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Ember Alerts: Assessing Wireless Emergency Alert (WEA) messages in wildfires using the Warning Response Model

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Abstract: When evacuation is necessary in a wildfire event, affected communities must be alerted and warned of the imminent danger and instructed on what to do to protect themselves. One channel available to message providers in the United States is Wireless Emergency Alerts (WEAs) disseminated via IPAWS. Recent wildfire events have shed light on the need to improve WEA strategies and messages when alerting exposed populations of imminent fire threat. The purpose of this article is to assess how, when and where WEAs have been used in US wildfires; whether they comply with guidance set out by Mileti and Sorensen's Warning Response Model (WRM); and whether the expansion in characters (from 90 to 360) of WEA messages has influenced compliance with the WRM. A quantitative content analysis was conducted of WEA messages sent during US wildfires from January 2020-April 2022. A total of 1,284 messages were manually coded based upon the content and style categories identified in the WRM. Descriptive analyses (and Chi-square tests) were performed to illustrate how 90-character and 360-character WEA messages differ by key content and style features. Results showed that certain content features (i.e., location, guidance, and the name of the hazard) were included more often than others (i.e., source, hazard description, hazard consequences, and timing information) and that the inclusion of most content features increased with increasing message character length. Additionally, when assessing message 'completeness', the use of acronyms was prevalent in both 90- and 360-character wildfire WEAs; whereas the inclusion of URLs was linked to increased message length. Wildfire WEAs also displayed inconsistency both within and across states in their use of terminology to trigger evacuation. These findings, among others, have implications for theory highlighting a growing need to confirm that message receivers understand and can act on the messages sent, regardless of the language used. In addition, for message creators, recommendations for effective WEA messages for wildfires are provided.

Keywords: wildfire, bushfire, wildland-urban interface fire, alerts, warnings, wireless-emergency alerts, warning response model, evacuation, emergency

Introduction

The intensity and size of wildfires is increasing around the world primarily due to climate change and population growth in wildland-urban interface (WUI) areas (Bowman et al. 2020). This is particularly relevant to the United States, which has experienced an average of 70,072 wildfires per year since 2000 (Hoover and Hanson 2021). However, while the number of wildfires per year has steadily declined since 1992, the number of acres burned has increased substantially. Most of these fires are contained to the wildlands; however, an increasing number have spread to nearby communities and caused large-scale evacuations (County of Sonoma 2020), deaths and injuries (Comfort et al. 2019), and significant destruction to property (Barrett 2020).

In these instances, a common policy in the US and other countries is to evacuate people from exposed areas before fire conditions become life-threatening. To do this successfully, affected communities must be alerted and warned of the imminent danger and instructed on what they need to do to protect themselves. Professor Emeritus Dennis Mileti devoted his research career to this vital step in emergency response: providing alerting authorities and other decision-makers with the tools to communicate hazards and disaster information effectively in order to prompt safe response of those most at risk; e.g., (Mileti and Beck 1975; Mileti and Sorensen 1990). His research has spanned various types of hazards including earthquakes (Mileti and Fitzpatrick 1992), terrorism (Averill et al. 2005; Wood et al. 2012), and dam and levee failures (Mileti and Sorensen 2019; Sorensen and Mileti 2018).

John H. Sorensen of Oak Ridge National Laboratory (ORNL), a longtime colleague and friend of Mileti, importantly noted that with all of the factors that affect message response, there are few that an emergency manager (or message provider) can actually affect. These include the delivery channel and timing of message dissemination, the geographical location targeted, public education and training, and the contents and design of the emergency message (Sorensen 2000 p. 123). Among the various delivery channels, Mileti and colleagues focused most recently on the communication of alerts and warnings via short message alerting systems, including Wireless Emergency Alerts (WEAs) disseminated in the US via the Integrated Public Alert and Warning System (IPAWS) (Bean et al. 2015, 2016).

The WEA program began in the US as a nation-wide system in 2012 (FEMA 2020). The system allows authorized federal, state, and local officials to send geotargeted, text-like messages to public WEA-enabled mobile devices under conditions of imminent threat. The WEA system also delivers AMBER alerts for missing and abducted children, public safety alerts, and 'presidential alerts,' which allow the President of the United States to send a message to the entire nation in a significant disaster or other type of event. Messages are received as text, accompanied by an audio signal and vibration. WEAs are disseminated to individuals based upon their wireless carrier, type of device, and geographical location, in that WEAs are broadcast using radio waves from local cell towers to the devices within a certain area. Individual users can choose to configure their phone for Spanish or English messages; and since WEA is an opt-out system, individuals can choose to opt out of any type of WEA message except for presidential alerts. In 2019, WEA messages were expanded from 90-characters to 360-characters, allowing for four times the amount of content.

Despite expanding the capabilities of the WEA system, the US media have expressed concerns that the system is underutilized, especially for wildfire events. In some cases, alerts have not gone out in time or at all to alert residents of an imminent threat (Marshall Fire Operational After-Action Report (AAR) 2022). In other cases, the messages may have been confusing, incomplete, or inconsistent with other messages, sources or systems (Doermann et al. 2020).

