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Themes and patterns in print media coverage of wildfires in the USA, Canada and Australia: 1986–2016

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ABSTRACT

Background. Media wildfire coverage can shape public knowledge on fire-related issues, and potentially influence management decisions, so understanding the content of its coverage is important. Previous research examining media wildfire coverage has primarily focused on either a single fire or issue, and provides little insight about the range of wildfire-related topics discussed in the media. **Aims.** We aimed to assess wildfire topics covered in print media between 1986 and 2016 across the USA, Canada and Australia. **Methods.** Machine learning-based automated content analyses were conducted to identify primary topics within news articles and to map relationships between topics. **Key results.** News articles related to wildfire were clustered into four topic areas: Fire Response, Management, Environmental Conditions and Property Preparedness. Notable between-country differences emerge: the US media coverage focuses most on firefighting; Canadian coverage, climate change; and Australian coverage, preparedness. **Conclusions.** Our results reveal that: (1) wildfire media coverage has increased over the past 30 years; (2) coverage is more varied than the common perspective, i.e. media continues to portray fires in a negative light; and (3) topic coverage varies significantly between countries. **Implications.** These findings can help identify gaps in media coverage, and provide insights into critical topics, or relationships between topics, that may need additional emphasis in conversations about how to better learn to live with fire.

Keywords: computational text analysis, cross-national analysis, environmental communication, management and climate change, news media, prescribed fire, wildfires.

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Introduction

Recent years have seen growing concern about the adverse impacts of wildfires, as well as increased recognition of the critical ecological role fire plays in many ecosystems and the management challenges associated with both areas (Pyne 2007, 2016). An important question is how such discussions are represented outside the fire management community. News media can be an essential mode through which narratives are developed and transferred, with some scholars arguing that portrayals of fire in the media are an important factor in shaping public perceptions of fire risk (Jacobson *et al.* 2001; Nilsson and Enander 2020). Studies have shown that for many people the news media is a primary source of information on many public policy issues, including those related to the environment, climate change, and natural disasters (Barnes *et al.* 2008; Hansen 2011; Zhao *et al.* 2011). Similarly, for forestry issues, Shindler *et al.* (1996) noted that over 80% of people said their views on forest management were informed by media sources – twice as many as said that about their friends or family. And for wildfires, research has found that mass media and family/friends were the most common wildfire information sources both before and during an event (Steelman *et al.* 2015).

Given this reliance on the media for information, it is important to understand the range and extent of topics that are actually covered in a specific media context and region. Communication researchers have identified a number of ways that media communication can act as an information gatekeeper that affects the information the public receives, which in turn can influence how the public perceives a topic (Shoemaker and Vos 2009).

For instance, the contextual information that is or is not provided on an issue, and the amount of attention media pays to a particular issue, can legitimise or marginalise certain topics and influence the issues people pay attention to – effectively making some topics more salient in the public discourse than others (Scheufele and Tewksbury 2007). Within the fire literature, one common narrative is that the media often focus on the negative aspects of wildfire (Ingalsbee 2017), potentially creating barriers to proactive fuels management efforts (e.g. the use of prescribed fire) and reinforcing aggressive suppression policies (Doerr and Santín 2016). Initial studies on media coverage have suggested that the news media neglects to promote a scientific perspective on wildfire, by either failing to emphasise the role wildfire plays in sustaining biodiversity or by disregarding the role of climate change in worsening fire conditions (Hovardas 2014; Anderson *et al.* 2018; Cordner and Schwartz 2019). Given the media's potential role as gatekeeper and framer of wildfire narratives, it is vital to assess how media sources discuss wildfires.

A more precise understanding of the full range of ways media discusses wildfires also may be important information for fire managers and policymakers. If the public understanding of wildfire is shaped by the media's framing of these issues, then it would also be prudent for policymakers and managers to be aware of how wildfire-related issues are described in media outlets. In addition, a few studies have shown that managers are often concerned about how their actions are perceived in the media and that this concern can influence their decisions. For example, one study found that increased newspaper coverage of a wildfire was positively correlated with suppression costs (controlling for factors such as the severity of the fire), suggesting that managers may use more resources on suppressing fires that receive more media coverage (Donovan *et al.* 2011). There is a need for research to better understand structural reasons why managers may feel that press accounts may personally hold them responsible if high-profile fires are not aggressively suppressed; there is also a need to better understand how fire is, or is not, presented in the news media, and what is emphasised, both of which can help managers and organisations identify areas where critical topics, or relationships between topics, may need additional emphasis in their outreach, both in general and specifically to the news media. This latter need is the focus of our research.

Media coverage of wildfires

To date, studies on wildfire media coverage have tended to engage in manual content analysis on a fairly narrow range of wildfire topics, generally focusing on articles around a single fire event (Boulianne *et al.* 2018) or how specific topics, such as climate change (Hopke 2020), firefighter safety (Cordner and Schwartz 2019), or resilience (Hughes and White 2006), are portrayed. An early finding was that wildfire media coverage tended to focus on the emotional toll of an event at the expense of factual information or educational content about fire's ecological role. For instance, in one of the first papers examining television news coverage of wildfires, Smith (1989) noted that

> television networks covered the 1988 Yellowstone fires in a stylized and stereotyped way; as fables about brave firefighters, powerful natural forces, bumbling bureaucrats, and anthropomorphized fires and forest creatures…. and by fire as a largely evil threat to Yellowstone Park as a national treasure. In perpetuating these myths, the news stories did a poor job of serving educated non-specialists seeking the information necessary to arrive at informed conclusions about the relevant ecological issues and related land management policies (p. 17).

In a more recent analysis of newspaper coverage during three major Australian wildfire events (in 1939, 1983, and 2009), Yell (2010) found an increase in affective content over time, with a growing number of articles in more recent events describing emotions like grief in dramatic and personal ways. It is important to note that an article that focuses on the affective component may not necessarily be a form of misinformation, even though it may be portrayed as such by many researchers. As Choudhury and Haque (2018) suggest, these types of news stories also may serve as reminders of individual and community resiliency, inspiring and promoting hope in the face of natural disasters. Another common finding is that wildfire-related media coverage often ignores the role of climate change in exacerbating the impacts of wildfires (Anderson *et al.* 2018; Cordner and Schwartz 2019). Morehouse and Sonnett (2010) noted, however, that climate change coverage could vary significantly by publication outlet, with some newspapers more likely to cover the climate context than others.

