.01$. Standard errors are clustered by respondent

	Expected		Preferred		Chi-square
	β	s.e.	β	s.e.	
homes	1.0510***	0.1042	0.4685***	0.0632	30.24***
wsmod	0.4836***	0.1779	0.3430*	0.1910	0.49
wshigh	0.7942***	0.2085	0.5073**	0.2258	1.53
avhours	−0.00008	0.0001	0.0000037	0.0001	0.28
grounddays	0.000049**	0.000023	−0.00003	0.0000	7.95***
duration	−0.0239***	0.0039	−0.0077**	0.0035	12.66***
cost	0.0249	0.0161	−0.1177***	0.0133	61.83***
Number of observations	7377		7380		
log-likelihood	−2383.8		−2544.1		
Pseudo-R^2	0.1169		0.0579		

less averse to additional fire duration and to exposing the watershed to moderate-severity wildfire when indicating their preferred strategy than when indicating their expected strategy. As the cost coefficient derived from the preferred response model is negative, Table 5 provides in its final column interpretable estimates of managers' willingness to trade off various attributes against cost. Were managers operating in absence of social and political constraints, they would be willing to allocate US$5.4 million to protect the highly valued watershed from high-severity fire, but only ~US$350 000 to protect the watershed from moderate-severity fire and US$70 000 towards reducing the duration of the fire by 1 day. Although the market values of most other strategy attributes in this study are not clearly defined, the expected value of homes saved can be calculated based on the given value of homes in each scenario within the CE. Respondents were willing to allocate almost US$4 million towards increasing expected home values protected by US$1 million. Although the total economic value of a home may exceed its market value, the fact that fire managers were willing to overinvest in protecting homes, even when socially and politically unconstrained, is an important result.

It is reasonable to expect that fire managers' relative levels of authority will affect the attributes they prioritise in selecting fire-management strategies. For instance, as agency administrators are responsible for developing suppression strategies, they may have different preferences than members of the incident command teams responsible for implementing them. Therefore, we estimated expected and preferred response models that included the choice attributes interacting with *aa*, a dummy variable set equal to 1 for agency administrator respondents. This dummy entered the model through interactions with each of the choice variables because it is expected that being an agency administrator affects the likelihood of selection of any given alternative through the effect of that position on attitudes towards each of the CE attributes. Coefficients on the agency administrator interactions reveal that agency administrator responses varied in several ways from respondents in the base case consisting of fire- and fuels-management professionals. Agency administrators demonstrated greater concern for home values than fire- and fuel-management professionals and less concern over high-severity fire in the watershed. Interestingly, when indicating their expected response, agency administrators had lower preference for protecting the watershed from moderate-severity fire than fire- and fuel-management professionals. However, when indicating their preferred response, agency administrators were more concerned than base-case respondents with moderate-severity fire. Agency administrators were generally unconcerned with personnel exposure; in models run on a sample limited to only agency administrators, reported in Table 6, all exposure variables were either insignificant or not of the expected sign.

Agency administrators showed greater sensitivity to cost than fire- and fuel-management professionals. However, even though agency administrators showed less preference for high-cost suppression strategies in the expected response model, they nonetheless demonstrated marginally statistically significant positive preference for higher-cost alternatives. Another interesting result from the agency administrator interaction models is that, whereas Chi-square statistics show that preferences of fire- and fuel-management professionals varied substantially across the expected and preferred models, preferences of agency administrators varied less widely.

Discussion

This study presents four substantial departures from standard CE methodology. First, we assume that managers make decisions according to utility functions in the same way that consumers, or respondents to a typical CE questionnaire, do. Although this assumption is unusual in the CE literature, there is significant support for it within the managerial literature, where many have argued that managers of competitive firms may not only make decisions according to processes of profit maximisation but may also be interested in maximising managerial utility (Williamson 1963; Awh and Primeaux 1985; Navarro 1988). Others have extended this idea to explain the behaviour of managers of non-profit and government organisations (Migué and Bélanger 1974; Tirole 1994).

Second, the majority of CE studies obey economic orthodoxy in assuming that respondents have only one underlying preference structure. However, several researchers, recognising that individuals may behave differently in different contexts, have proposed that individuals may have distinct preference orderings in their roles as consumers and as citizens (Sen 1977; Margolis 1982; Etzioni 1986; Lutz 1993; Hausman and McPherson 1996; Nyborg 2000), or that they may have context-dependent risk preferences (Weber *et al.* 2002). In the context of wildfire management, Kennedy *et al.* (2005) and Wilson *et al.* (2010) have proposed that managers' personal risk preferences may differ from those imposed by the agency. Therefore, the idea that managers may maintain multiple preference structures across their roles as employees and citizens is not unprecedented. Pseudo-R^2 values calculated from the expected and preferred models differed substantially. It is possible the divergent explanatory power across the expected and preferred models is explained by the difficulty managers had in embodying two discrete preference structures. Future studies eliciting multiple preference orderings might test this by doing so across multiple treatments, and therefore ask individual respondents to embody only a single preference structure. Alternatively, the difference in explanatory power may be indicative of the relative heterogeneity between individual manager preferences and the expectations of federal wildfire management authorities – although the individual values of managers may vary substantially, explicit and implicit fire-management expectations are more clearly defined and consistent. This explanation is supported by several studies that indicate managers often feel they have limited leeway in determining the appropriate course of action on a given event (Kennedy *et al.* 2005; Canton-Thompson *et al.* 2008).

