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Research Note

Federal fire managers' perceptions of the importance, scarcity and substitutability of suppression resources

Crystal S. Stonesifer[A,B], *David E. Calkin*[A] and *Michael S. Hand*[A]

[A]US Department of Agriculture Forest Service, Rocky Mountain Research Station, 800 East Beckwith Avenue, Missoula, MT 59801, USA.
[B]Corresponding author. Email: csstonesifer@fs.fed.us

Abstract. Wildland firefighting in the United States is a complex and costly enterprise. While there are strong seasonal signatures for fire occurrence in specific regions of the United States, spatiotemporal occurrence of wildfire activity can have high inter-annual variability. Suppression resources come from a variety of jurisdictions and provide a wide range of skills, experience and associated mobility and logistical needs. Dispatch centres and regional and national resource allocation centres move suppression resources to respond to demand. However, little is known about the decision-making processes driving the allocation of limited resources at the national scale, particularly during periods of increased resource scarcity. Moreover, an understanding of these systems provides no insight into the impressions from the field regarding the value and relative scarcity of specific resources. We designed and implemented an online survey of United States Forest Service employees who have direct or indirect responsibility for ordering suppression resources, with the main objective of identifying which resources the field perceived to be most important, most scarce and which were without acceptable substitutes. In this research note, we present a preliminary overview of a selection of results of our survey and discuss the next steps for potential future analyses of the dataset.

Additional keywords: fire economics, fire management, fire suppression.

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Background and objectives

Wildland firefighting operations in the United States (US) consist of a complex system of interagency cooperation. Resource allocation decisions in this system are driven by a combination of spatiotemporal variability in fire occurrence, multi-jurisdictional land ownership associated with fire activity and a large pool of multi-jurisdictional suppression resources representing a variety of ground- and aviation-based resource types. When fire activity is minimal or regionally concentrated, the resource allocation system for meeting suppression demand is relatively straightforward and mainly involves getting the closest resources available to the fire in the shortest time. However, when there is concurrent high fire activity in multiple regions, resource scarcity may be exaggerated and a level of unmet demand is inevitable. When fire demand exceeds resource supply at the local response level, regional or national managers allocate and prioritise scarce resources across areas of need. This decision-making process is highly complex and requires decision-makers to consider complicated tradeoffs (e.g. values at risk, benefits from fire, probability of success, firefighter exposure), which becomes even more difficult as the geographic scale broadens. Consequently, national-level resource allocation decisions are based largely on mental heuristics and are neither well documented nor well understood outside of the closed, national-level circles where these decisions are made.

Given the limitations of existing data systems, it is difficult to accurately characterise suppression resource supply and demand and to learn from resource allocation decision-making processes. Historically, national reports of resource use and scarcity have come from the Resource Ordering and Status System (ROSS), which is the national all-hazards incident dispatch system in the US. In ROSS, resources are grouped into specific resource categories, such as 'crews', 'engines', 'airtankers' and 'helicopters', then are further divided into subcategories based on resource capabilities and capacities (e.g. type 1–3 helicopters, corresponding to heavy, medium and light helicopters; see Table 1). ROSS data can be used to report on the total number of requests by resource type and whether those requests were ultimately filled or unfilled, with the percentage of 'Unable-To-Fill' requests frequently used as a figure illustrating unmet suppression demand (for examples, see NICC 2017 wildland fire summaries for 2000–2016). While this dataset can provide useful insight into overall resource ordering patterns, ROSS data reports do not capture the nuance in a complicated system of multi-jurisdictional resource ordering and allocation. For example, ROSS does not reflect resource requests that are filled at the local response level. Additionally, system changes in ROSS or in dispatch protocols could affect analysis of annual trends. More importantly, when resources are stretched thin and regional and national control of limited resources becomes more evident, we hypothesise that ROSS