Twenty-two years ago, Sorensen advised that a comprehensive national warning strategy and consistent messaging strategies are vital for efficient and safe responses from those under threat (Sorensen 2000). More recently, the US Department of Homeland Security's Science and Technology Directorate published a report identifying several communication-based needs for wildfire events including standards on a national evacuation doctrine to promote "consistent evacuation terminology, authorities, and thresholds" (Berlin and Hieb 2019). While Mileti and Sorensen (1990) have issued guidance on proper message content, style, and dissemination (via their Warning Response Model, described hereafter as the WRM), and Doermann et al. (2020) has applied these guidelines to wildfires, no US policy on disaster communication exists. In turn, message creators and providers are forced to rely on intuition and hope that the message they pose delivers the right information to prompt quick and effective protective action.

To the authors' knowledge, no formal study has been performed to analyze agencies' usage of WEAs and their adherence to the WRM guidelines in wildfire events. The purpose of this paper is twofold. First, we discuss how, where and when WEAs have been used in wildfires in the US and more specifically whether they follow the guidance set out by Mileti, Sorensen and colleagues. We also explore whether the expansion of WEAs from 90-character to 360-characters in 2019 has influenced compliance with the warning response guidelines. The following section provides an overview of effective warning messages in terms of content, style and completeness.

Literature Review

Effective warning messages, that is, those that have a greater likelihood of prompting protective action response among message receivers, include key contents to inform and instruct the public at risk. In their review of the social science literature, Mileti and Sorensen (1990) documented five key types of content that motivate people to take timely and appropriate protective action in response to a warning message. These include: a description of the threat/event (i.e., hazard) and what is happening; protective action guidance (what to do); the location and population at risk (where it is happening); the time (by which the public should begin taking the protective action and when the protective action should be completed); and the name of the message sender or source (who is sending the message). Mileti (2018) later stated that warning messages should also include content about the time when the message expires and the potential hazard impacts or consequences (e.g., to people, animals and/or property), explaining that this additional content will help message receivers to understand why protective actions have been recommended. Similar suggestions have been made by Kaltenberger et al. (2020), who argue in favor of including tangible and understandable information of an expected damage scenario in warning messages. The WRM has informed research on numerous studies focusing on short messages for imminent threat including, but not limited to, earthquakes (Sutton et al. 2020; Sutton and Wood 2022), tornadoes (Sutton et al. 2021) nearfield tsunamis (Sutton et al. 2018), and radiological and active shooter events (Wood et al. 2015).

In addition to message content, Mileti and Sorensen (1990) identified a set of specific stylistic factors (i.e., the presentation of a message) that affect message outcomes. These factors include the need for messages to use unambiguous language; be specific; relay a sense of certainty; be as complete as possible; and be consistent within the message, through messages over time, and across messages sent by various organizations (Williams and Eosco 2021). The style in which messages are presented will affect message receiver understanding, trust (Burgeno and Joslyn 2020), and ability and willingness to take action (Weyrich et al. 2019). Importantly, researchers have found that the inconsistent use of words, phrases, and even colors used to convey levels of danger within and across hazards may be perceived as ambiguous or result in confusion and misinterpretation (King 2019), which are key factors that affect the likelihood of responding to a warning.

The five message content areas in the WRM served as the foundation for the structure of the nation's Common Alerting Protocol, which informed the design of WEAs distributed through IPAWS (Bean 2019). Researchers have demonstrated that the contents identified in the WRM should be included for all types of hazards and should not vary across messages of differing lengths; see (Sutton and Kuligowski 2019). For example, researchers have conducted public message testing to examine the effects of message length on protective action delay (Wood et al. 2018), and the inclusion of maps on threat personalization (Bean and Madden 2019; Liu et al. 2017).

Scholars have also conducted post-event research on the effect of a false alert following the dissemination of an intercontinental ballistic missile (ICBM) message in 2019 (DeYoung et al. 2019) and conducted lab experiments where recipients received simulated WEA messages about an active shooter (Kim et al. 2019). Limited attention, however, has been dedicated to evaluating the contents and style of WEA messages sent during actual events to persons at risk of imminent threat. Bean et al. (2021) investigated the contents of Covid-19 messages (n = 213) sent via WEA in March and April 2020, at the outset of the Covid-19 pandemic, finding that 5 messages (less than 3%) were complete (i.e., they did not differentiate between 90-character and 360-character messages). However, no work has been found to the authors' knowledge that assesses the contents and style of WEA messages sent during wildfire events. In fact, Doermann et al. (2020) has provided guidance on ways to write an effective WEA message for wildfires and developed a prototype short message creation tool to assist message providers with the creation of 360-character WEA messages. However, assessing the extent to which current wildfire WEAs conform to these strategies and guidance remains a neglected topic.

Longitudinal research investigating the contents and style of imminent threat messages has not been possible until recently. In 2020, FEMA-IPAWS (Federal Emergency Management Agency - Integrated Public Alert & Warning System) created a publicly accessible data repository containing WEA messages dating back to 2012, allowing researchers to study how WEA use, patterns, and strategies have evolved. In particular, as the WEA platform expanded message lengths from 90- to 360-characters in December 2019, this is an ideal time to assess whether the extra characters have been utilized in the most effective way.

As research is needed on how WEAs have been used in wildfires in the US and more specifically whether they conform to the WRM, the following research questions are pursued:

- To what extent are the eight content features (hazard, its description and its consequences, source, guidance, impact time, expiration time, and location) included in wildfire WEA messages, and how does the increased number of characters (from 90 to 360) influence the inclusion of these eight features?
- How complete are wildfire WEA messages in terms of their use of hyperlinks and acronyms, and does the level of completeness differ between 90 and 360-character messages?
- How consistent are wildfire WEA messages regarding the use of terms to trigger household evacuation and how might these terms differ by state/location?