Although this body of work does begin to provide insight into the content of wildfire media coverage, it does not provide a clear sense of the prevalence of and interrelationships between different topics, and how these individual topics fit within the larger discussion. A comprehensive assessment of topics covered in wildfire coverage is needed to provide a baseline for beginning to understand whether the media is, in fact, legitimising or marginalising specific perspectives. For instance, how often is the ecological role of fire raised? And in relationship to what other topics? This study, therefore, sought to take a broad assessment of the range and variability of wildfire-related topics that are covered in the media, focusing on newspaper (both print and online, when available) coverage of wildfire from three countries – the United States, Canada, and Australia – across a 30-year time span. We focused on these three countries due to their similar language and general similarities in relation to scale of fires, fire impacts, and general fire management approaches. In addition, because a comparison of research across these three countries found that many of the social

dynamics are similar, with primary differences mainly reflecting institutional differences (McCaffrey 2015), we were interested in seeing whether and how fire media coverage might differ between countries. We chose newspaper coverage, as opposed to radio or television, because it allows for the more in-depth and complex discussion of a topic that we were interested in exploring, and also because research has found that it is a more common source of wildfire information for the public than radio and television (Steelman *et al.* 2015).

Methods

Large-scale content analysis

Many forms of automated content analyses are now available to make sense of what is expressed in large databases such as news media or other forms of generated text content. Though these approaches cannot a substitute for the precision and rigor of manual coding, they are sometimes the only way of reasonably assessing the breadth of discussion in any given subject. To make sense of wildfire-related newspaper content in thousands of articles over a 30-year span across three countries, we employed a topic-modelling approach. Topic models, of which there are distinct types, are an algorithmic approach to inferring semantic content from large bodies of text (corpora), and have been used to study the vast amounts of content generated via online platforms (such as on social media) in the scientific literature (Wang and Blei 2011; Yau *et al.* 2014) and, in the case of environmental resilience, in public agencies' internal documents (Selles and Rissman 2020). Originally developed by computer scientists (Blei *et al.* 2003), this approach has been used in a variety of academic disciplines and has been employed in environmental contexts to better understand domains such as ecosystem services (Droste *et al.* 2018), environmental resilience (Selles and Rissman 2020), climate change (Tvinnereim and Fløttum 2015; Stoddart *et al.* 2016), wild food foraging (Sachdeva *et al.* 2018), and natural disasters (Deng *et al.* 2020). Regardless of the particular topic-modelling algorithm used, one of the outputs of the models involves clusters of co-occurring and semantically coherent lists of words, which can be labelled as an idea or topic.

Developing the corpus

We gathered our corpus of newspaper articles from the USA, Canada, and Australia using the LexisNexis Academic database, which contains full texts of news articles from several thousand sources by country. Articles were collected from all available sources on LexisNexis between 1 January 1986 and 31 December 2016. To search articles about wildfires, we used a LexisNexis SmartIndexing (https://internationalsales.lexisnexis.com/glossary/lexisnexis-smartindexing-technology, accessed 2 September 2022) classifier term called 'forest fires.' Using an indexed term, rather than searching for terms like 'wildfire' within the body of the articles, allowed us to: (1) filter out more colloquial or metaphorical uses of fire-related terms (e.g. rumours spreading like wildfire), and (2) broaden the search to include articles that might be about wildfires but use terms that might vary based on local usage (i.e. bushfire). Duplicated articles, i.e. articles from the same newswire service that were printed in various outlets, were also removed using LexisNexis's de-duplication algorithm with the more conservative (high-similarity) setting (https://lexisnexis.custhelp.com/app/answers/answer_view/a_id/1102580/~/deduplication-on-nexis, accessed 2 September 2022).

These criteria yielded a final corpus containing 71 404 articles across the 30-year period (Fig. 1), including 37 859 articles from the USA, 16 489 articles from Canada, and 17 056 articles from Australia. Fig. 1 shows that significantly more articles about fires have been published in the decade between 2005 and 2015 than the two prior decades. Some of this change in publication rate of wildfire-related articles may be attributable to constraints (i.e. access rates with digital versus non-digital content) in the LexisNexis database or the SmartIndexing term. However, an analogous

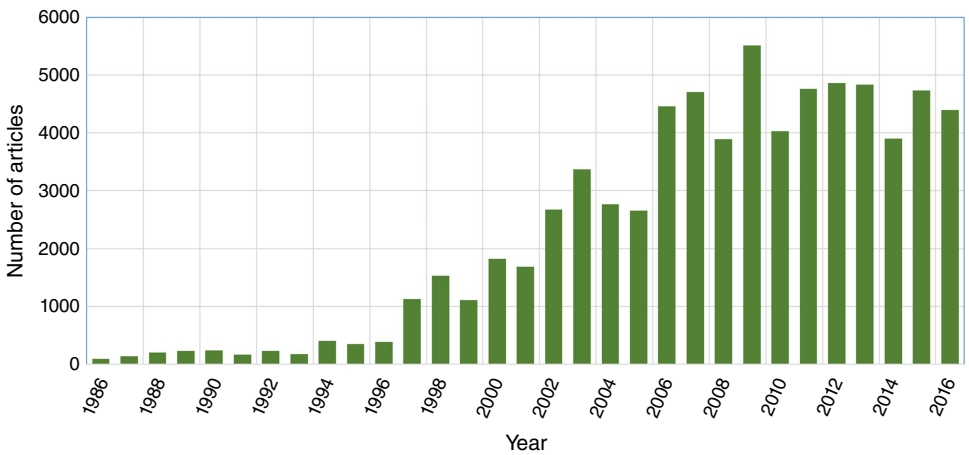

Fig. 1. Number of wildfire-related newspaper articles per year.

