Developing and pilot-testing warning messages for risk communication in natural disasters

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Abstract

Early warning systems are an essential tool for managing flood emergencies. Alert and warning applications and mobile-phone messaging services have become increasingly widespread among major international emergency agencies as means of communicating risks to the population, and their effectiveness in reducing human and material damages during flood events is significant. Despite their crucial importance, one of the main challenges in the field of emergency communication is the lack of protocols for systematic and standardized production of warning messages. While emergency agencies produce messages on a diversity of topic areas, there are no protocols for structuring their content according to communication functions, exhaustive identification of the relevant areas of action, or classification of content according to different topics. With a view to this opportunity for improvement, the aim of this article is to propose a method for creating a catalog of warning messages enabling their systematic composition and organization. To exemplify the successive stages in the development of such a catalog, we present here the resources and methodological process followed by the authors of this article when commissioned with this task by the emergency services of the Valencian Autonomous Region (south-east Spain) for flood-risk communication. The warning message catalog was pilot tested with experts and user focus groups. Developing warning message catalogs offers a vital resource that can enhance the outreach and operability of warning systems in the current context of increased flood risk due to climate change.

Keywords Early warning · Alerts · Flood · Natural hazard · Vulnerability · Non-structural measures

1 Introduction

Sending alert and warning messages to exposed communities have been shown to significantly mitigate both material and human losses during natural disasters and emergencies (Carsell et al. 2004; Fakhruddin et al. 2020; Intrieri et al. 2020). These messages are designed to disseminate critical information for prevention and response, as well as foster safety behaviors among the affected population. Emergency management agencies have developed and implemented harmonized systems to alert populations about specific hazards or potentially disastrous events, their probability and general recommendations on preparation and immediate behavior. However, emergencies and disasters also require communicating relevant and more detailed information on self-protection and safe behavior during the whole disaster life cycle. While alert systems are usually designed in a highly protocolized and standardized manner, warning systems require a more contextualized communication according to the particular characteristics of the emergency and affected population (Sorensen 2000; Leonard et al. 2012; Pescaroli and Magni 2015). This need of adaptation to the local socio-territorial context and the particularities of the event is a challenge to emergency agencies, which need ready-to-use informative and warning contents that facilitate a fast and efficient response. This difficulty to create contextualized warning content results in the usage of messages of a generic unstructured nature and the lack of standardized repositories. This research paper outlines the procedure employed to develop a comprehensive and easy-to-use catalog of pre-written, structured, and tested warning messages in the case of flood events in the southeastern coast of Spain. The objective of this study is to serve as a benchmark for risk managers and emergency response agencies in the creation of similar locally adapted warning message catalogs.

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By doing so, this tool is intended to supplement the necessary protocolized alert systems aimed at communicating an immediate risk situation. This catalog of warning messages is an applied social science contribution to address the challenges posed by climate change and the escalating frequency and intensity of extreme events. Amidst this climate crisis, it is crucial to bridge the gap between scientific disaster studies and applied risk management (Spray et al 2009; Ortiz et al. 2021) in order to minimize the human costs associated with floods.

2 Literature review

The specialized literature establishes a conceptual distinction between alert and warning. The term alert is frequently utilized as a signaling mechanism to denote the occurrence or potential occurrence of a significant event (Alexander 2002; National Academies of Sciences, Engineering, and Medicine 2018). The primary role of these alerts is to garner attention and make the population aware of an important situation. Essentially, they serve as the initial notice of a potentially impactful situation. Unlike alerts, warnings are designed to provide a more comprehensive set of information about the situation (Pescaroli and Magni 2015; FEMA 2023). The primary function of a warning is to provide specifics about the event that the alert has indicated, and critically, to guide people towards appropriate protective measures. While alerts awaken one's awareness to the occurrence of a situation, warnings enrich this awareness with detailed and contextualized information and practical steps for mitigation (Lundgren and McMakin 2018; Basher 2006). Thus, the two-step process of issuing alerts followed by warnings ensures not only heightened awareness of an event, but also an informed and appropriate response to it (Höppner et al. 2010). However, this conceptual distinction does not always apply to the practice of risk communication, and it can be hard to find a precise differentiation between both terms, and it is common to find warning-style content in alert communication and vice versa. Actually, the term Early Warning Systems is usually defined as "the provision of information on an emerging dangerous circumstance where that information can enable action in advance to reduce the risks involved" (Basher 2006), and are usually enacted before the hazard becomes active (UNISDR 2012; Kelman and Glantz 2014). Thus, Early Warning Systems can be interpreted in the intersection of alerts and warnings. The warning message catalog produced in this project is intended to cover both early warning and warning and, therefore, the whole life cycle of the flood event.

In recent years, there have been significant advances in emergency communication strategies, which make "2.0 alert and warning systems" an emerging and promising field of work. The ceaseless development of information and communication technologies and their widespread use by the population represent a window of opportunity for increasing the outreach and effectiveness of these systems. For this reason, the main international emergency agencies have incorporated these technologies into their communication systems and created applications and mobile-phone messaging services to inform endangered communities in emergency situations (Reuter et al. 2017; Fischer et al. 2019). These new channels afford important advantages, such as instantaneous communication with the user, selective messaging via geolocation, and versatility in the use of infographics (Cumiskey et al. 2015). Examples of alert and warning applications used by government agencies include the NINA app (by the German Federal Office for Civil Protection and Disaster Assistance), the FEMA app (by the US Federal Emergency Management Agency), and Disaster Alert (by the Pacific Disaster Center), among others. In the United States, mobile-phone messaging services have been used for sending alerts mainly via the WEA (Wireless Emergency Alert) system. In the European Union, recent legislation has advanced towards incorporation of this system into the warning and alert strategies of all European emergency agencies. Thus, article 110 of European Parliament Directive 2018/1972 requires member countries to put in place mobile-phone-based warning systems ensuring the broadcast of alerts to all communities that may be affected by emergencies, including meteorological phenomena such as floods. One of the most relevant examples of protocolization of alerts is the Common Alert Protocol (CAP). CAP has been an approved system since 2004 for the standardized delivery of alerts for any type of natural, technological, or public health hazard. It provides a format for communicating key emergency facts in a standardized manner through the following questions: what is the emergency, where is the affected area, how soon should people act, how severe will it be, how certain are the experts, and what actions should people take. CAP also uses an XML-based data format that allows for coordinated information exchange among different alert technologies, such as cell phones, radio, television, or networks based on the Internet. This alert-oriented system has been progressively adopted by major emergency agencies worldwide.