Methods

We conducted a quantitative content analysis of WEA messages sent during wildfires from January 2020-April 2022. We manually coded each WEA message drawing from the content and style categories identified in the WRM. We provide descriptive analyses (and Chi-square tests) to illustrate how 90-character and 360-character WEA messages differ by key content areas.

Sample

We obtained a dataset of WEAs (n = 4,239) representing all historical messages sent by local Alerting Authorities (AA) (i.e., not including AMBER Alerts, which are sent by the National Center for Missing and Exploited Children, or messages sent from the National Weather Service for severe weather-type of events) from June 2012 to April 2022. We filtered the complete dataset by event (wildfire, brushfire or vegetation fire) and timeframe (from January 2020-April 2022), resulting in an initial wildfire dataset consisting of 1,898 WEAs. Of these, 32.35% (n = 614) had identical content in both the 90-character (n =

307) and the 360-character (n = 307) messages. Therefore, we focused our study on the 1,284 unique WEA messages sent for wildfire events between January 2020-April 2022.

Coding scheme

All 1,284 WEAs in our sample were coded for content and style features identified in the WRM described above. We also coded for the use of consistent terms to trigger (or prompt) evacuation across messages (Kim and Wogalter 2015). Table 1 shows and the defines each variable (or feature) coded, the number of WEA messages within the sample that contained that feature, and an example WEA message for each variable. Contents include the name of the hazard type (e.g., wildfire), any description of the hazard or its hazard characteristics, hazard consequences, the source of the message, the guidance provided to message receivers (on what to do in response to the hazard), impact or action timing (specifically including the time to expect impact or the time to take action), expiration time, and the location. In addition to these eight content features, we also identified the presence or absence of two stylistic features that could facilitate message "completeness": the use of abbreviations or acronyms (which could decrease message completeness) and URLs (which could enhance it).

Table 1: Table listing each feature/variable (and its definition), the number of WEA messages within the sample that contained that feature and an example WEA message for each.

Variable		**Definition**	**No. WEA messages (% of total)**	**Intercoder Reliability**		**Example WEAs**
				90 Char.	**360 Char.**	
Warning Response Model – content features	Hazard	The name of the impending hazard type, threat, or event that has precipitated the message	722 (56.2%)	1.0	.82	Dangerous wildfire approaching this area, evacuate Fort Supply to the south. -Woodward EM
	Hazard Description	Information describing the hazard	150 (11.7%)	.78	.92	Fast Moving wild fire in area. Be aware of your location and be prepared to evacuate
	Hazard Consequence	Information about potential consequences from the hazard	54 (4.2%)	1.0	1.0	PGE Alert: Wildfire danger may require temp. power shutoff within 24 hrs bit.ly/3jRQwVA
	Source	Name of organization providing the information in the message	570 (44.4%)	.89	.92	Mendo Sheriff has issued an Evac Order for the Bell Springs Area. Go to MendoReady.org
	Guidance	Information about how people should protect themselves or the actions they should/could perform	840 (65.4%)	.98	.95	Fire Danger. Stay Alert. Leave area if you feel unsafe. Follow 1st Responders direction.
	Impact Time/ Time to Act	When message receivers should expect hazard impact / should take action	467 (36.4%)	.92	.72	Evacuation order now in effect for Silver Reef … OR Level 3 Evac, LEAVE NOW! brush fire…
	Expiration time	When message expires / how long to take action	9 ~1%	1.0	1.0	For safety, SCFD 4 keeping Nelson Creek evac at a Level 2 overnight. We will update in am.
	Location	Landmark; Town/city/county; Road/intersection/ highway; Zone or Zonehaven info	1233 (96.0%)	1.0	1.0	Grizzly Ridge N W side of Lake Davis, including Walker Mine; Evac Cannon at HWY 36W S to Pettyjohn and W of Pettyjohn; Zone 4A1. Leave now

Message style - complete	Abbreviations/ Acronyms	Use of abbreviations or acronyms of organizations or other	437 (34.0%)	.89	.79	NPC Sheriff orders Level 3 Go Evacuation for Lenore area Level 2 SET East of Cooks Grade
	Hyperlink	Presence of hyperlink	285 (22.2%)	.79	1.0	Town of Paradise issued an Evacuation Warning due to Fire. Info at www.TownofParadise.com.

Another message style feature -- the consistency of the language used across messages -- was also of interest, in terms of their reference to evacuation. In the U.S., there are five common approaches used by agencies to alert and warn communities to evacuate in a wildfire. The five approaches vary by the number of notification phases (or levels) enlisted and the terminology used, among other factors. One of the approaches consists of Level 1, Level 2, and Level 3; where the first level instructs the public to be ready and alert, the next to be prepared to leave if needed, and the third to go. Another unique, but similar approach is the Ready, Set, Go stages for evacuation. Both approaches use three notification phases (increasing in intensity). Other approaches consist of two notification phases: Evacuation warning, Evacuation order; Voluntary evacuation, Mandatory evacuation; and Pre-evacuation, Evacuation (where “Pre-evacuation” is the stage prior to “Evacuation”). Because of the variation in expressing very similar concepts, we conducted additional coding to identify terms or words that trigger evacuation (i.e., words that serve as a signal to evacuate), allowing us to identify consistency of language as it varies by states/jurisdictions. Table 2 shows the different terms used to trigger evacuation in WEA messages, their frequency across the 1,284 WEA sample and example WEA messages to show how the terms are used in actual messages.