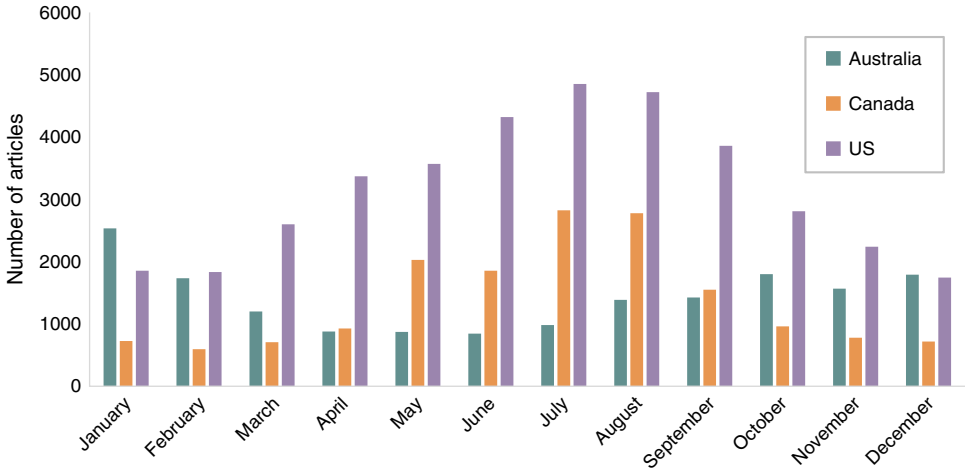

Fig. 2. Seasonality by month of wildfire-related articles per country.

search within the New York Times' historical archives showed similar results – the period between 1981 and 1985 showed an average of 25 wildfire-related articles per year, whereas in 2015 there were about three times as many articles, suggesting that much of this increase is likely due to increased news coverage. Over 1600 publications (the majority being local papers) from each country were represented, with a median of five articles per publication. Several outlets contributed over a thousand articles to our database, including the *Denver Post*, the *New York Times*, the *Vancouver Sun*, the *Washington Post*, *Edmonton Journal*, *Globe and Mail*, *St Petersburg Times*, *Prince George Citizen*, and *Canberra Times*. A full list of publication outlets can be found in the Supplementary Materials. Unsurprisingly, a seasonality trend emerged: within the northern hemisphere the number of articles about wildfires peaked in July and August, and in Australia the highest number of wildfire-related articles were published in January (Fig. 2).

Topic modelling

All data cleaning and topic modelling was done within the R Statistical Software (R Core Team 2014) using the Structural Topic Modelling package (Roberts *et al.* 2014). Structural Topic Models (STM) have several distinct advantages over other topic-modelling approaches such as LDA, especially for examining changes or variations in semantic content as a function of metadata such as Country. To prepare the data for topic modelling, we removed most common stop words (i.e. very commonly used words that carry minimal meaningful information), converted all words to lowercase, removed punctuation, and stemmed all words (i.e. fire as a stem for fires, fired, firing) in the corpus.

After these processing and cleaning steps, a topic model was fit to the entire set of 71 404 articles across the three countries covered in our corpus. The optimal number of topics to be modelled was selected using optimisation algorithms within the STM library, which calculate various metrics such as model residuals, semantic coherence, exclusivity, number of iterations to convergence, and held-out likelihood over any range of user-specified number of topics (Ks) (Roberts *et al.* 2014). We calculated these metrics for topic models ranging from 20 to 200 topics, with the analyses suggesting that 60 topics could provide an acceptable level of model error (i.e. lowering the residuals) without losing the semantic coherence of the topics themselves. After a thorough review of the initial 60 topics, we removed 35 topics from further analysis:

- Nine topics, approximately 17% of the corpus, were removed because they appeared to mainly comprise words irrelevant to the analysis, like 'copyright' or 'all rights reserved' – text that would most likely occur in the header or footer of digital newspaper articles.
- Twenty topics, ~23% of the corpus, were removed due to content focusing on a single fire or a high level of geographic specificity (e.g. a topic about Alberta might contain words such as 'Alberta', 'canwest', 'Canadian', 'Edmonton', etc.). Although these might be interesting aspects to explore in future work, they were too narrow in scope for the current objective.
- Six topics, ~7.4% of the corpus, were removed because wildfire or fire, in general, appeared to be tangential to the topics themselves. For instance, topics emerged about wildfires in popular culture such as best-selling books about fire on the New York Times Bestseller list, or announcements about local events where someone was giving a talk about fires.

The entire list of 60 topics, and further information about each of these omission decisions, can be found in the tables located in the Supplementary Materials. The remainder of the analysis focuses on the remaining 25 'core' topics.

Topic cluster detection and network analysis

To further assess co-occurrence and interrelationships, we conducted analyses to identify communities of topics within the core set of 25 topics. We first created a correlation

network, a graphical depiction of a correlation matrix between pairs of topics, using the R package *qgraph* (Epskamp *et al*. 2012). We used the spin-glass community detection method within the *Igraph* package in R (Csardi and Nepusz 2006). As with other community detection algorithms, the spin-glass method designates communities within the network such that the links within a cluster (i.e. number and weight of edges between nodes) are stronger within a cluster than between clusters (Reichardt and Bornholdt 2006). Because the spin-glass algorithm is probabilistic in nature, we repeated it 100 times to understand the optimal number of communities or clusters to model. Taking the median over 100 repetitions revealed a set of four clusters of topics within the set of 25 topics. The layout of the network structure is organised using the Fruchterman–Reingold algorithm (Fruchterman and Reingold 1991), a force-directed layout (Fig. 3). In this layout, nodes (or topics, in the present case) that are more interrelated are placed closer together. Topics that have weaker connections, and are less central to the semantic content of the articles, are located on the periphery of the graph. How often topics co-occur in an article is indicated by the thickness of the edges (links between nodes), and the positive or negative direction of relationship is depicted in blue for positive relationships and orange for negative relationships. The thickness and colour of the edges are based on partial correlations. So, topics that are most likely to co-occur in the same article will be joined with a thick, blue edge, and topics that are not likely to occur together will be joined with an orange link. Finally, we scaled the size of the nodes to reflect topic proportions within the model (multiplied by a constant factor for readability).

Results

This section first describes the results of the overall topic model, examining cross-country trends of particular topics, and then discusses the relationships between the topics themselves and how these inter-topic correlation networks differ by country. The overall proportion of each of the remaining 25 core topics, comprising over 50% of the corpus, is shown in Table 1. Based on the descriptive words, we assigned a label to each topic: although only the seven most highly related words are shown in Table 1, the label was assigned after a more thorough review of the 15–30 most highly rated words.

Two items are important to note. First, a given article is composed of all 60 topics to varying degrees. For instance, it may comprise 30% of Topic 1, 20% of Topic 2, etc. summing to 100%. When we say an article is primarily composed of Topic *X*, we mean that Topic *X* was the most dominant topic in that particular article. Second, topic labels were chosen by the researchers as a way of summarising across the vector of words that each topic describes. Because people can have different interpretations of groups of semantically coherent words, we also provide the most characteristic words for each topic in Table 1. Finally, we provide some excerpts from news articles to give readers a deeper understanding of the topics in question. These articles are selected on the basis of topic proportion; articles that contain the highest proportion of a given topic are considered to be exemplars of that topic (Roberts *et al.* 2014).