The main objective of these apps and technology-based systems is to inform users before and during different emergency situations, such as natural hazards, technological disasters, or other situations that pose a risk to the population. The majority of warning apps cover various types of hazards, while applications specialized in a single type of hazard are less common (Tan et al. 2017). The information transmitted by these apps usually comes from the authorities responsible for emergency management. Messages are delivered through push notifications to users who have previously

downloaded these apps from the Google or Apple markets. Typically, the information is location-based and the users who receive the notifications are within the influence zone of the hazard during the message delivery. These apps usually alert the population about imminent hazards that can cause widespread damage and provide advice on ideal behaviors to prepare, respond, and recover from the effects of these events (Reuter et al. 2017).

According to a review of 57 apps conducted by Tan et al. (2017), the predominant communication format of these applications consists of a one-way interaction between the authorities and the general public. It is challenging to find experiences of bilateral communication that provide information, gather the response from the general public, and aggregate it to redistribute in the form of new alert messages. As an example, the FEMA App allows users to upload photos of places affected by a disaster and share their location to make them known to other interested individuals (Reuter et al. 2017). Furthermore, Tan et al.'s (2017) review reveals that the majority of these apps are designed to transmit immediate and general response recommendations or alert/early warning messages, thus, covering to a lesser extent the necessary information to prepare the population before the event and guide their recovery actions in the post-event phase. Specifically, only one in four warning apps offers information on the preparedness and recovery phases. Considering the conceptual distinction between alerts and warnings outlined previously—alerts as the initial notice of a potentially significant event, and warnings as more detailed information providing guidance on appropriate protective action—the emphasis on alerts can be seen as a distinctive characteristic of these applications.

In parallel to these developments, research has been conducted into the factors influencing the population's response to alert and warning messages (Mileti and Peek 2000; Leonard et al. 2008; De la Cruz-Reyna and Tilling 2008; Grothmann and Reusswig 2006; Kuller et al. 2021; Thieken et al. 2023). The comprehension and adherence to flood warnings are influenced by a range of psychological, social, and technical factors. Psychologically, emotions like fear and anxiety shape how individuals interpret and respond to alerts. While these emotions capture attention, they can also impede a precise understanding of the warnings (O'Neill and Nicholson-Cole 2009; Perreault et al. 2014). Risk perception is also crucial in this sense, as people are more likely to take warnings seriously when they perceive their properties and personal safety to be at risk. Trust in information sources is another significant psychological factor, for people are more inclined to follow warnings from reliable sources (Heitz et al. 2009; Terpstra 2011; Wachinger et al. 2013). On the social front, interpersonal communication networks among family members and neighbors play a key role in risk perception. An individual is more likely to

follow warnings when their social environment does so as well (Nagarajan et al. 2012). Additionally, social and cultural norms influence how individuals interpret and react to warnings, whether through trust in authorities or traditional practices for facing floods. The trust and reputation of local institutions has been shown to be a very important predictor of compliance with warnings (López-Vázquez and Marván 2003; Terpstra et al. 2009). Likewise, it has been observed that individuals with prior experience of flooding tend to be more receptive to warnings (Armaş and Avram 2009; Botzen and van den Bergh 2012; Wood et al. 2012). In this sense, when alerts refer expressly to past floods, the attention of users is higher and maintained over time (Bradford et al. 2012; Wagner 2007).

Lastly, technical factors related to message quality and communication channels are fundamental for understanding the impact of warnings on the population. The technical characteristics of a message can influence comprehension and compliance with flood warnings. Clarity and specificity of warning message, use of simple language, and timely and reliable delivery are critical technical aspects for ensuring an appropriate and prompt response from individuals (Hagemeier-Klose and Wagner 2009; Bean et al. 2015; Sutton et al. 2014). There is a broad consensus regarding the importance of tailoring warnings to local linguistic contexts (Bell and Tobin 2007; Peric and Cvetković 2019), although exists the difficulty of crafting tailored messages for each social group considering the need to communicate warnings quickly and massively (Küller et al. 2021).

Currently, the impact of warning apps on the general public is a challenging issue due to the limited available information. However, a study by the Red Cross on how the population seeks information during disaster situations reveals that only 20% of the population currently uses mobile apps to stay informed (Wade 2012). The need to download apps by non-expert or non-enthusiast users, such as those interested in meteorology, represents a barrier to the use of such resources. That explains why current initiatives like the EU-Alert system promoted by the European Union have opted to design a system based on push notifications, which ensures the delivery of alerts to the entire population located in the area of influence of an active hazard.