Table 2: The different terms used to trigger evacuation, their frequency across the WEA sample, and example WEA messages for each term

Variable		No. WEA messages (% of total)	Intercoder Reliability		Example WEAs
			90 Char.	360 Char.	
Consistency – terms to trigger evacuation	Level 1, Level 2, Level 3	248 (19.3%)	1.0	1.0	level 1 evacuation notifications on all of Eagle Creek Road prepare to evacuate
	Ready, Set, Go	165 (12.9%)	1.0	1.0	Level 2 BE SET to evacuate in the South Damascus area map https://bit.ly/3bDabVL [a]
	Evacuation Warning, Evacuation Order	627 (48.8%)	.92	1.0	Evacuation Warning due to Alisal Fire. Be prepared to leave. More info: ReadySBC.org
	Voluntary Evacuation, Mandatory Evacuation	194 (15.1%)	1.0	1.0	MANDATORY EVACUATION for Zone 21 and 33. These are unpopulated areas …
	Pre-evacuation, Evacuation	22 (1.7%)	1.0	.79	Pre-Evacuation order for Ptarmigan neighborhood. Prepare to leave the area.

[a]In cases where WEA messages contained more than one type of term to trigger evacuation (e.g., in this case "Level 2" and "BE SET"), the messages would be categorized under all relevant terms.

Each WEA was manually coded by a single coder and cross checked by another member of the research team to ensure consistency. Each content and style category was coded using a binary presence-absence model where 1 = Present and 0 = Absent. A second researcher was also trained on the coding scheme and a random sample of 60 messages (n = 30, 90-character messages and n = 30, 360-character messages) was selected for secondary coding. Inter-coder reliability was conducted reaching levels ranging from .72 to 1.0, which is deemed to be reliable (Krippendorff 2011).

Data Analysis

Of these 1,284 unique WEAs, descriptive statistics were performed to understand differences in content and style features across all messages as well as between 90-character and 360-character messages, and to understand trends in uses of evacuation terms across U.S. states. We conducted additional Chi-square tests to identify how likely were the observed frequencies for the critical warning contents and style elements appearing in 360-character messages versus 90-character messages sent for the same hazard event, when additional characters were provided.

Results

As shown in Figure 1, 79% of the 1,284 wildfire-based WEAs were sent during the third quarter of each year which equates to the northern hemisphere summer months of July, August and September for both 2020 and 2021 (notably, we accessed data in the second quarter of 2022, therefore the data for the third quarter is not included here). Also important to note, however, that while the WEAs revealed a strong seasonal signal they also show fires can occur year round.

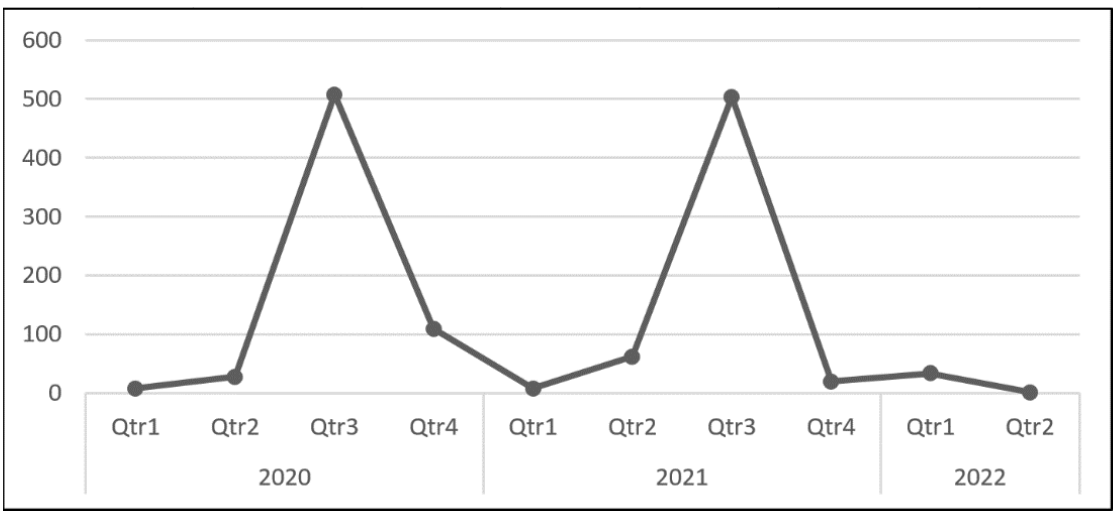

Figure 1. Frequency of wildfire WEAs sent from 2020 to Quarter 2 of 2022

Message Content

We start by describing the content and style features found across the complete dataset and then show how these features differed by message length. Three content features were included in all WEA messages more than 50% of the time. These include location (96%, n = 1233), guidance (65%, n = 840) and the name of the hazard (56%, n = 722). Less frequently, messages included the hazard description (12%, n = 150), hazard consequences (4%, n = 54), and expiration time (1%, n = 9).