Table 1. Resource type descriptions

Resource Ordering and Status System (ROSS) suppression resource types defined in the National Wildfire Coordinating Group's Data Element Standards and included as potential answers for multiple choice and dropdown questions. Full descriptions of the multitude of specific resource categories and subcategories can be found in user support documentation for the ROSS (www.ross.nwcg.gov/userguide.htm). Resource type descriptions from NICC 2016; NIFC 2016; NWCG 2008; USDA Forest Service 2013

Fire resource category	Description	Fire resource type	Description
airtanker	fixed-wing aircraft capable of transport and delivery of fire retardant solutions	airtanker, VLAT	very large airtanker; >= 8000 gal (30283.3 L)
		airtanker, type 1–2	large airtanker; 1800–7999 gal (6813.7–30279.5 L)
		airtanker, type 3–4	single or multi-engine airtanker; <= 1799 gal (6809.9 L)
fixed wing	aircraft with stationary wings; not an airtanker	fixed wing, lead plane qualified	can be ordered as a lead plane or an Aerial Supervision Module (ASM), which is a fixed wing aircraft with 2 crew members working dual roles as air attack and low-level lead operations
helicopter	aircraft that depends primarily on rotors for lift	helicopter, type 1	largest capacity helicopter
		helicopter, type 2	medium capacity helicopter
		helicopter, type 3	smallest capacity helicopter
crew	an organised group of firefighters under the leadership of a crew boss	crew, type 1	also 'hotshot crew'; group of 18–20 firefighters with the highest level of crew standards and qualifications required
		crew, type 2 IA	also type 2 initial attack crew; group of 18–20 firefighters; significant crew standards required, although not as stringent as for type 1 crews
		crew, type 2	crew of 18–20 firefighters; skills, capabilities and qualifications can be variable and few qualifications are required beyond basic firefighter training
group	people organised into a unit, other than a crew	rappellers, load	helicopter load of ~15–21 firefighters configured as a rappel module who deploy via rope rappel from hovering helicopters
		smokejumpers, load	plane load of ~2–16 firefighters configured as a crew who deploy via parachute
		faller, advanced	a position within a group or an individual ordered as a single resource sawyer; an advanced faller is the most highly qualified sawyer certification
equipment	an apparatus that is used for wildland fire operations	dozer, any type	common abbreviation for bulldozer; a tracked vehicle with a front mounted blade used for exposing mineral soil for fireline or firebreaks
		engine, type 3–7	wildland fire engine, various tank capacities and pump pressures, staffed by a minimum of 2–3 firefighters
		water tender, tactical	tanked water vehicle intended for use on or near the fire line, primarily for delivering water in support of operations

data may not reflect the true demand for resources and the associated level of unmet demand because resource ordering practices likely change with levels of resource scarcity. When faced with difficulty acquiring their preferred mix and number of resources, fire managers may, for example, change their suppression strategies, make resource substitutions or capitalise on personal relationships or other channels outside of ROSS to acquire their desired resources. Thus, true demand for resources is likely misrepresented in ROSS data reports. Finally, the relative importance of specific resources with respect to suppressing fire at different management stages, as well as an assessment of the unique capabilities of specific resources cannot be ascertained from ROSS reports.

We designed a survey aimed at fire managers with recent fire experience to enhance our understanding of this complicated system from the perspective of the operations personnel directly affected by resource availability. By targeting managers with direct or indirect responsibility for ordering suppression resources, we hoped to achieve our main objective of identifying which resources the field perceived to be most important, most scarce, without acceptable substitutes, and how these results intersect. Critically, we aimed to isolate questions related to importance, scarcity and substitutability so that we could distinguish between a resource that is high value, scarce and with few substitutes versus one that is low value, readily available and with many potential substitutes. In this research note, we present a brief discussion of the survey design and methods, introduce a sample of the results and discuss the potential implications on the current system of resource allocation and dispatch in the US. The results of this work should help efforts to improve efficiency of Federal firefighting operations by identifying those resources that are currently most limiting fire management operations and informing pre-season resource acquisition strategies.