Overall topic description and prevalence

The most prevalent topics in the entire dataset were: Firefighting efforts (approximately 4.3% of the corpus;, the Fire Season (4.2% of the corpus); the Local Fire Response (3.7%); and Fire Survival Stories (3.6%). The prominence of the first three topics was unsurprising because they provide necessary information about the spread of a wildfire and the firefighting response. The fourth topic, Fire Survival Stories, appeared to have a more emotional valence: articles primarily composed of this topic tended to depict highly personal, individual or family-level tales of close calls, survival despite the odds, and the loss of homes, family members, pets, etc. A sense of the emotional content of these articles can be seen in a short excerpt from an article in *The Globe and Mail* (Toronto) on 7 May 2016:

> …two weeks later, the roads were opened and Ms. Carifelle and her children were allowed to come home. Miraculously, their house was still standing. …'Finding her home still standing made Ms. Carifelle feel blessed, but that blessedness was not without complication. 'You have guilt,' she says. 'But you end up being humble. I don't think I was very humble before, but it teaches you to be very grateful and humble for what you have.' ('Slave Lake's Wildfire Experience May Aid Fort McMurray Residents')

Of the remaining 21 topics, one set of topics was based on environmental factors that can influence wildfires such as Drought (2.2%), Weather (2.2%), Climate Change (1.8%), and Water (1.0%). Another set of topics was related to management issues such as Forest Management (2.1%), Prescribed Fire (1.8%), and Legislation (1.3%).

A topic labelled Ecology (1.9%) was characterised by words such as tree, pine, plant species, beetle, and wildlife. Articles that contained higher proportions of this topic were more likely to discuss a wide range of considerations around fire and ecological systems and processes. For example, an article that was predominantly composed of the Ecology topic discussed the historical co-evolution of oak trees with fire:

> Oaks evolved with periodic burning over thousands of years. Woodland fires, less volatile than prairie fires, crept slowly across the forest floor. The flames were low – not at all like the dramatic crown fires that consume the western forests. Oaks with thick bark and deep

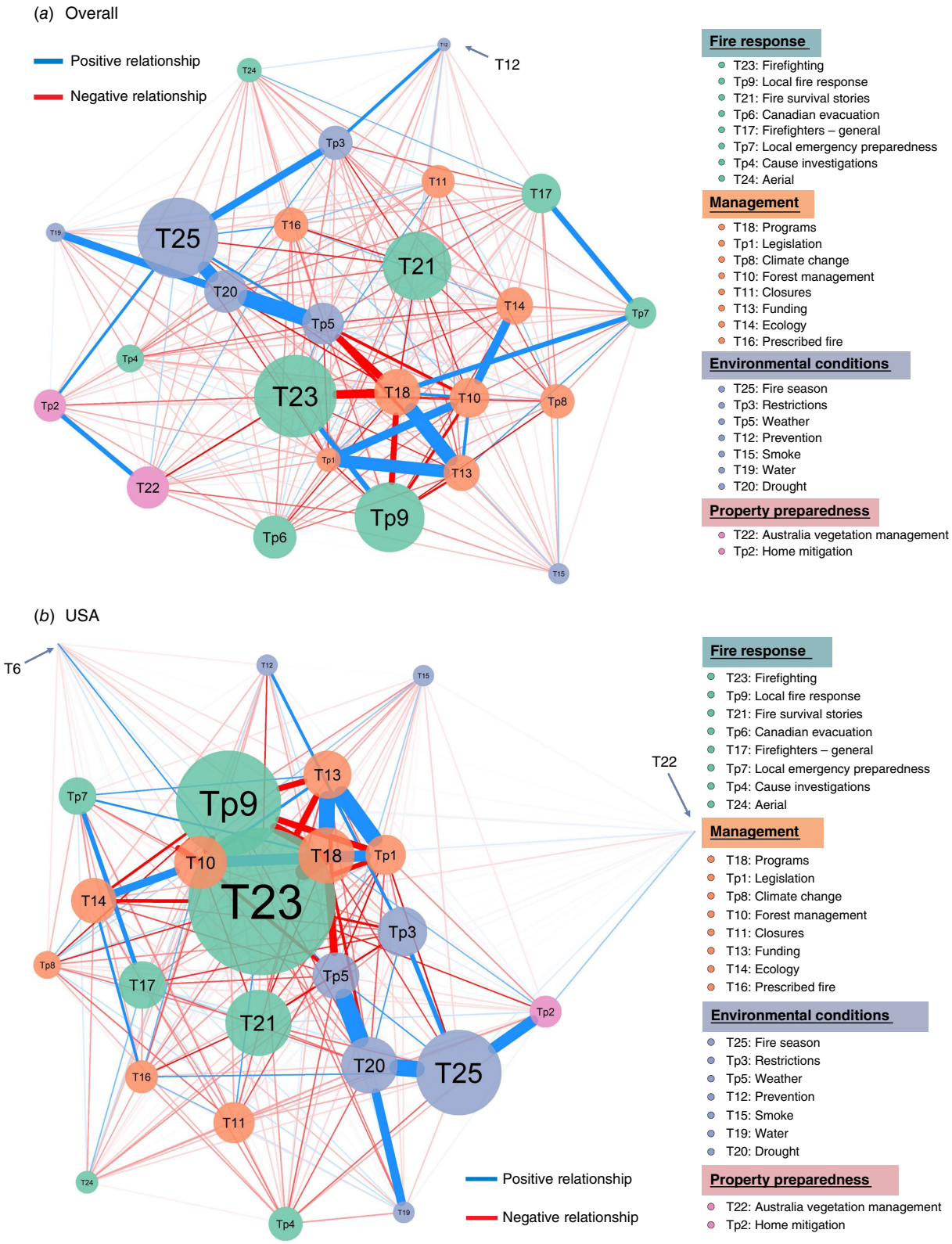

Fig. 3. Correlation network graphs of topic communities – (*a*) overall, (*b*) USA, (*c*) Canada and (*d*) Australia corpora. Topics in each grouping are listed in order of prevalence. Topics listed with a prefix 'T' vs 'Tp' are an artifact of the *qgraph* package used to create these network graphs, e.g. Topic 5 defaults to Tp 5 and Topic 15 defaults to T15.