Additional coding and analyses were performed to better understand how location of the hazard and/or area affected was described across WEA messages. Four strategies emerged: WEA messages included landmarks (e.g., natural or human-made), jurisdictional boundaries (e.g., names of towns, cities, counties, features), sections of the road network (e.g., road, intersection, highway marker, etc.), and evacuation zone (e.g., locally identified zones or zones via commercial products like Zonehaven™). The majority of WEA messages (69%, n = 888) included jurisdictional names or boundaries; 55% (n = 708) of the messages identified sections of the road network and 45% (n = 579) used landmarks. It is important to note that these percentages add up to more than 100% since one message could include more than one location type. Only 5% (n = 58) referenced evacuation zones.

Looking across the complete dataset, we found that none of the messages contained all eight content features, with the highest percentage (27%, n=341) of the messages containing only three. Forty percent (n = 516) of the messages contained at least four of the content features while less than 1% (n = 8) contained seven. Figure 2 shows the frequency of individual messages containing some or all of the message content features.

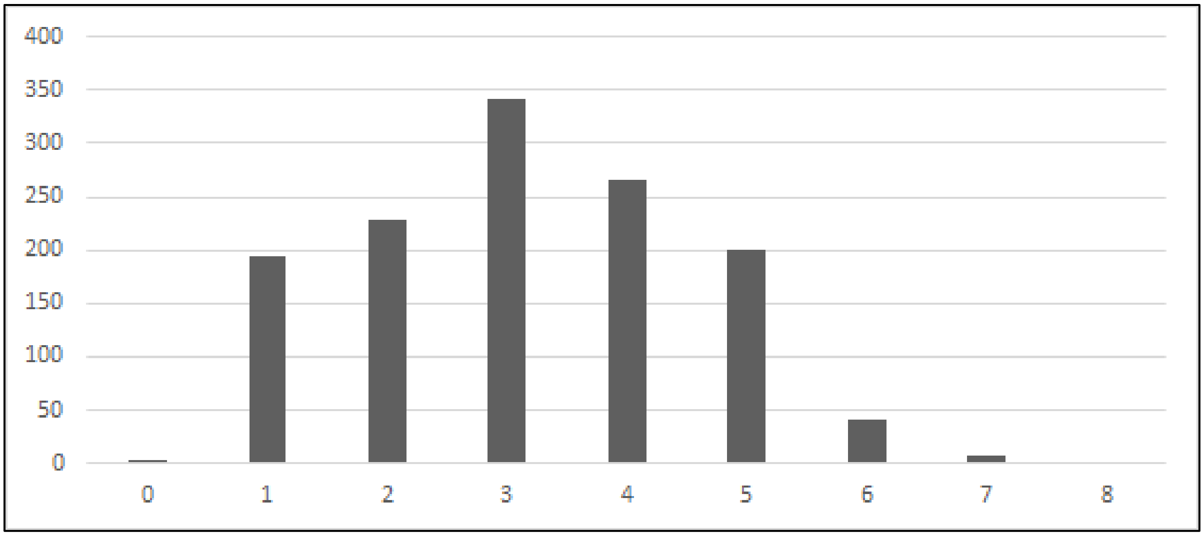

Figure 2: Frequency of individual WEAs containing 0 to 8 content features

When controlling for message length, we found that the 360-character messages consistently included more of the content features than their 90-character counterpart for each hazard event (Table 3). Chi-square results showed significant relationships (*P*< 0.001) between the inclusion of the content feature and increased character length for all features except for expiration time.

Table 3. Chi-square results testing if the increase in characters (from 90 to 360) influenced the inclusion of additional message content features

	χ^2 (df)	*P*	90 c	360 c	Total
Total messages	-		642	642	1284
Hazard	30.39 (1)	0.00	312	410	722
Hazard description	45.93 (1)	0.00	36	114	150
Hazard consequences	40.9 (1)	0.00	4	50	54
Source	42.5 (1)	0.00	227	343	570
Guidance	181.1 (1)	0.00	305	535	840
Time to act/ impact time	89.4 (1)	0.00	152	315	467
Expiration time	5.5 (1)	0.038[a]	1	8	9
Location	25.0 (1)	0.00	599	634	1,233

[a]Fisher's exact test computed since minimum expected count is 4.50

Next, we investigated the frequency of WEA messages with 0 to 8 content features included by message length (Figure 3). We found that more than half of 360-character messages (n = 375, 58%) contained four or more of the content features. By comparison, only 22% (n = 141) of the 90-character messages contained at least four content features. Some 360-character messages (n = 8) included seven content features whereas none of the 90-character messages did so, and in some cases 90-character messages did not include any of the features necessary for a warning message.