Survey design and implementation

Our survey was designed in the online Survey Monkey program (www.surveymonkey.com, accessed 25 January 2017) and administered via direct email invitation to a select list of US Department of Agriculture Forest Service (USFS) employees. The target audience was limited to Federal employees per regulations for survey administration and further constrained to USFS employees due to consistent availability of email addresses. The email invitation list was manually compiled and targeted employees with key upper-level Incident Command System (ICS) qualifications (e.g. type 1–3 Incident Commander, Operations Sections Chief, etc.; US Department of Homeland Security 2008) and specific Agency job titles that may be coincident with Agency Administrator and line officer credentials (e.g. Fire Management Officer, District Ranger, etc.). To populate the invitation list with potential Agency Administrators, we searched for these key job titles in the USFS global address book in Microsoft Outlook and exported the associated email addresses. Ultimately, 1235 email invitations were distributed. To boost participation for this voluntary survey and to lend credibility to our efforts, the survey invitation email was preceded by an email letter of support from the office of the Director of Fire and Aviation Management for the USFS. The survey was open for 20 days, from 6–26 May 2016, and reminder emails were sent on days 7 and 14 to those recipients who had yet to respond or complete the survey in full.

We organised questions into three subject areas: resource importance, resource scarcity and resource substitutability. Respondents were presented with 31 questions, including 11 demographics questions. To facilitate future statistical modelling and analysis, open text responses were limited, and the majority of the questions were multiple choice, choice matrices and categorical dropdown styles. Table 1 describes the 16 types of suppression resources that were included and their description. We did not give this table to survey recipients; we provide it here for the reader's benefit as a concise summary of suppression resources and standards that may not be common knowledge outside of the US. Respondents were always provided with an open text, 'other' option when presented with these resource lists. A copy of the complete survey instrument can be found at http://www.fs.fed.us/rmrs/projects/effectiveness-suppression-resource-utilization (accessed 30 January 2017) or obtained directly from the authors.

We first asked respondents to identify the single most valuable resource in direct attack and indirect attack operations (list described in Table 1). According to the National Wildfire Coordinating Group, the main distinction between direct and indirect attack is the distance between the suppression activities and the actively burning fuel; direct attack involves treatments to the flaming front (e.g. wetting) and indirect attack involves treatments 'some considerable distance away from the fire's active edge' (e.g. constructing a fuel break and using backfiring techniques; http://www.nwcg.gov/glossary/a-z, accessed 28 November 2016). Both terms are widely understood in the fire community, however, to standardise respondents' answers, we specifically defined direct attack in this context as those actions that are frequently associated with initial attack and extended attack incidents (early fire containment efforts), while indirect attack activities were defined as those associated with large fire support, frequently long-duration incidents. Because we were targeting experienced fire managers, we expected that our audience would have a common understanding of these basic terms, therefore, we provided only this limited guidance defining direct and indirect attack.

In the next section, respondents were asked to reflect on their wildfire experience to identify the relative scarcity of resource types. Scarcity was defined for the survey taker as the difficulty acquiring desired suppression resources given competing resource demand, and we asked respondents to rank resource type scarcity as 'not scarce', 'somewhat scarce' or 'very scarce'. We explicitly directed respondents that scarcity in this context was not simply the raw number of resources by type, because this varies dramatically. For example, there are relatively few large airtankers (23 were on federal contract mid-season 2016; http://wildfiretoday.com/documents/AirTankersContracted_5-24-2016, accessed 11 July 2016) compared with wildland fire engines, which number in the thousands and come from private contractors, local and state governments and national agencies. There were 5290 unique wildland fire engines (types 3–7) that responded to wildfire and prepositioning incident requests in 2016, as of a 25 November 2016 ROSS query.