Regarding the elaboration of warning messages, there is a wide consensus on the need to generate messages that are brief, avoid technical jargon, are based on the potential impact of the reported threat and are recognized as valid by the local population (Harbach et al. 2013; Murphy et al. 2018; Perera et al. 2020a, b). However, as yet there are no protocols for developing standardized warning messages (Neußner 2021; Perera et al. 2020b), and more specifically, there are no clear guidelines on the use of terminology, the textual design of messages, the adaptation of content to the local particularities of the populations, or the coverage of

areas for preparedness and action (Grothmann and Reusswig 2006; Jacks et al. 2010; Shrestha et al. 2016; Neußner 2021).

Evidence of this lacuna can be found in the type of information that emergency agencies generally have available for issuing advice and recommendations for action in response to extreme weather events. Often, this information is neither standardized nor structured in such a way that emergency services can handle it effectively (Morss et al. 2016; Abunyewah et al. 2018; Neußner 2021; Perera et al. 2020a, b). More specifically, as has been observed in the analysis of a diversity of sources carried out within this project (see Method section), messages are not classified according to subject areas or types of emergency situations, are not always organized to follow the main life-cycle phases of an extreme event, and their text structure is not standardized in line with communicative objectives and functions. In other words, most emergency agencies issue basic warning messages, but lack catalogs or message packages with comprehensive and systematically structured content. As a result, while there are standardized protocols for alert messages (such as the CAP protocol), warnings are often heterogeneous in terms of length, text composition, terminology, and topic distribution. Furthermore, and as found in the review of messages undertaken by the authors of this paper (see the following sections), these messages tend to focus only on basic topics, and therefore, do not cover all the specific needs and emergencies that can arise during preparation, action, and recovery phases. This heterogeneity and lack of completeness can reduce the scope and communicative effectiveness of warning messages and diminish trust among receivers.

To address the need for uniformity in warning messages elaboration, some analysts have called for platforms such as catalogs or libraries, based on structured content and standardized message-writing protocols (Párraga-Niebla et al. 2014, 2016; Chaves and De Cola 2017). Such platforms would facilitate more effective and functional use of warning messages, thus, enhancing the impact of the authorities' emergency communication strategies throughout the disaster's life cycle. This system, which aims to deliver automated mass warnings to the population's mobile devices, represents an opportunity to improve and institutionalize standardized messaging protocols.

With this opportunity in mind, the emergency services of the Valencian Autonomous Region (south-east Spain) commissioned this research team with the task of creating a catalog of systematically structured risk warning messages covering the whole range of potential responses that can arise during the full life cycle of a flood emergency and enabling effective handling by emergency agencies. This project was one of a number of initiatives aiming to improve the region's warning systems in the wake of a catastrophic flood in the south of the region in September 2019. This event, the

second most economically costly environmental disaster in the history of Spain (CCS 2021), is used here as a case study in order to illustrate the methodological decisions made during the project as well as its final results. This project was envisioned as a pilot study for the creation of a protocol to pre-design warning messages that considered the particular needs that the local population had during this specific flood event. It pursues, therefore, the need to adapt the messages to the particular socio-territorial context as well as to the unique requirements imposed by a particular type of disaster (floods), while serving as a reference or guide to similar actions in other contexts and hazards.

The event chosen as a case study and model for structuring the phases of the message catalog development was the September 2019 flood, occurring in the Vega Baja area in the extreme south of the Valencian Autonomous Region. This event resulted from the formation of a cold drop bringing with it a major episode of torrential rain. Extreme rainfall was recorded at some points, for example 521.6 l/m2 in 72 h in the city of Orihuela, representing almost twice the annual average for this region of south–east Spain (CHS 2019). The flooding was the result of several factors, among them the overflow of the Segura River, the bursting of a dike containing the river, and flash floods caused by the presence of wadis and ravines across a large part of the area. During the episode, a total of four people died. The heaviest social and economic losses were in the agricultural sector and local businesses, in addition to material and structural damage to housing, particularly in the residential neighborhoods of vulnerable groups (Núñez Mora 2019). According to data from the Spanish Insurance Compensation Consortium, the flood was the second most costly since records began, being the 2010 Lorca (Murcia Region) earthquake first in terms of insured damages, accounting for more than 550 million euros. The 2019 floods in Vega Baja had an estimated cost of more than 450 million euros. Also, the area has suffered other recent severe flood events in 2012 (239 million euros) and 2021 (91 million euros) (CCS 2021).