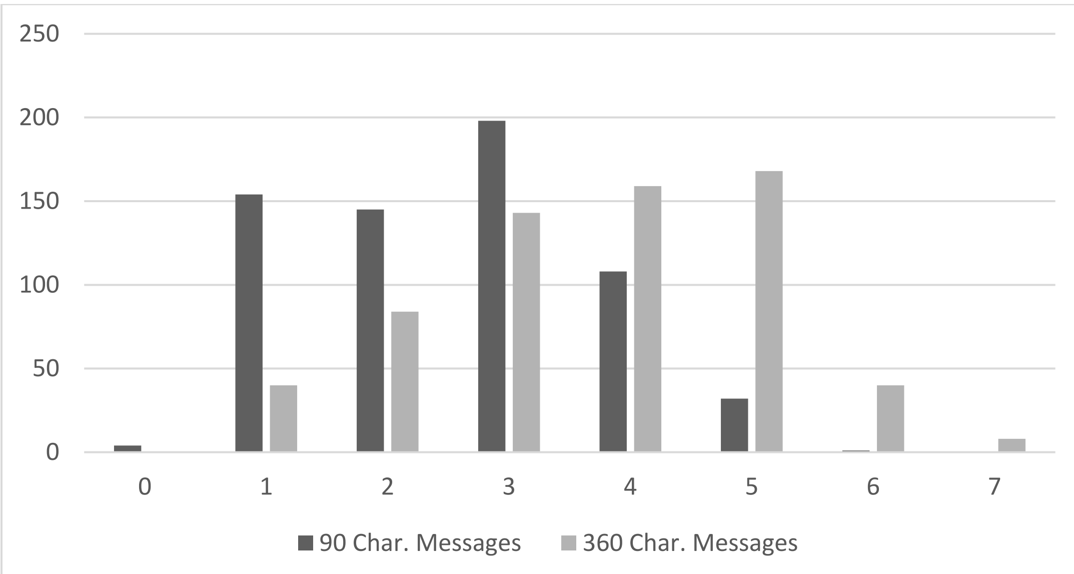

Figure 3: The frequency of WEA messages with 0 to 8 content features by message length

Message Style

Next, we turn to message style features, focusing on completeness and consistency across the entire set of WEA messages and then show how these features differ by message length. To study message completeness, we investigated the use of abbreviations or acronyms (representing an incomplete message) and the inclusion of hyperlinks (representing a strategy to complete the message). Abbreviations or acronyms were used in 34% (n = 437) of the messages and hyperlinks were included in 22% (n = 285).

When considering how these features differ by message length, we found that fewer 360-character messages used abbreviations/acronyms (193) compared with 244 90-character messages. However, there was a greater inclusion of hyperlinks (197 360-character compared with 88 found in the 90-character message set). Only the use of hyperlinks was found to be statistically significant ($P<0.001$), as shown in Table 4.

Table 4. Chi-square results testing if the increase in characters (from 90 to 360) influenced the completeness of the message

	χ^2 (df)	*P*	90 c	360 c	Total
Total messages	-		642	642	1284
Acronyms	9.0 (1)	0.003	244	193	437
Hyperlinks	55.6 (1)	0.00	88	197	285

While nearly 1,000 of the WEA messages in our complete dataset did not include a URL, we were interested in how hyperlinks were represented in text (i.e., as a bit.ly or with a more recognizable root, such as .gov). Therefore, we conducted additional analyses to identify the types of URLs that were included in WEA messages. Table 5 shows that, of the messages that used hyperlinks (n=285), 31% of messages (n=89) directed a message receiver to ".org" web domains; other hyperlinks directed message receivers to ".com" (21%), ".gov" (23%), and ".net" (17%) domain names. In both 90-character and 360-character messages, bit.ly or shortened URLs were infrequently used in WEAs.

Table 5. Frequency of URL type used in WEAs by character limit

Type of URL	90 Char.	360 Char.	All
No URL	554	445	999
.com	12	48	60
.gov	28	38	66
.net	0	48	48
.org	37	52	89
.us	2	2	4
bit.ly	9	9	18
Grand Total	642	642	1284

To investigate message consistency, we turn to the use of terminology to trigger evacuation within and across US state boundaries. Across all states, Evacuation warning, Evacuation order terminology was most widely used (n = 627, 49%); followed by Level 1, Level 2, Level 3 (n = 248, 19%); Voluntary evacuation, Mandatory evacuation (n = 194, 15%); Ready, Set, Go (n = 165, 13%); and Pre-evacuation (n=22, <2%).

Most WEAs in our sample were sent by alerting authorities within California (n=762, 59%), followed by Washington state (n=158, 12%) and Oregon (n=150, 12%). All other states (17 in total) sent fewer than 40 WEAs, and of these states, five are located in the eastern half of the US (e.g., North Carolina, South Carolina, Tennessee, Kentucky, and Oklahoma), an area not as often associated with wildfire events. With that said, Tennessee communities have experienced a number of fires, including the 2016 Chimney Tops 2 fire that killed 14 and injured close to 200 people (Kuligowski et al. 2020).

Within the state of California, 78% (n = 594) of the messages used the “Evacuation Warning, Evacuation Order” terminology to trigger evacuation; while 22% (n = 167) of the messages used “Voluntary Evacuation, Mandatory Evacuation” terminology, and only 5% (n = 35) used “Ready, Set, Go” terminology. While the California-based messages using Ready, Set, Go were all sent in 2020, the use of “Voluntary Evacuation, Mandatory Evacuation” terms were more prevalent in 2021 (60%) than 2020 (40%). WEA messages sent in Oregon and Washington also varied their use of terms to trigger evacuation. Within Oregon, four different sets of terminology to trigger evacuation were used: “Ready, Set, Go” (n = 77, 51%); “Level 1, Level 2, Level 3” (n = 117, 78%); “Evacuation Warning, Evacuation Order” (n = 4, 3%); and “Pre-evacuation, Evacuation” (n = 6, 4%). The percentages add up to more than 100 as some of the messages from Oregon contained more than one terminology type. Within Washington, 80% (n = 127) of the messages included “Level 1, Level 2, Level 3” terms; 15% (n = 23) of the messages included “Ready, Set, Go” and only one message used “Evacuation Order, Evacuation Warning” terms.