In the final section of the survey we grouped questions related to the substitutability of resource types. Specifically we asked respondents questions targeted at identifying the unique capabilities of resource types and what actions managers took when they could not get their first choice resource. In one question, we provided a choice matrix by resource type and asked respondents to rank the substitutability of individual resources. The response scale included 'not substitutable', 'somewhat substitutable' and 'highly substitutable'. Respondents could also select 'no opinion' if they had no experience with that particular resource type for both of these scarcity and substitutability questions.

Results

We received 553 responses from unique individuals, 475 of which were complete. For this preliminary analysis, we excluded all responses that did not come from complete surveys and 28 additional respondents were disqualified because they lacked recent (since 2013) fire experience ($n = 447$; 36.2% response rate).

The response sample of 447 employees well represented fire experience in most of the 10 geographic regions (Geographic Coordination Areas; https://gacc.nifc.gov/, accessed 11 July 2016) in the US, with the exception of the Alaska Area ($n = 1$) and the Eastern Area ($n = 16$). These results are consistent with expectations, due to the relatively limited fire activity on USFS lands in these geographic areas. The respondents were generally college-educated, with many years of fire and USFS employment experience. Of the respondents, 79.1% had obtained at least an associate degree, with 48.4% earning a bachelor degree and 14.7% completing a graduate degree; 66.0% had worked for 20 years or more with the USFS and 73.8% reported at least 20 years of fire experience. Respondents were generally highly qualified in many areas of the ICS; for example, 58.4% were qualified as type 3 or higher incident commanders. Most respondents (67.6%) had experience working on an incident command team in some capacity and 42.9% had 13 or more unique fire assignments since 2013, with an average assignment length for all respondents of 12 days.

The single most important suppression resources and their associated scarcity assessments are shown in Fig. 1. For direct attack, respondents most frequently identified type 1 crews (30.2%) and wildland fire engines (28.2%) as the most important resource. Responses generally categorised the scarcity of