(*Continued on next page*)

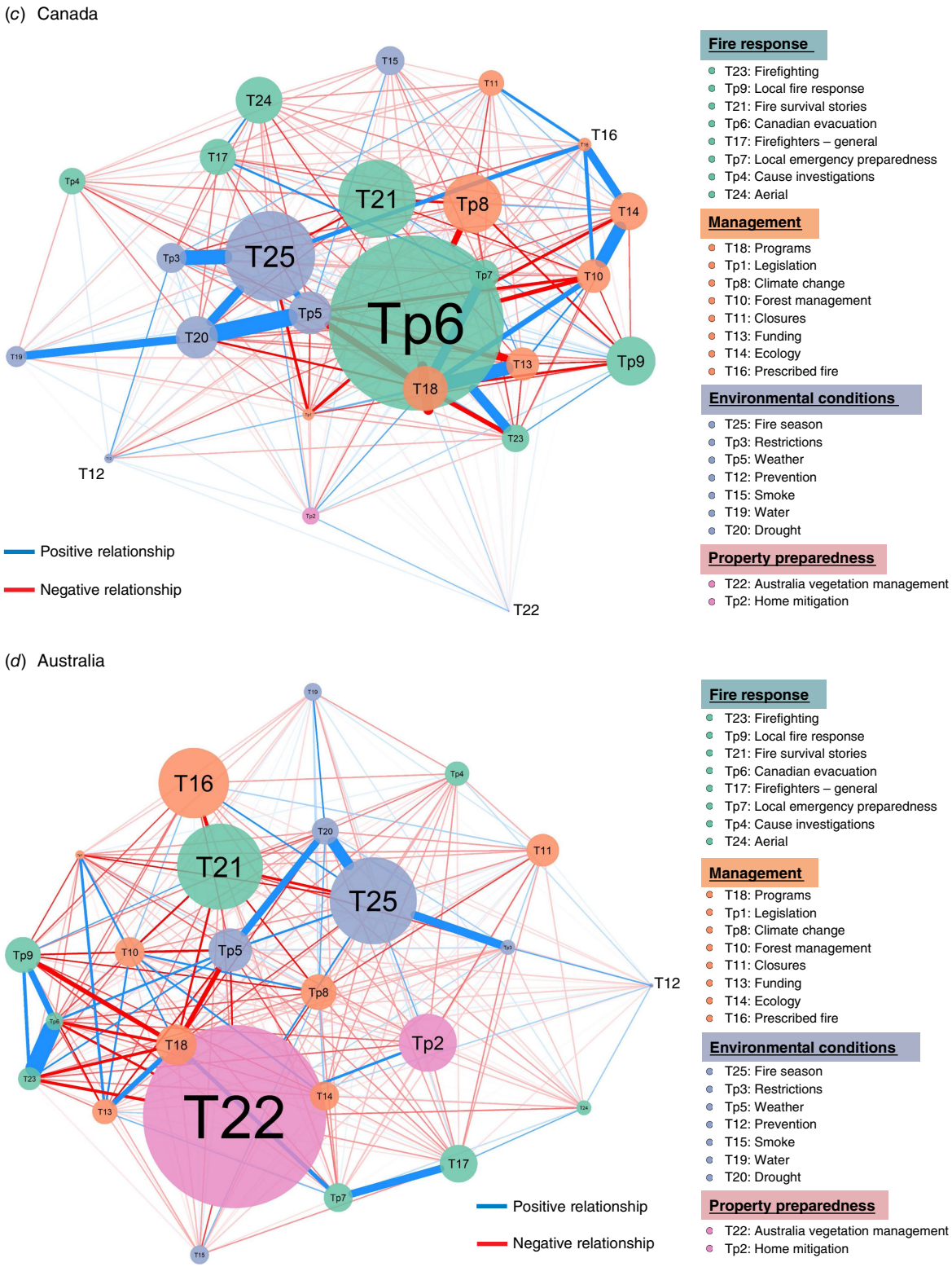

Fig. 3. (*continued*)

root systems adapted over thousands of years to survive this type of fire. Oak trees are not only resistant to fire, they are dependent on it. …. It's taken a century of fire suppression for newcomers to realize what indigenous people knew long ago: oak woodlands must be burned to remain healthy. Without fire, they rapidly decline.

Table 1. Topic proportions, overall and by country, and descriptions.

Topic labels	Overall topic proportion (%)	Australia (%)	Canada (%)	USA (%)	Top (stemmed) words describing topical content
Firefighting	4.3	1.1	1.4	7.0	fire, firefight, burn, blaze, contain, acr, said
Fire season	4.2	4.3	4.5	4.1	fire, said, wildfir*, season, year, can, forest
Local fire response	3.7	1.8	2.5	5.0	fire, said, firefight, brush, depart, blaze, road
Fire survival stories	3.6	4.2	3.9	3.2	said, home, hous*, peopl*, just, back, one
Programs	2.4	2.0	2.3	2.7	will, communiti*, plan, citi*, meet, project, program
Canadian evacuation	2.3	0.9	8.8	0.0	fire, said, evacu*, kilometr*, home, blaze, resid*
Drought	2.2	1.3	2.1	2.7	rain, said, year, drought, dri, normal, weather
Australia vegetation management	2.2	9.0	0.1	0.1	said, bushfir*, tree, council, news, reserv, area
Weather	2.2	2.1	2.2	2.2	wind, weather, temperatur*, high, storm, day, heat
Forest management	2.1	1.5	1.7	2.5	forest, log, land, said, manag*, timber, tree
Firefighters – general	2.1	1.9	1.8	2.3	firefight, said, work, fire, crew, train, fight
Ecology	1.9	1.4	1.9	2.2	tree, pine, plant, speci*, beetl*, year, wildlif*
Funding	1.9	1.2	1.7	2.3	million, cost, fund, state, year, said, money
Prescribed fire	1.8	3.5	0.7	1.6	burn, fuel, control, will, prescrib*, manag*, area
Climate change	1.8	1.8	3.0	1.3	climat*, chang*, research, carbon, global, warm, scientist
Restrictions	1.8	0.7	1.5	2.4	burn, ban, fire, restrict, campfir*, permit, condit*
Closures	1.7	1.6	1.3	2.0	park, road, area, trail, close, nation, creek
Home mitigation	1.7	2.9	0.9	1.5	home, hous*, properti*, can, tree, build, area
Local emergency preparedness	1.6	1.4	1.5	1.8	emerg*, said, help, depart, volunt*, assist, disast*
Cause investigations	1.5	1.2	1.3	1.6	charg*, court, investig*, fire, said, arson, set
Aerial	1.3	0.7	2.3	1.1	plane, air, aircraft, pilot, helicopt*, fli*, said
Legislation	1.3	0.5	0.6	1.9	state, bill, presid*, vote, hous*, senat*, bush
Smoke	1.1	0.9	1.5	1.0	smoke, air, health, qualiti*, said, pollut*, peopl*
Water	1.0	0.9	1.1	1.0	water, river, flood, fish, suppli*, flow, use
Prevention	0.7	0.2	0.5	1.0	firework, said, use, law, enforc, drone, juli