Discussion and Conclusion

This study investigates the content and style features and consistency of the 1,284 wildfire WEA messages sent from January 2020 to April 2022. We coded each message for the presence or absence of eight content and two style features identified within the WRM and the terminology used in the messages to trigger evacuation. Furthermore, we investigated how the inclusion of the content and style features varied by message length, in order to concretely identify how alerting authorities were using the 270 additional characters found in longer WEA messages.

Overall, none of the WEA messages (90- or 360-character messages) contained all eight content features. Additionally, a non-trivial number (n=4) of 90-character messages did not include any of the features necessary for a warning message.

While most of the WEA messages included the hazard type, fewer messages contained a description of the hazard, such as its movement, and potential consequences. The additional detail about hazard consequences, described by some researchers as “impact-based warnings” (Potter et al. 2021, 2018), can affect message perceptions, such as understanding the threat, the risk it poses, and how it may affect populations. Importantly, messages that do not include details about the hazard as it evolves over time risk being viewed as incomplete or ambiguous (Weyrich et al. 2018). Notably, a fraction of wildfire WEAs did not include a reference to the hazard type at all; instead, they simply alerted message receivers via content such as: “Level 3 evacuation” or “Evacuate now.” If message receivers are actively monitoring conditions, aware of fire danger, and comprehend the terminology used, such a message may be sufficient. However, a lack of context could result in delayed action as the receiver investigates the veracity of the message.

The source of the message was used in less than half of the wildfire WEAs studied. While source is an essential content feature to include, it is possible that so few messages included source due to inconsistencies in input requirements across communication platforms. During an event, alerting authorities must navigate multiple dissemination platforms, some of which are pre-programmed to include the source (such as opt-in providers) and others, such as social media, that automatically include the source as part of the log-in activity. Additionally, restrictions of only 90 characters may deter message creators from including the source. This is especially the case for some sources since if they follow the guidance from the WRM to reduce the use of abbreviations or acronyms, the full titles for some sources (e.g., Los Angeles County Sheriff's Department) may take up almost half of the message. It is for this reason, among others, that alerting authorities should take full advantage of the added 270 characters provided by the recent system upgrades to include the message source (non-abbreviated) as part of the message content.

Over half (65%) of wildfire WEAs included protective action guidance. Researchers have found that the inclusion of guidance increases perceptions of self-efficacy, which is especially important for those who are unfamiliar with the hazard (Sutton et al. 2021). WEAs that do not offer instructing information rely on the knowledge and understanding of the message receiver to recognize the terminology used to trigger evacuation, and to know what to do under dire conditions. Those who lack knowledge are more likely to delay action as they confirm with others, an activity Mileti characterized as "milling" (Wood et al. 2018).

Guidance was often indicated by the use of terminology to trigger evacuation. However, analysis found that five different types of terms, or jargon (Willoughby et al. 2020), were used to trigger evacuation across the WEA messages and these types can by categorized by one of three different communication approaches. First, the use of the Level 1, Level 2, Level 3 terminology represents technical thresholds that indicate when a warning should be sent and when actions should be taken. The communication of technical information is primarily designed for scientists and technical communicators, not necessarily for the public (Bullock et al. 2019). A second type of communication approach is operationally-focused and encompasses the terms: Pre-evacuation; Voluntary evacuation, Mandatory evacuation; and Evacuation warning, Evacuation order. In this case, the message utilizes language which is meaningful to the organization's operations and response plans, rather than public-focused messaging (Weick and Sutcliffe 2015). The third communication approach is action-oriented and is actualized by the Ready, Set, Go terminology (see, for example, (Wood et al. 2012)). These steps infer to the message receiver that an action needs to occur. While inciting action is a positive thing, the success of this approach relies on the message receiver knowing or understanding all three actions in the process. Without that understanding, a message that instructs receivers to "Get Set" may be difficult to interpret without reference to other actions. In a recent survey conducted with 660 residents of Southern California, Gordon & Chimenti (n.d.) found that of those who had wildfire experience, 41% were familiar with Ready, Set, Go, and 36% were unfamiliar; for those with no wildfire experience, more than 56% were unfamiliar with the terminology.

Additionally important to note is that the evacuation terminology use differed among messages sent even within the same state. California, for example, has provided a list of standard evacuation terminology of which Evacuation warning, Evacuation order is included ("California OES Wireless Emergency Alerts" n.d.). However, the data suggest that even after these statewide guidelines were released in May 2020, jurisdictions within California continued to use other terms. Within and across states within the US, efforts to develop evacuation terminology that both reflects the needs of the users and is standardized across jurisdictions will increase its clarity among message receivers, which in turn will improve public response.