The severe damage that occurred during the event was a consequence not only of the high intensity of the rainfall, but also of additional factors such as the exposure and vulnerability of the population. The Vega Baja territory is an alluvial plain of the Segura River basin, which, as a consequence of its geological and hydrological characteristics, has been exposed to recurrent flooding (Gil-Olcina and Canales 2023). It is also a highly anthropized region due to agricultural activity, the development of second-home tourism and urban growth. In fact, most of the anthropized territory in this region is located in flood-prone areas. As a consequence of the combination of agriculture and residential tourism, the demography of the area is extremely heterogeneous, encompassing both labor migrants from developing countries attracted by agricultural employment, and residential
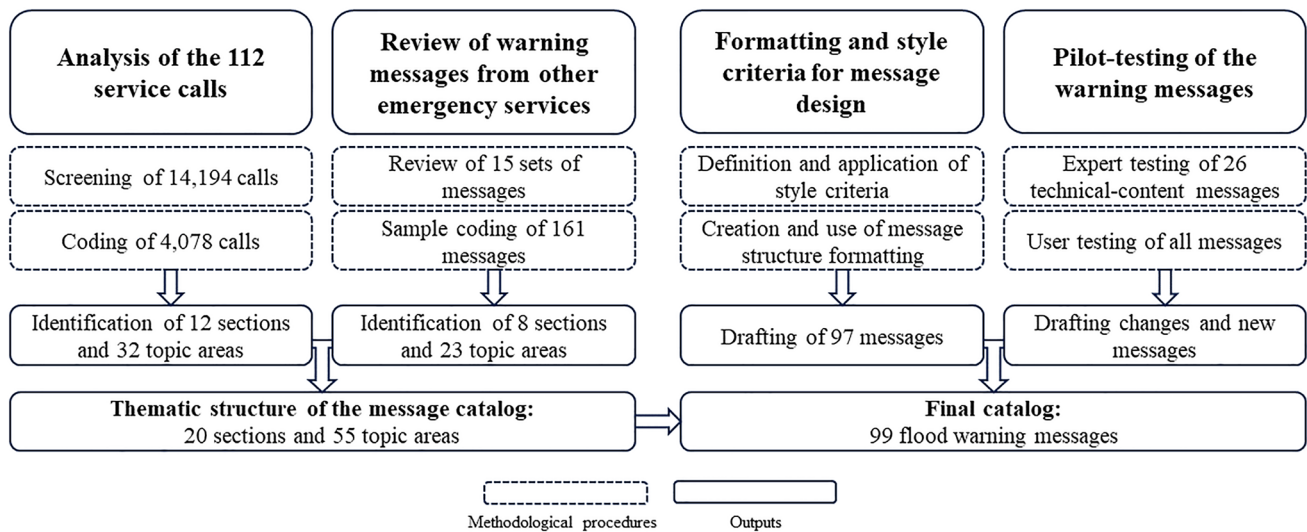
Fig. 1 Summary of the entire methodological procedure

migrants from EU countries drawn by the region's tourist facilities (Canales and López-Pomares 2011). These two groups tend not only to be unaware of the area's natural hazards, but also sometimes of how to prepare, act, and recover in response to extreme events (Aznar-Crespo et al. 2020). Thus, the socio-demographic complexity of the Vega Baja, combined with the high level of natural hazard described above, increase its exposure to risk. This was materialized during September 2019. The catastrophic nature of this flood makes the event an ideal case study for identifying the wide variety of needs and emergencies experienced by the population throughout the phases of the disaster life cycle. For the purposes of this study, these needs and emergencies were taken as the topic areas that shaped the content structure of the warning message catalog.

3 Method

The methodological design was aimed at completing three different tasks required for the development of the message catalog: 1) designing the catalog's content structure, 2) writing each specific message, and 3) pilot testing the messages. Figure 1 summarizes the methodological procedure carried out throughout the research process.

The first step in giving form to the message catalog was to design a content structure that exhaustively covered the range of categories of problems and needs experienced by the population during a flood event. These categories were determined through two procedures: (1) an analysis of the calls received by the 112 service (equivalent to 911 in other countries) of the Valencian regional government during the 2019 flooding in the Vega Baja region; and (2) a review and

analysis of alert and warning messages published by other national and international emergency agencies.

3.1 Analysis of the calls received by the regional emergency services

The purpose of the analysis of calls received by the 112 service throughout the life cycle of the September 2019 flood disaster was to identify, based on the experience of a real case, the main types of needs and emergencies experienced by citizens during this catastrophic flood event. This enabled us to identify the areas of action to be considered when creating warnings.

To perform this analysis, the Valencian regional government emergency services provided access to their database of calls to the 112 service during the torrential rainfall episode. The database totaled 14,194 calls made from 10 to 20th September 2019, which we took to be a period of sufficient length to cover all the population's information and emergency needs before, during, and after the rainfall episode. Since the database also included calls unrelated to the event, it was filtered in order to retain only those made for information and emergency needs arising from the downpours in the municipalities of the Vega Baja, thereby yielding a final sample of 4,078 calls.

Once the database had been compiled, the calls were analyzed in order to code the different types of information and emergency needs stemming from the event. Coding was performed on the basis of two different sources of information: (1) the default classification of the calls made by the emergency services in their registration process; and (2) the written comments of the 112 operators, which recorded additional information and aimed to understand in greater depth

the reason for the call. In the process of coding, we identified general categories or families of problems on the one hand, and more specific information and emergency needs on the other. The general categories then became the basis for the different sections of the catalog that is any general issue that included a set of specific topic areas (e.g., securing a dwelling), while the specific problems were taken as its topic areas, that is any specific issue that was included, together with others, within a section (e.g., removal and protection of exposed objects from outside the dwelling). At this stage, a total of 12 sections and 32 topic areas were identified.

3.2 Review of warning messages from other emergency services

Since the sections and topic areas obtained through the analysis of 112 calls were taken from a single case study, in order to ensure the exhaustiveness of the catalog's sections and topic areas and its generalizability to other flood events and fields of study, we reviewed a number of sets of flood-risk warning messages published by a range of national and international emergency agencies. Thus, this analysis complemented and completed the list of sections and topic areas identified in the previous phase.

To this end, we reviewed technical documents and official websites including batteries of advice and recommendations for dealing with the effects of heavy rains. All sources were studied until information saturation was reached that is until the contents became redundant and no new information could be found. In total, 15 sets of messages were reviewed, nine from Spanish emergency agencies (the Valencian Autonomous Region, Catalonia, Murcia, Andalusia, the Basque Country, Navarra, the Canary Islands, the External Affairs Ministry and the General Direction of Civil Protection), and six from international agencies (the National Oceanic and Atmospheric Administration, NOAA, USA; the Federal Office for Civil Protection and Disaster Assistance, Germany; Ready.gov, USA; the Centre for Disease Control and Prevention, CDC, USA; the Health Security Agency, UK; and the Royal Society for the Prevention of Accidents, RoSPA, UK).