A third departure from standard CE methodology is that stated-preference environmental valuation studies generally imply through the framing of the questionnaire and the description of the cost attribute (or bid method in CVM) that respondents face a budget constraint, which is usually equal to their personal or household budget constraint. In neither of the models predicting fire managers' expected or preferred strategies are managers' personal budget constraints understood to constrain the selection of fire management alternatives. Indeed, as noted previously, managers' program budgets are not directly influenced by the selection of fire-management strategies. This has implications for interpretation of results from this study. Because fire managers choose strategies by maximising their professional utility and because the cost of each strategy is borne by taxpayers and not by fire managers personally, rather than identifying fire managers' WTP for fire-management attributes, MRS when $\beta_k = \beta_c$ must be interpreted as willingness to allocate federal funds towards marginal improvements in the attribute x_l, not as WTP as in a typical environmental valuation CE study.

Finally, we represent fire scenarios visually and spatially. It is not unusual to present information regarding choice experiment attributes visually (e.g. Smyth *et al.* 2009), and, indeed, several recent studies have extended this concept through the use of virtual reality technology to demonstrate potential changes in attribute levels; however, we are not aware of any previous CE studies that have presented experimental attributes spatially. It is possible that the spatial presentation of information may have cognitive effects on respondents' interpretations of scenarios (e.g. Severtson and Burt 2012). This should be studied further, especially because any cognitive biases introduced in presenting risk information spatially in the CE context are likely also to influence use of spatial decision-support systems.

Despite recent policy emphasis on appropriate risk management and cost containment, analysis of the data revealed that respondents did not feel cost was a constraint bounding selection of an expected wildfire management response. Indeed, with respect to expected response, if managers considered suppression expenditures at all, they tended to select more expensive suppression strategies. This result corresponds to the model of bureaucracy put forth by Niskanen (1968), which suggests that bureaucrats seek to maximise their total budget. Alternatively, we may observe this result because the ceiling for suppression costs was set too low; that is, the US\$15 million maximum suppression cost within the survey instrument may not have been set sufficiently high to cause respondents to factor cost in their decision-making. Under either explanation, this result appears to confirm assertions of previous studies that the current management environment provides limited opportunity costs of committing suppression expenditures, and therefore managers have few incentives to meet stated cost-containment objectives (see Donovan and Brown 2005; Thompson *et al.* 2012).

The difference between cost coefficients across the expected and preferred models indicates that the positive sign of the cost coefficient within the expected model may be driven largely by social and political factors, which respondents were asked to consider when selecting an expected strategy but not when selecting a preferred strategy. These sociopolitical considerations may include agency and community support and perceived professional liability. For example, if a fire breaks through fire lines and causes resource damage, a fire manager who has accumulated a high level of suppression expenditures can more effectively argue that the fire escaped despite much effort having been directed at containing the fire. Some managers may have also interpreted higher cost as implying the availability of other resources in addition to the aviation and ground days specified in the strategy, though such behaviour would presumably have affected the expected and preferred responses equally.

Analysis of divergences between expected and preferred models indicates other areas where social and political factors appear to have played an important role in determining preferences. In the absence of sociopolitical factors, managers did not respond as strongly to the presence of homes within the potential fire path. Additionally, they exhibited increased tolerance for moderate-severity fire within watersheds. This may suggest that fire managers recognise that mixed-severity fire may, under many circumstances, improve ecosystem health and be a necessary component of future fire management. Based on Chi-square statistics, there appeared to be less divergence between the expected and preferred strategy among AAs than fire- and fuels-management professionals. This may be due to the fact that AAs have more direct control of the selection of fire-management strategies than members of incident command teams or fire managers in other roles. Finally, in both the base models and the AA-interaction models, the signs and significance levels of personnel exposure coefficients followed no discernable pattern; even when coefficients were significant and of the expected sign, estimated coefficients were small in magnitude. This suggests that personnel exposure was not a major consideration in strategy selection.

As a matter of policy, protecting human life (both public and firefighter) is paramount and other studies found manager preferences in accordance with this priority. A previous study (Tutsch *et al.* 2010) found that potential for loss of life was the most important factor determining Canadian fire managers' preferences for wildfire outcomes. It is likely that the difference between the current study's results and those of Tutsch *et al.* is driven by differences in the way safety risks were presented to respondents. The loss of life attribute in Tutsch *et al.* encompassed risk to residents, whereas in our study, firefighter exposure was the only life and safety consideration. Additionally, whereas Tutsch *et al.* included an attribute that directly specified whether a fire would result in major or minor potential for loss of life, in our survey instrument, the connection between firefighter exposure and accidents or fatalities was less direct. It is possible that managers believed firefighter injuries and fatalities are unrelated to the amount of fireline exposure and can be managed through adherence to established safety protocols. Since we administered this study, USFS leadership has emphasised to fire managers the importance of weighing increases in firefighters' exposure to hazardous conditions against the potential gains of further fire suppression activity. Therefore, it would be interesting to evaluate whether manager preferences have changed over the last several years owing to this increased emphasis.

Our work here could provide a foundation for several future research directions. First, because we elicit multiple choice-set responses from each respondent, it would be possible to extend our analysis through the use of a mixed logit model or a random components model to respectively account for preference heterogeneity or differences in error variance. Second, it will be important to identify the cause of discrepancies among our study and previous studies with respect to attitudes towards protection of human life. Finally, this dataset can be used to examine possible biases in perceiving and managing risk, and in particular how the fire managers jointly considered wildfire probability contours, suppression strategy likelihood of success and values at risk. Continued attention to incentive structures paired with a focus on cognitive limitations and improved models of human behaviour should prove fruitful.

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