Similar to hazard description and consequences, the inclusion of timing information (and especially expiration time) was lacking among the WEA messages. The original WRM included lead time or the time the disaster will occur, which helps to indicate how much time a person has for taking action (Mileti and Sorensen 1990). Message expiration time was later added (Mileti and Sorensen 2019). While 36% of WEAs included impact time or time to act, less than 1% included expiration time. Under some conditions, such as the early stages of wildfire warning communication, the inclusion of expiration time may remain valid, providing a clue to the message receiver that additional updated information will be forthcoming. However, under conditions of imminent threat, such as an order to evacuate, the use of the word NOW or IMMEDIATELY may suffice to both motivate action as well as clearly indicate when that action should take place. With that said, additional research is warranted on the inclusion of timing information in WEA messages for wildfire events.

Almost all WEAs studied included content about the location of the hazard; however, the way in which location was described varied. For example, only a small number of WEA messages included a reference to evacuation “zones.” Instead, most included jurisdictional names or boundaries, sections of the road network, landmarks, or a combination of these. Research has found that people unfamiliar with an area prefer the use of more well-known location references including city, towns, and popular landmarks to better understand hazard location, whereas county names can be confusing (Sutton and Woods 2016). Additionally, there seems to be a recent push for the identification and use of evacuation zones in wildfire-prone areas, e.g., (Lewis 2022). While the use of zones has a short history, it has been viewed by some as a panacea to several evacuation issues, including over-evacuation, simultaneous evacuation of multiple areas, people unaware of their local geography, and difficulty communicating geography, among others. Potential pitfalls when communicating evacuation zones to the public via WEA messages is when they are referred to only via shorthand (e.g., ZoneEA) and when they are included at the expense of more detailed location information (often difficult to include in 90-character message). The WRM clearly articulates the need for location information to help message receivers understand and personalize the threat; its absence, including the use of shorthand, could lead to delay. This is especially the case for tourists who are likely unfamiliar with evacuation zones within the areas visited. Therefore, it is recommended that if evacuation zones are included in a WEA message that they are also accompanied by further description or identification of the area and increased public education around the use of these zones before a fire occurs.

Finally, as WEAs have increased four-fold in character count, message writers have the opportunity to increase message completeness by offering greater detail about the hazard, impact, consequences, source, time, location, and guidance. Across the board, except with expiration time, our Chi-square results showed a significant relationship between the inclusion of content features and increased character length. Completeness can also include a decrease in the use of abbreviations or acronyms (still prevalent in both 90- and 360-character wildfire WEAs) and an increase the use of hyperlinks to direct message receivers to additional information. Results also showed a significant relationship between the inclusion of appropriate style features (i.e., an increase in hyperlinks) and increased character limit. WEA messages are very short and likely incomplete; therefore, including a trusted and credible link to additional information will help receivers to track the unfolding event and also confirm information. However, additional research is needed to explore whether adding a URL leads to extended delays in taking protective actions and/or overloaded websites (that crash during an event).

Theoretical and Practical Implications

Without a doubt, wildfires will remain a threat to populations at the wildland-urban interface. Recent events have demonstrated that fires are a year-round concern, especially in some locations in the US. As the recent FEMA-USFA report suggests (Karels 2022), attention to effective messaging to alert persons to dangers and prompt protective actions remains a high priority. As this study has shown, the WEA system serves as a valuable channel to notify populations at risk; it has also highlighted some areas for improvement.

A few key items emerge. While we do not yet have research to support the use of zones for evacuation messaging, it is likely to remain a practice among some jurisdictions. In light of this, research suggests that message receivers will still need and benefit from detailed geographical information in addition to the zone identified. Until residents and other members of the public have been sufficiently educated about the use of evacuation zones, fire risk communicators and responders must continue to communicate location information that will assist the message receiver in rapidly identifying and confirming the threat and risk.

Additionally, our evaluation of WEA messages has shown the inconsistencies across jurisdictions in their use of terms to trigger evacuation. Each of the communication types (i.e., technical, operational and actionable language) carries meaning among those who have expertise in wildfire jargon (Williams et al. 2017), but may result in differing interpretations and confusion among non-experts (King 2019). Because wildfire movement is not restricted to city, county, or state lines, it will become important for risk communicators to consider adopting a more consistent approach to wildfire evacuation trigger language that can be applied across contexts and agencies. This would greatly aid the wider use of WEAs as varying alert and warning message standards inhibit the use of WEAs across neighboring jurisdictions that use a different language.

Limitations and Future Research

This study presents a content analysis of historical wildfire WEA messages. We do not know how many people received these messages or acted upon them. Future research would benefit from studying human behavioral response following the receipt of a WEA for wildfire. We also do not know how people perceived or understood the differing terms to trigger evacuation. If jurisdictions continue to use variations in these terms, there will be a growing need to confirm that message receivers understand and can act on those messages, regardless of the language used. This will be of particular importance as wildfire events cross jurisdictional boundaries and state lines. Future research should also investigate how to effectively communicate location including the use of geographical location terms and zones. Finally, Mileti and Sorensen's WRM provides the foundation for this work and the work of many others in the field of hazards and disasters. However, lacking a consistent title, this model has also been referred to as the Mileti and Sorensen model and the "hear-confirm-understand-believe-personalize-respond" model, among others. As a seminal model in hazards and disasters, future research and practice would benefit from the use of one consistent title to ensure WRM's proper application and increase its accessibility both within and outside of the hazards field.

DATA AVAILABILITY STATEMENT
Anonymized data, models, or code that support the findings of this study are available from the corresponding author upon reasonable request.

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NOTATION LIST
Not applicable.

SUPPLEMENTAL MATERIALS
Not applicable.

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