Once all the messages had been collected, those that featured repeated or very similar content were eliminated. The result was a final sample of 161 messages, which were then classified according to time phase and subject matter. The framework used for this process was the provisional content structure (sections and topic areas) stemming from our analysis of calls to the 112 service during the 2019 flood in the case study. However, messages not fitting this content structure were also found; hence, it was decided to undertake a new coding of sections and topic areas based on the content of the messages that could not be included in the initial categories. This yielded the final content

structure of the catalog, which comprised 20 sections and 55 topic areas, and was divided into four time phases to cover the whole life cycle of the disaster.

3.3 Formatting and style criteria for message design

In systematically structuring the text content of the messages, three sources were drawn on (1) the text messaging style manual created by the Valencian regional government emergency services; (2) Covello's "message mapping" model for writing and formatting warning messages, widely used in the specialized literature (Covello 2006); and (3) the content analysis of alert and warning messages published by other emergency agencies undertaken in the previous phase.

First, the text-message style manual created by the emergency services in the case study was consulted in order to determine basic message-writing criteria. Special attention was paid to providing a clear identification of the source of the message (emergency agency), creating a header with the basic data identifying the risk phenomenon, and structuring the content in a clear, concise and systematic way. Also, the specialized literature was consulted in search of message-writing models that would enable us to fulfill the criteria set forth in the style manual, and as a result, Covello's (2006) message mapping model was chosen. This framework, used by the US Environmental Protection Agency (EPA) and the World Health Organization (WHO), is one of the most widely adopted in the emergency communication field. In addition to its seminal nature, the model was selected because it enables clear and concise organization of the text content of messages. The framework provides the following guidelines for warning messages, subsequently adopted in this study:

- Structure the text content of the messages into three sections with different communicative functions: (1) *the header*, which includes the essential information content of the message; (2) *the supporting fact*, which specifies and exemplifies the features of the alert or specific actions for preparing, acting and recovering; and (3) *additional information*, expanding on the information in the previous sections.
- Avoid technical jargon, aiming to make the content of the messages understandable to all target audiences, while maintaining rigor in using specific terminology when required by the phenomenon described.
- Use infographic resources, such as capitals to stress certain content and segmentation into paragraphs to guarantee that target audiences receive clear, well-defined information.

This model was adopted to structure the content of the messages and make their style as concrete and specific as possible. Also, before writing the messages, we reviewed the sample of 161 messages published by other emergency agencies in order to capture their basic style and to learn about highly technical topics such as first aid, road traffic, and rescuing people.

When writing the messages, the research team was divided into two groups, one responsible for writing the text and the other for reviewing its content and suggesting improvements. After a series of drafting and revision sessions, a provisional catalog of 97 warning messages was retained, all systematically organized into the three communicative sections of header, supporting fact, and additional information. In cases requiring expansion, however, further sections were added in order to provide supplementary support or information. The final number of messages was obtained by information saturation, occurring when the content of each of the catalog's topic areas was completed.

3.4 Pilot testing of the warning messages

In the last stage of the study, the warning messages were tested. The purpose of this was to verify that they were technically valid, comprehensible and easy to use. To this end, two types of testing were undertaken: expert testing and user testing.

3.4.1 Expert testing

For this test, experts validated those messages that contained specific technical content. 26 messages were identified as highly technical, mostly dealing with first aid, traffic, and rescue of people. Six experts were consulted: two health professionals specialized in medical emergencies; two firefighters specialized in environmental disasters; and two members of the civil protection technical department. These specialists were asked whether the information: (1) was technically correct; (2) could be expressed more appropriately; and (3) needed to be edited to add or cut content. The experts reviewed all the selected messages and made comments and suggestions for changes that both validated and enhanced their content.

3.4.2 User testing

The second test aimed to verify whether final users understood the content of the messages appropriately and whether the warnings were clear and useful enough to enable receivers to perform the recommended preparation, response, and recovery actions. The test aimed to assess the communicative effectiveness and comprehension of the messages by the end receiver. Hence, they were tested according to the following criteria:

- *Expression and language*: terminology used to enable full comprehension of the weather phenomena and recommended actions.
- *Salience*: whether the message effectively conveyed the seriousness of the emergency situation.
- *Appropriate exemplification:* the use of appropriate examples to illustrate the recommended action in a practical way.
- *Explanatory power*: whether the message described fully how to implement the relevant action.
- *Feasibility*: feasibility for the general public of the recommended actions.

The ultimate goal of the test was to identify areas for improvement and to gather recommendations for corrections and changes enhancing their effectiveness in each of the five dimensions evaluated. Three focus groups were conducted and designed with internal heterogeneity regarding three age groups: young people (aged 18 to 30), adults (31 to 65), and older people (over 65). Each group consisted of nine participants: three young people, three adults, and three older people, all from different municipalities of the Vega Baja, with a total of 27 taking part: 14 men and 13 women. All participants had directly experienced the 2019 flood event in Vega Baja. These mixed focus groups enabled participants from each age group to share their understanding of the messages, thus, making it possible to develop more balanced proposals for improvement, from the standpoint of a more general understanding. All the messages in the catalog were tested in this way. At each session, a message-by-message presentation of the catalog's contents was made and participants were asked: (1) whether the content of each message was understandable to the general public (expression and language); (2) whether the message had the features necessary to warn the population sufficiently and appropriately to the emergency (salience); (3) whether the messages offered accurate and practical examples (appropriate exemplification); (4) whether the recommended actions were explained in an clear and understandable way (explanatory power); and (5) whether the recommended actions were feasible and could be easily implemented in the domestic setting (feasibility). Researchers recorded participants' suggestions for improvement, and after all the sessions had been held, the research team proceeded to modify the messages in accordance with these recommendations.