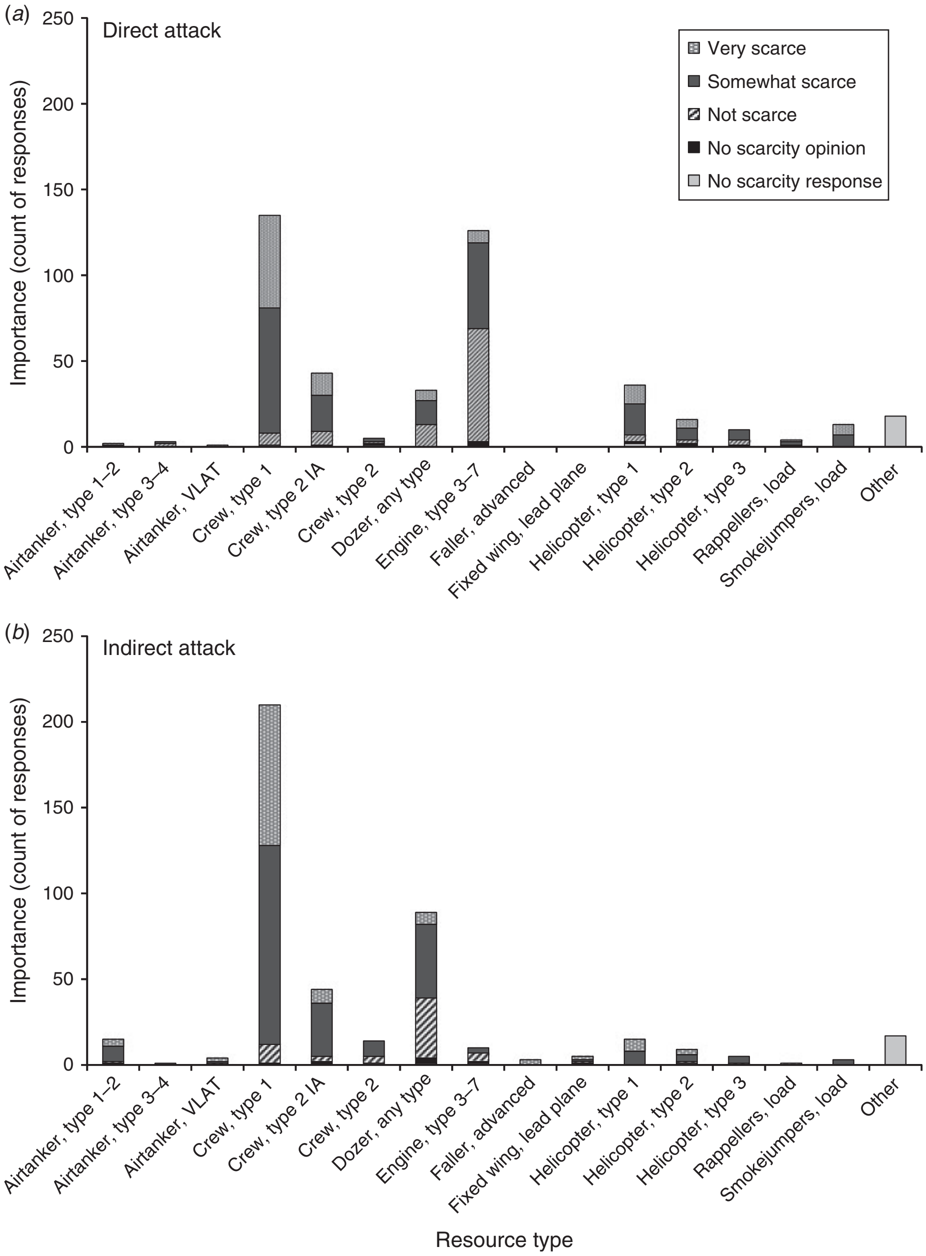

Fig. 1. Survey results for resource importance versus scarcity. The single most important suppression resource type in (*a*) direct attack operations and (*b*) indirect attack operations. Column height indicates the number of respondents who ranked that resource as most important, and the columns are broken out into respondents' corresponding assessments of scarcity for their self-identified high-value resource ($n = 447$ for each panel). VLAT, very large airtanker; IA, initial attack; dozer, bulldozer; faller, sawyer.

type 1 crews as somewhat scarce (54.1%) and very scarce (40.0%), whereas wildland fire engines were categorised as not scarce (52.4%) and somewhat scarce (39.7%). In contrast, for indirect attack, nearly half of respondents identified type 1 crews (47.0%) as the most important resource, while also generally categorising them as somewhat scarce (55.2%) and very scarce (39.0%). The next most represented indirect attack resource with respect to importance was the dozer (bulldozer; 19.9%), followed by type 2 IA crews (9.8%). Dozers were generally characterised as somewhat scarce (48.3%) and not scarce (39.3%), and type 2 IA crews were mostly categorised as somewhat scarce (70.5%).

In terms of which resource types were substitutable, we see that across all resource types lead planes, type 1 crews and advanced fallers (sawyers) have the highest representation of responses in the not substitutable category (Fig. 2). Type 2 crews were most frequently identified as highly substitutable (43.6%) and only 8.9% of respondents called this resource