(Chicago Herald. 29 July 2013. 'How The Mighty Are Falling. The Oak Tree, Once Abundant In Our Woodlands, Is Now In Serious Decline')

Forest health was an overarching concern in an article that discussed the impact of fire suppression policy on the prevalence of forest pests like the mountain pine beetle (*Edmonton Journal*, 19 March 2012; 'U Of A Research Finds Beetles, Fungus Endanger Iconic Pines'). Another article noted the importance of fire for creating a habitat for an Upper Michigan peninsula population of Kirtland's warbler (*New York Times*, 13 August 1996; 'Kirtland's Warbler Finally Finds Lots Of Burned Forest To Call Home').

These types of articles convey many of the ideas that fire ecologists are concerned with: the impact of fire suppression policy, the critical ecological role of fire in many ecosystems, and the role of invasive species. Unsurprisingly, the Ecology topic was correlated with the Forest Management topic, which consisted of words such as forest, log, land, manag-, timber, and tree. Articles within this latter topic were usually broader in scope than those that just covered the impacts or causes of wildfire. For instance, an article about a US Forest Service proposal to increase logging in the Sierra Nevada, and its impact on wildfires, discusses the reason for the proposed changes and reactions to the proposal from forest managers:

> The recommendations come in response to a request from the Bush administration for a comprehensive review of the Sierra Nevada Framework, the sweeping management plan adopted at the end of the Clinton administration that nearly ended commercial timber production in the Sierra. Regional forester Jack Blackwell said the proposed changes appeared to be a solid, common-sense approach to address the growing threat of catastrophic fires. … 'It's ecologically balanced, it leaves the largest trees on the landscape, and it's economically balanced,' Blackwell said. (Contra Costa Times, 7 March 2003; 'Sierra Plan Revisions Fell Tree Defenses')

Many of the Ecology articles also noted the complicating factor of climate change. This latter topic comprised words like climate, change, research, carbon, global, warm, and scientist. The role of wildfires was discussed as both an impact and cause of climate change. One article discussed climate change in this way:

> The researchers have measured, in the first comprehensive study of its kind, how snowy landscapes tainted by carbon particles from inefficiently burned fuels and forest fires are absorbing more of the sun's heat than the less sooty snow cover of centuries past. About 80 per cent of 'black carbon' pollutants are man-made, the researchers estimate, with forest fires accounting for the rest.. (The Calgary Herald, 11 June 2007; 'Dirty Snow Adds to Global Warming')

Finally, two topics that emerged were specific to Canadian and Australian fire management issues. Canadian Evacuation (2.3%) was found overwhelmingly in articles from regional Canadian publications and consisted of words such as fire, evacuation, kilometre, home, and blaze. Articles that were composed mostly of this topic tended to communicate locally relevant information about the threats of fires to residences, evacuation routes, and firefighting updates. Similarly, the Australian Vegetation Management topic (2.2%) was found primarily in regional Australian newspapers. Articles that contained high proportions of this topic were usually focused on discussions around vegetation clearance regulations for individual properties, particularly the tradeoffs between bushfire risk reduction and adverse environmental impacts, as can be seen in the following excerpt:

> The laws were introduced after the devastating 2013 Blue Mountains bushfires in which more than 200 homes were destroyed. Residents in designated areas were permitted to remove trees within 10 metres of their homes, and other vegetation within 50 metres. …However, Minister for Emergency Services David Elliott said last Wednesday that 'it was clear some people were clearing trees for reasons which had nothing to do with bushfire protection'. …. [therefore] the scheme would be 'strengthened' with various exclusions including koala habitats, littoral rainforests, Aboriginal places and trees within 100 metres of the coastline. 'The scheme will exclude critically endangered plants, critical habitats, all mangroves and saltmarshes and a range of critically endangered ecological communities', he said. (St. George & Sutherland Shire Leader, 18 August 2015; 'Changes to Be Made To 10/50 Vegetation Clearing Laws')

Topic clusters and network analysis

The clusters detected by applying the community-detection algorithm identified four clusters that we labelled Fire Response, Management, Environmental Conditions, and Property Mitigation. The Fire Response cluster contained the four most prevalent topics noted earlier (Firefighting, Fire Survival Stories, etc.), and other topics such as Local Emergency Preparedness and stories about Firefighters (see Fig. 3, top panel). The largest topics in terms of prevalence in the overall corpus of newspaper articles were found in this cluster, indicating that a large portion (roughly 16%) of articles about wildfires over the past 30 years contained some discussion of Response to wildfires, whether from a firefighting perspective, survival stories, or an update on local conditions. Interestingly, the relationships among the topics within this cluster were not as strong as among topics of the other clusters. However, the topics of Firefighting and Local Fire Response were strongly tied, as were the topics of Firefighters – General and Local Emergency Preparedness.

The Management cluster contained the second more frequently mentioned set of topics (adding up to ~8%), and included the topics Climate Change, Forest Management, Prescribed Fire, and Ecology. The core of this cluster showed interrelationships between topics indicative of the range of considerations and tools many managers must contend with in devising sustainable forest and fire management approaches. The following editorial depicts the confluence of these management-related topics:

> Since 1976, the conservation sales tax has allowed the Department of Conservation to broaden programs. More land has been acquired for public use. New programs have allowed the department to manage a broad array of non-game species…. In some designated areas, nature will be allowed to take its course. In others, tree cutting, controlled burning or other management will be essential to maintain unique features. About 10 percent of each state forest is set aside as old growth stands. …. (St. Louis Post Dispatch, 21 March 1991; 'A Prescription For Healthy Forests Well-Managed Harvesting Of Trees Improves Environment')

The topic of Forest Management was also positively correlated to the topics of Ecology, Legislation, and Funding. In turn, Ecology was positively correlated to Prescribed Fire, which suggests that wildfire-related articles can provide fairly nuanced coverage about the role of prescribed fire in promoting forest health. Similarly, the Funding topic had a strong positive correlation with the topic of Programs; articles with high portions of this latter topic tended to focus on specific programs or group management activities, generally with a focus on fire preparedness, such as the US Firewise or Canadian Fire Smart programs, but also on various landscape management and grant programs. Given this last item, it is not surprising that a strong positive correlation emerged between the Programs and Funding topics.