The resulting revisions of the messages can be classified into five types according to the extent of the changes made: (1) messages with no major changes (spelling mistakes and modification of a few words, 40 messages); (2) messages with minor changes (small changes to the wording

of sentences and to important words in the body of the message, 42 messages); (3) messages with moderate changes (rewording of some complete sentences and changes to examples in messages about recommended actions, 14 messages); (4) messages with major changes (almost complete modification of the text, 1 message); and (5) new messages (composition of new messages on phenomena not covered in the previous phases, 2 messages).

4 Results

The outcome of the previously cited sources and methodological procedures was the final total of 99 tested messages making up the flood warning messages catalog.

The content structure of the catalog was divided into two dimensions: the temporal and the topical. Firstly, and as had been evidenced by the 112 calls analysis and the literature review, messages delivered before the onset of rainfall are distinct from those sent in the later phases of the event. For this reason, the catalog was divided into three temporal blocks, one for each of the main phases of a flood event life cycle (Moe and Pathranarakul 2006), namely: preparation, action, and recovery. Also, an additional Forecasting first section was included, following the explicit request of the Emergencies Coordination Center, with a more alert-oriented content regarding meteorological information for the 72, 48, and 24 h prior to the rainfall. Although these are not warning messages in the strict sense, they follow the same structure as the rest of the messages in the catalog.

Within each of these temporal stages, different sections and topic areas had been identified in the analysis of the calls received by the regional 112 service, as well as from the review of alert and warning messages from diverse national and international emergency services. Table 1 shows the final sections (e.g., in Phase 2: Sect. 1. Provision of essential resources") and topic areas (e.g., "1.1. Food, medicines and others") of the warning message catalog, divided into the four main life-cycle phases of the flood event.

As will be shown in the following pages, all the messages included in the catalog comply with the following style and formatting criteria:

- *Expression*: the messages are written to be easily understood by the general public, avoiding technical jargon. Thus, the terms used are generally comprehensible, although rigor was maintained in the use of certain specific terms when the phenomenon required it.
- *Length*: the messages are economical in length, aiming to give the essential information in the fewest possible words. However, in no case was important information omitted for the sake of brevity.

Table 1 Phases, sections, and topic areas of the flood risk warning message catalog

	Number of messages
Phase 1: Forecasting	
1. Meteorological information	7
1.1. Rainfall forecast (72 h)	1
1.2. Heavy rainfall forecast (48 h)	1
1.3. Very heavy rainfall forecast (48 h)	1
1.4. Heavy rainfall forecast (24 h)	1
1.5. Very heavy rainfall forecast (24 h)	1
1.6. Subsequent heavy rainfall forecast	1
1.7. Subsequent heavy rainfall forecast	1
Phase 2: Preparation	
1. Provision of essential resources	14
1.1. Food, medicine and other	7
1.2. Information on the event	3
1.3. Drawing up an action plan	4
2. Securing dwellings	7
2.1. Hazardous products	1
2.2. Elements exposed to the outside	1
2.3. Energy supply	2
2.4. Ducting and seepage areas	3
3. Care of dependents	4
3.1. General dependent population	1
3.2. Elderly dependents	1
3.3. Children	1
3.4. Ill people	1
4. Road traffic and circulation	5
4.1. Vehicle status	2
4.2. Road circulation	3
5. Education and services	2
5.1. Schools and education centers	1
5.2. Businesses and administrative services	1
6. Outdoor activities	5
6.1. Sports	1
6.2. Leisure activities	4
7. Animal care	2
7.1. Domestic environment	1
7.2. Urban and rural environments	1
Phase 3: Action	
1. Water infiltration into properties	4
1.1. Living areas	3
1.2. Garages and basements	1
2. Traffic emergencies	4
2.1. Vehicle parking	1
2.2. Road emergencies	3
3. Flooding and storms	5
3.1. Waterlogged areas	1
3.2. Mountain areas	1
3.3. Urban areas	1

Table 1 (continued)

	Number of messages
3.4. Coastal areas	1
3.5. Thunderstorms	1
4. Landslides and rockfalls	2
4.1. Natural environment	1
4.2. Street furniture	1
5. Assistance and rescue of people	7
5.1. Social environment	1
5.2. Outdoor emergencies	4
5.3. Injured people	2
6. Evacuation of people	7
6.1. Evacuation from dwellings	2
6.2. Information	2
6.3. Guidelines for action	3
7. Animal protection	3
7.1. Household environment	1
7.2. Urban and rural environment	2
8. Essential resources and supplies	6
8.1. Food and water	2
8.2. Energy	1
8.3. Communication systems	3
Phase 4: Recovery	
1. Personal safety	5
1.1. Household environment	2
1.2. Urban and rural environment	3
2. Cleanliness and hygiene	6
2.1. Return to the home	5
2.2. Community environment	1
3. Personal injuries	2
3.1. Injured people	2
4. Insured damages and aid	2
4.1. Insurance	1
4.2. Other financial assistance	1

- *Language*: since the message catalog was originally written in Spanish, the formal mode of address (*usted*) is used in order to increase the recipient's trust in the source of the information and the content of the message. Gender-inclusive language formulas are also used. Had the messages been written in another language, such as English, this type of consideration would not have been necessary.
- *Style*: the messages are written to be easily understood by the general public, to make effective warning of danger, to instill trust among receivers and to provide a practical guide to preparation, action and recovery. In order to ensure the formulation of comprehensible and practical messages, we took as a model the criteria from the literature for evaluating the communicative quality of content broadcast via mobile devices (Fis-

cher et al. 2019). Hence, the messages were composed according to the following style guidelines: (1) *salience*, i.e., the ability of the messages to communicate the exact severity of the expected rainfall event, and consequently to put the population on alert as appropriately as possible to the magnitude of the event; (2) *trust*, i.e., the ability of the messages to inspire credibility in their content; (3) *coherence*, i.e., the ability of the messages to make their content understandable through suitable use of vocabulary and grammar; and (4) *actionability*, i.e., the ability of the messages to spur users into action and provide them with enough adequately explained and exemplified information for them to make effective preparations before the event, take appropriate action during it, and recovery satisfactorily after it.