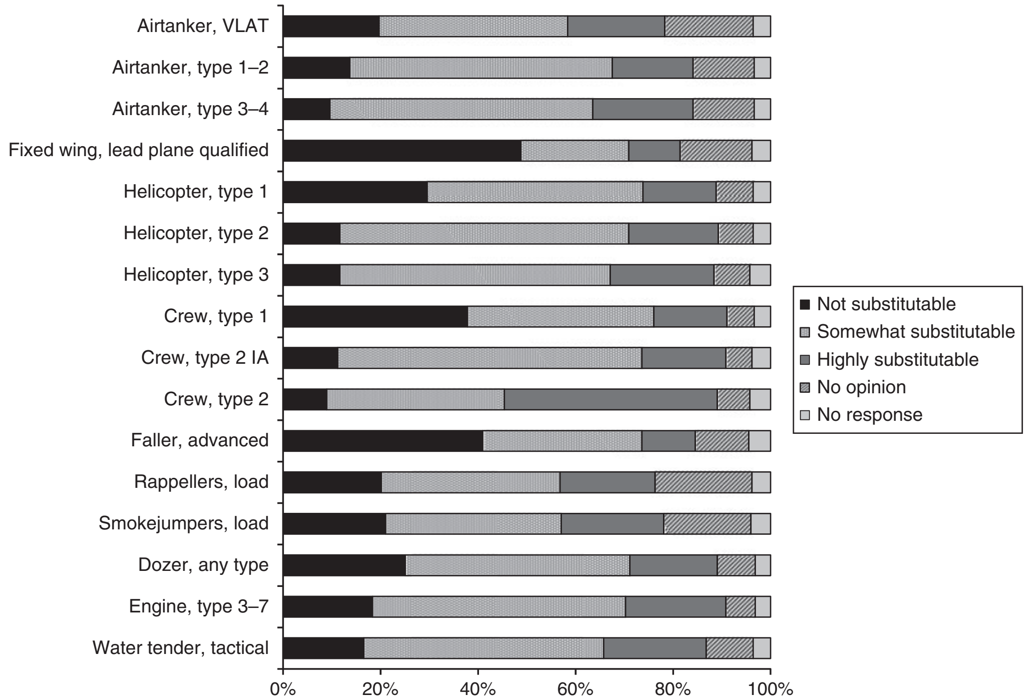

Fig. 2. Survey results for resource substitutability. The distribution of substitutability category responses by resource type. For each resource type category (y-axis), $n = 447$.

not substitutable. Few respondents (9.6%) also classified type 3–4 airtankers as not substitutable. Finally, very large airtankers (VLATs), rappellers and smokejumpers have the highest proportion of responses in the no opinion category, perhaps suggesting niche roles for these resources not encountered by all managers.

Discussion

These results provide initial insight into the field's view of relative importance, scarcity and substitutability of suppression resources in USFS wildfire management. These early data summaries clearly point to operational preference by wildfire response phase (direct and indirect attack) for specific resource types, potentially with associated measures of scarcity. For example, a clear theme evident in our results is that type 1 crews were generally perceived to be most important in both direct (30.2%) and indirect attack (47.0%), and they were also perceived to be scarce (94.2% ranked this resource as somewhat scarce or very scarce). We did not specify in our survey whether the type 1 crews were specifically Interagency Hotshot Crews (IHCs), which are nationally available crews of 18–20 highly experienced firefighters, from multiple jurisdictions but predominantly from Federal agencies (www.fs.fed.us/fire/people/hotshots/ihc_stds.pdf, accessed 28 November 2016). Data system limitations and shifting resource qualifications and availabilities affect our ability to definitively report on the number of crews by type, particularly during the off-season, but we can use filled ROSS requests to provide summaries of historical resource use. From this, there are 107 IHCs that responded to wildfire and prepositioning requests in 2016 (from a 25 November 2016 ROSS query). Additionally, as of December 2016, the state of California Department of Forestry and Fire Protection (CALFIRE) provides 196 12–17 person type 1 inmate crews (http://calfire.ca.gov/communications/downloads/fact_sheets/Glance.pdf, accessed 28 November 2016), and ~50 more type 1 crews come from various California counties and the California Conservation Corps. These crews do not meet minimum interagency standards for a type 1 crew and do not respond to incidents outside of the state. Related to this, a frequent refrain when respondents were provided with an open text field for comments, was that some expressed a preference for Federal over non-Federal or contract crews. Further analyses will draw from these comments and explore respondents' preferences for type 1 crews in regions where IHCs are the only type 1 crews available. Further, we will explore responses related to preferences for other crew types and potential issues or opportunities related to resource substitution between crew types. For example, type 2 crews, which were generally not perceived to be scarce (the same November 25 2016 ROSS query yielded 351 type 2 crews used to fill fire or prepositioning requests in 2016), were ranked as the single most important resource by few respondents for both direct (1.1%) and indirect (3.1%) attack. This may be explained by the wording of the question; type 2 crews may be viewed by the field as a useful but ancillary resource that works best in conjunction with other resource types. Therefore, respondents would not be inclined to select this resource as the single most important suppression tool. Future analyses could help illustrate whether the current level of investment in particular crew types is scaled to the level of demand from the field, including factoring in the mobility of specific crews (nationally, regionally or locally available), the capabilities provided by enhanced qualifications (e.g. type 2 IA crews can be broken into squads, whereas type 2 crews generally cannot) and potential preference for specific crew ownership.