The topic of Climate Change was part of the Management cluster and was often included with articles that also contained the Ecology and Forest Management topics, but it was also positively correlated to several topics within the third cluster, which we labelled Environmental Conditions. This cluster contained the topics of Drought, Smoke, and Water, which were all positively correlated to Climate Change from the Management cluster. The link between climate change and the Environmental Conditions cluster is illustrated by the following extract:

> Despite its pristine image, the Arctic has a serious smog and soot problem. Scientists from three federal agencies are now engaged in the most ambitious effort yet to measure airborne pollutants in the Arctic and gauge their effect on the region's climate. For three weeks this month, and another three weeks this summer, they are marshaling satellites, instrument-laden aircraft, oceanographic ships, and ground stations to study the gases, aerosols, and black-carbon soot that accumulate in the region from human activities and wildfires. (Christian Science Monitor, 16 April 2008; 'U.S. scientists to study Arctic smog')

The strongest subgroup of topics within the Environmental Conditions cluster was dominated by the Fire Season topic, which showed positive ties between the topics of Drought, Weather, Restrictions, such as burn bans put in place when fire risk is elevated, and Prevention. This suggests that articles containing topics about Environmental Conditions are focused on alerting the public to likely conditions for the coming fire season, what factors are influencing the potential fire risk, and actions to limit potential fires.

Finally, the last cluster, labelled Property Preparedness, was made up of two topics focused on actions community members could take to mitigate fire risk on their property: Home Mitigation, about actions that home or landowners take to protect their homes from wildfire (making homes ignition resistant or managing vegetation around structures); and Australia Vegetation Management, which focused on vegetation management considerations and bushfire risk reduction within Australia. As might be expected, this cluster most frequently arose in conjunction with the Fire Season topic, suggesting that an article discussing the upcoming wildfire season likely also informed property owners about mitigation activities they could undertake.

Country-based variability in topic clusters

To examine differences in topical coverage by country, we filtered the overall model of topical prevalence (discussed above) by country, so that we had three datasets, each showing topical prevalence for each newspaper article from the USA, Canada, and Australia. Then for each country-specific set, we once again computed correlation networks. To maintain some consistency and increase ease of interpretability, we retained the topic clusters from the Overall network, assuming that they can conceptually be grouped within the same cluster of topics.[1]

Across countries, the two topics that remain relatively consistent in terms of high prevalence are Fire Survival Stories and Fire Season. Beyond this, each of the countries show notably different patterns, both in terms of the dominance of topics and in the strength and pattern of relationships among topics (Fig. 3, panels 2–4). In the USA, stories

[1]Note that we graphed it both ways – i.e. maintaining topic clusters or devising new clusters for each country specific graph. There was not much movement either way, so we remain confident in our interpretation. Country-specific clusters are available in case readers or reviewers would like to see them (supplementary materials e.g. correlation matrices by each country).

about firefighting efforts clearly dominated the conversation, with the topics about Firefighting (7%) and Local Fire Response (5%) notably dominant, followed by Fire Season (4.1%), Fire Survival Stories (3.2%), and interestingly, Drought (2.7%). In Canada, the Canadian Evacuation topic (8.8%), best described as containing specific updates and advice for residents in Canada about evacuation procedures was most dominant, followed by the topics of Fire Season (4.5%), Fire Survival Stories (3.9%), Climate Change (3%), and Local Fire Response (2.5%). The most common topics in Australia take a slightly different turn, with less focus on firefighting and more emphasis on preparedness activities: the Australia Vegetation Management (9%) topic dominates, followed by the topics of Fire Season (4.3%), Fire Survival Stories (4.2%), Prescribed Fire (3.5%), and Home Mitigation (2.9%).

Compared with the overall network, the focus of the American corpus on firefighting and local fire response distinctly outweighs discussion of other topics. However, there is also clear evidence that the wildfire discussion in the American news media goes beyond firefighting, with some interesting connections between topics apparent in Fig. 3, particularly in the Management cluster where very strong links between the Legislation, Funding, Programs, and Forest Management topics can be seen. Ecology is a more peripheral topic but with strong links to Forest Management and, to a lesser degree, Prescribed Fire. Also notable is the relatively small size and peripheral nature of both the Home Mitigation and Climate Change topics.

Fire Response topics also were prevalent in the Canadian corpus, but the most dominant topic was Canadian Evacuation, which was closely related to specific topics from within the Management and Environmental Conditions clusters. Notably, and in distinct contrast with the American network, the topic of Climate Change from the Management cluster was closely related to discussion of Canadian Evacuation, as were topics of Forest Management and Ecology. From the Environmental Conditions cluster, the topics of Weather and Drought also were most closely correlated with the central topic of Evacuation. In Canada, Prescribed Fire was a fairly peripheral topic in the discussion, but had strong connections with Ecology, Forest Management, and Closures.

From a conceptual (and visual) standpoint, the correlation network from the Australian set of articles is most dissimilar to the other two. Part of the explanation may be that Australian articles were the least numerous in our overall corpus, so they are least represented in the overall network. This translates into a network graph with the noisiest mapping between the cluster labels from the Overall network to the topic communities in the Australia network. But, part of the difference may also reflect that the Australian fire conversation, and therefore the media, may focus less on firefighting and more on preparedness and mitigation. The prominence of the Australian Vegetation Management topic appears to reflect a significant tension in the Australian conversation around balancing adverse impacts to native environmental amenities (e.g. native plants, koala habitat) with reducing bushfire risk. Interestingly, Prescribed Fire is much more dominant in the Australian articles but seemingly as more of a standalone topic, co-occurring with few other topics in the Management cluster.