- *Spacing*: the content of the messages is divided into three sections: header, supporting fact and additional information. The spaces between sections were kept small to ensure comfortable, effective reading.
- *Bold type*: bold type is used in the message header to stress its importance and differentiate it from the rest.
- *Capitals*: capital letters are used in the header to stress the most representative words, i.e., those ensuring immediate recognition of the message content.
- *Italics*: some messages include text in italics, thereby indicating to the emergency services that inclusion of the information is optional and dependent on the specific circumstances of each event. For example, not all rainfall events are accompanied by thunderstorms, so the text on the latter is written in italics to show that it is optional.
- *Brackets*: some messages use square brackets to indicate that the emergency services personnel should specify information on the particular characteristics of the event, such as the level of alert, the heaviness of the expected rainfall or the day and times of the event's duration. Square brackets are also used where necessary to include a link to a website where the receiver could access additional information of interest. In this case, [link] appears in the text.
- *Header*: all messages include a header with basic data on the identity of the agent issuing the information and the phenomenon reported (e.g.: "Information from the Emergency Coordination Centre of the Valencian Government on Rain Alert").

The messages are also presented in a way that ensures that the emergency services can make easy and effective use of the catalog. Thus, each individual message card is designed in the form of editable slides that include: (1) the topic and time code; (2) the informational content; and (3) additional resources facilitating fast and convenient use of the catalog.

Fig. 2 Message Card for Phase 1: Forecasting/Section 1: Meteorological information

1. *Time and topic codes of the messages*: each of the cards include information on the time phase (forecast, preparation, action and recovery), the section and the topic area of each message. In addition, all the messages have been assigned a number from 1 to 99.[1] Each of the four phases of the event life cycle have also been numbered, as well as sections and topic areas.

2. *Information content*: in most cases the content of the messages follows Covello's (2006) threefold structure consisting of a header (bold text), a supporting fact (first bullet point below the header) and additional information (second bullet point below the header).

3. *Additional resources*: at the bottom of each card, there is a section of "Other resources", providing links to websites enabling emergency personnel to expand on the information if necessary. Lastly, a "keywords" section was created to help emergency personnel speed up message location. There are four to seven keywords per message card, all relating to synonyms or associated concepts. To avoid overlap and broaden the search range, these keywords are always different from the terms appearing in the other sections of the card.

Below, we present a summary of the main objectives and content of each phase of the event, as well as a sample of messages for each section of the catalog in both, their original version in Spanish and their translated version into English.[2]

4.1 Phase 1. Forecasting

This phase includes warning messages that provide information on the weather forecast issued by emergency services 72, 48, and 24 h before the rain begins. Messages in this section convey the information provided by central meteorological services and the official declaration of the alert level (yellow, orange, or red) as the onset of rain approaches (Fig. 2).

4.2 Phase 2. Preparation

This phase includes messages aimed at preparing the population for the onset of rainfall and the occurrence of emergencies. It provides information to help exposed populations get ready for the probable event by assembling all essential resources (food, medicine, water, etc.), securing their homes to prevent water infiltration or energy supply failures, and avoiding contamination by hazardous products or other potential accidents. Additionally, this phase includes messages related to special care for dependent populations (elderly, children, ill people) and animals (domestic or farm), as well as preventive information on how to behave when driving, engaging in outdoor activities, and staying informed about educational activities and other public services (Figs. 3, 4, 5, 6, 7, 8, and 9).

4.3 Phase 3. Action

Messages during this phase aim to explain and exemplify specific actions and behaviors while the disaster or emergency is active. Communication during this phase will provide information and recommendations useful for various scenarios that can occur during the flood event, such as how to behave if water infiltrates homes, garages, or basements,

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[1] While the initial number of messages drawn up by the research team was 97, subsequent testing yielded two new messages, thus, bringing the total to 99.

[2] The complete and original version of the catalog (in Spanish) can be found in this link or by requesting it directly to the authors: https://iuaca.ua.es/es/inundaciones-sequias/comunicacion-del-riesgo.html

Fig. 3 Message Card for Phase 2: Preparation/Section 1: Provision of essential resources/Topic Area 1.1. Food, medicines and other

Fig. 4 Message Card for Phase 2: Preparation/Section 2: Securing dwellings/Topic Area 2.1. Hazardous products

Fig. 5 Message Card for Phase 2: Preparation/Section 3: Care of dependents/Topic Area 3.3. Children

Fig. 6 Message Card for Phase 2: Preparation/Section 4: Road traffic and circulation/Topic Area 4.2. Road circulation

Fig. 7 Message Card for Phase 2: Preparation/Section 5: Education and services/Topic Area 5.1. Educational centers