Econometric modelling of these data may help illuminate patterns specific to relative importance versus costs for specific resource types. For example, only 0.6% and 4.3% of respondents ranked heavy airtankers (type 1–2 and VLAT types combined) as the single most important resource type for direct and indirect attack, and these were also both most frequently categorised as somewhat substitutable resources. It is particularly interesting that few respondents ranked airtankers of any size as the single most important resource in direct or indirect attack, considering the general public sentiment that airtankers are critical to success in firefighting efforts (http://www.latimes.com/local/la-me-wildfires29-2008jul29-story.html, accessed 28 November 2016). This fact also contrasts the level of investment in aviation in fire suppression compared with overall expenditures. Heavy airtankers are predominantly a USFS contract resource, and on average, from 2007–2011, they accounted for 4.8% of total expenditures, representing approximately 56.8 million US dollars per year to support a fleet of just 12–19 resources (total contract heavy airtankers during this timeframe; Calkin *et al.* 2014). Because crews, wildland fire engines and bulldozers are multi-jurisdictional assets, we cannot report on percentage of total expenditures in the same way for these resources. However, future work may examine the use of daily cost estimators by resource type and historical resource assignments to arrive at a comparable cost metric for each resource type ranked by suppression importance.

In this research note, we present only a portion of our results, and further analyses and modelling may highlight other interesting patterns. For example, after asking respondents to identify the single most important resource for various suppression stages, we ask them next to identify the three most important resources. In addition, we explicitly asked respondents in the substitutability section of the survey to identify those resources that critically require other resource types to be truly effective. Early data summaries suggest that there may be key linkages between specific resource types with respect to importance. For example, a common narrative in fire management is that the presence of ground resources is critical to the effectiveness of aviation suppression actions; early analyses suggest that we will see evidence of this theme in our results. Comparison of responses to the single most important resource question versus the three most important resources question, coupled with information on critical resource needs regarding effectiveness, may allow us to suggest a more efficient suppression response model that makes these critical resource linkages with specific dispatch protocols.

Our survey results are particularly interesting when compared with recent research on fireline production in US large wildfire management. Holmes and Calkin (2013) demonstrated that crews' actual production rate, based on reported fireline contained, averaged just 35% of published fireline production rates (Broyles 2011). In related work, Katuwal *et al.* (2016) examined daily fire perimeter progression and reported a negative relationship between line production and total crews assigned. There is a potential disconnect between these manuscripts and the early analysis of our survey results demonstrating that the field perceives crews, specifically type 1, as highly important in indirect attack (large fire management). The indirect relationship between the number of crews assigned and the expected fireline production for large fires shown by Holmes and Calkin (2013) and Katuwal *et al.* (2016) indicates that crews are likely engaged in other tasks outside of fireline construction; our results suggest that the field perceives this work to be of high value. Large fires account for the majority of expenditures in US fire suppression (Calkin *et al.* 2005), yet it is difficult to recreate the operational history for large, complex fires, specifically identifying the location, actions and outcomes of resources assigned. This underscores the need for more thorough operational data collection efforts aimed at enhancing our understanding of the complex dynamics of large fire management.

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