Discussion

Our analysis of newspaper articles over 30 years and three countries finds a body of text covering a wide range of topics relevant to understanding wildfire causes, impacts, and management considerations. The media's role as gatekeepers, agenda-setters, and framers of information means that news reports not only reflect societal beliefs but also help to form, change, and update them. Therefore, the topics and topic networks presented in the current work are, in part, a reflection of public epistemologies surrounding forestry and wildfires. By this metric, our analyses reveal that: (1) media attention to wildfire-related issues has increased over the past 30-year timespan; (2) the coverage is more varied and complex than the common belief that the media tends to focus only on negative aspects of fire; and (3) relative topic coverage varies significantly between countries.

Although we did find that a dominant topic across all three countries' coverage, Fire Survival Stories, contained quite a lot of emotional content, this topic rarely appeared to contain what has been termed inflammatory content (Anderson *et al.* 2018), designed to spark outrage or strife. Rather, these articles appeared to be used as an effective (and possibly, affective) means of conveying the human toll of wildfires by using stories that would appeal to readers. A useful next step may be to conduct a thorough sentiment analysis of these articles to assess whether the content is written in a way that is mostly uplifting, or somehow exaggerating the tragedy.

Further, although topics associated with firefighting were common across countries, our analysis suggests the belief that media coverage of wildfires emphasises fire suppression efforts appears to mainly reflect coverage in the USA. These findings also raise questions about Cordner and Schwartz's (2019) conclusion that media coverage during the 2016 Carlton and Okanagon Complex fires was largely silent on the impact of fires on firefighter safety. Given the large amount of US media attention on firefighters and firefighting efforts, this apparent silence is unlikely due to a lack of attention on firefighters, but may simply indicate that safety is not the primary frame by which the media discusses firefighting. Similarly, looking across countries suggests the finding that media coverage often ignores the role of climate change in exacerbating the impacts of wildfires (Anderson *et al.* 2018; Cordner and Schwartz 2019) likely reflects the US focus of the studies rather than an automatic media lack of interest. Indeed, it is likely that a similar content analysis

for a Canadian fire would reach a different conclusion given that Climate Change was one of the most prevalent topics in Canada. It is also worth noting that, even with the country-based variation in the prevalence of climate change, the topic is present in every country-specific corpus we analysed, and is strongly tied to topics such as forest management, ecology, and smoke.

Ultimately our analysis indicates that the media discussion around wildfire is much more complex than merely firefighting and suppression; we also observe frequent discussion around complex topics of management, fire ecology, and prescribed fire. Perhaps, though, what is most striking is how fire appears to be discussed differently in the media in each of the three countries. The US media coverage appears fixated on firefighting as the dominant feature of wildfires, whereas Canadian coverage attends more to issues of climate change and Australian coverage focuses more on preparedness. Notable also are the links between topics that exist in one country but not in another. In both the USA and Canada, there were strong links between Ecology and Forest Management, as well as between Ecology and Prescribed Fire, although the latter emerged as a fairly small and peripheral topic in Canada. Conversely, in Australia, the topic of Ecology was less common and more peripheral, with no strong links to other topics. Another striking difference is that although Forest Management was a less dominant topic in Australia compared with the USA, Prescribed Fire was a much more dominant topic there compared with both the USA and Canada, but with few strong links to other topics. These findings raise intriguing questions about what the differences in coverage of wildfires across countries may reflect. Although they may in part be due to differences in environmental contexts, they also likely reflect different policies or legal and institutional structures. In a review of fire social science research, McCaffrey (2015) found that findings across countries were generally similar, and that when differences were found they appeared to reflect different policies, such as how evacuations are handled, or institutional structures. The differences may also reflect larger societal or political narratives, such as those related to climate change.

Though this work makes strides in describing the breadth and variation in wildfire-related topics covered by newspapers across three countries, further work needs to be done. Notably, the current analysis reflects the entirety of the 30-year period for which we gathered articles; it is likely that the prevalence of some topics has changed over time. We plan to examine longitudinal trends in topic prevalence, as well as whether and how relationships among topics may change over time. For instance, how has the relative emphasis on the topics of Ecology or Climate Change varied over time? Related to the temporal analysis, we also hope to assess seasonal trends in our future work. Examining the prevalence of different topics during peak versus off-season periods could provide insight into how the fire conversation varies over the course of the year.

Finally, future work may also explore variations in the discussion of wildfires by the scale of the news outlet. Local newspapers may more commonly report on issues of local significance, focusing perhaps on alerts or specific fuels management interventions – they may be better placed to integrate local contextual considerations into the discussion. However, international, national or regional newspapers may present a wholly different context, focusing, for instance, on fires that occur in touristic sites or more controversial regional or national policy elements. A key question with this type of analysis, however, will be the degree to which the rapidly changing media environment can be accounted for. Many local newspapers have folded during the course of our analysis and others have been bought by large conglomerates, making it unclear how much unique local coverage actually exists. Article types may be another avenue for researchers to explore. How might opinion pieces vary from more standard articles reporting 'objective' news? Other, more contemporary sources of information, such as social media, may be yet another place for researchers to understand wildfire-related information (Sachdeva *et al.* 2016; Boulianne *et al.* 2018; Sachdeva and McCaffrey 2018).

Conclusion

This study is distinguished by (1) the extent of articles analysed (over 70 000 articles across three countries and a 30-year span), and (2) the broad and exploratory approach we took to understand and describe the range of topics covered in wildfire media coverage. A key factor that differentiates this work from much of the analyses of wildfire media coverage thus far is that where many researchers approach the topic with hypotheses in mind, the current work is primarily exploratory in nature. Our bottom-up approach aimed to understand and describe the landscape of wildfire media coverage, and helps set the base rate for what topics we might expect the media to cover, against which other hypotheses can then be measured. For instance, climate change may be a topic of interest to many researchers, but without knowing the relative importance or prevalence of this topic compared with others, it is difficult to make claims about whether the media are doing an adequate job of informing readers about the role climate change plays within fire-prone ecosystems. A deeper understanding of the information emphasised by the news media in its wildfire-related coverage, which topics are most prevalent, and common associations between topics can also help ensure that any perceived media influence is based on empirical rather than anecdotal evidence. This information could provide insights into the different types of information individuals have access to, and facilitate identifying the best ways to introduce new information and considerations in the ongoing conversation of how to better learn to live and thrive with fire.

Supplementary material

Supplementary material is available online.

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Data availability. The data that support this study will be shared upon reasonable request to the corresponding author.

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