Fig. 8 Message Card for Phase 2: Preparation/Section 6: Outdoor activities/Topic Area 6.2. Leisure activities
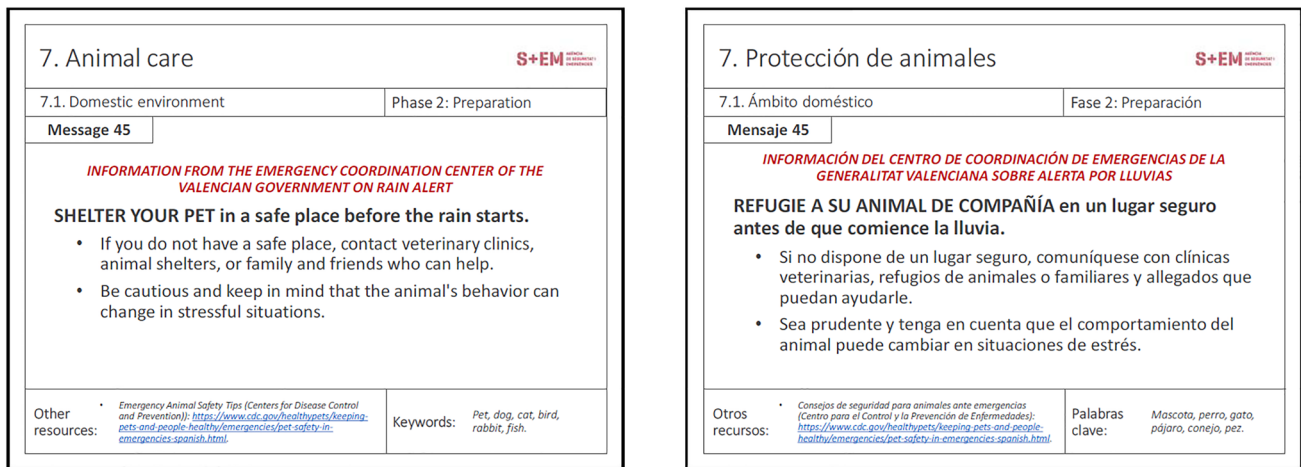
Fig. 9 Message Card for Phase 2: Preparation/Section 7: Animal care/Topic Area 7.1. Domestic environment
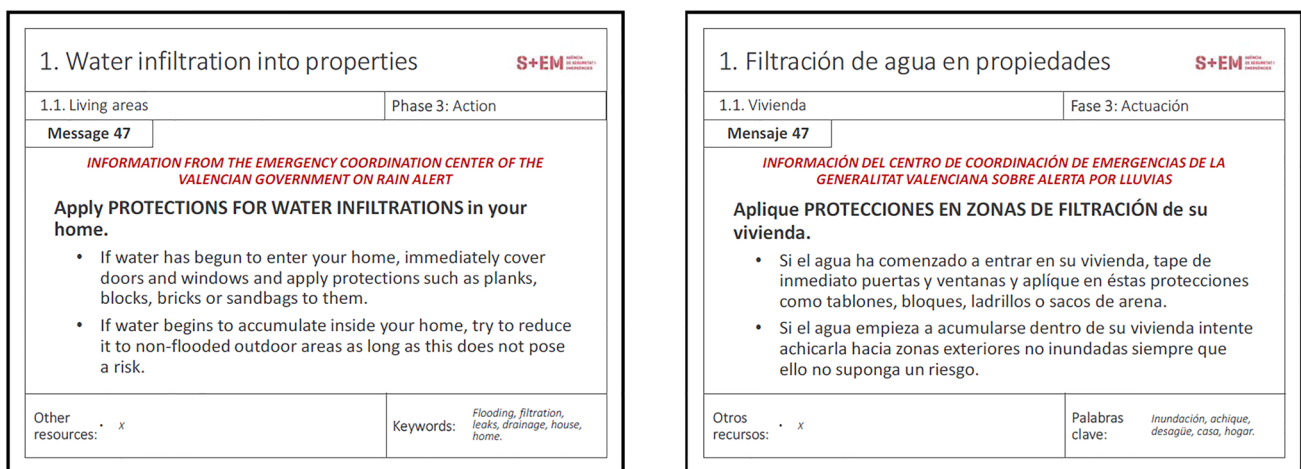
Fig. 10 Message Card for Phase 3: Action/Section 1: Water infiltration into properties/Topic Area 1.1. Living areas

or if the recipient finds themselves stuck in traffic, a flooded area outdoors (mountains, coast, urban areas), or in situations related to landslides or rockfalls. Messages in this phase also include relevant information regarding vehicle use, road emergencies, assistance, rescue, or evacuation of people or animals (Figs. 10, 11, 12, 13, 14, 15, 16 and 17).

4.4 Phase 4. Recovery

In this final phase of the emergency, sections include messages that provide recommendations for a safe and effective return to normalcy, such as sanitary guidelines and secure behaviors. Additionally, they address the human consequences of the event, including physical and psychological health, and social organization, as well as the material consequences, providing information on insurance and financial

assistance to confront the economic cost of the damages (Figs. 18, 19, 20 and 21).

5 Discussion and conclusions

The significant benefits of warning systems compel academics, policymakers, and emergency services to work together to produce knowledge on protocols for their systematic elaboration, especially in the current context of increased disaster risk due to climate change and of rapid technological development. This study, carried out in response to the opportunities for improvement in this area, advocates using catalogs as a means of systematically developing and organizing warning messages for effective risk communication. While most of the effort of risk management institutions and emergency agencies has been put in the protocolization of

2. Traffic emergencies

2.2. Road emergencies	Phase 3: Action

Message 54

INFORMATION FROM THE EMERGENCY COORDINATION CENTER OF THE VALENCIAN GOVERNMENT ON RAIN ALERT

DO NOT CROSS WITH YOUR VEHICLE bridges, tunnels and level crossings that do not offer safe passage conditions.

- If you have doubts about the strength and safety of these structures, choose to stop your vehicle and make a U-turn as long as it is safe.
- If you are trapped in any of these structures, call 1·1·2 immediately..

| Other resources: | • *Driving recommendations in rainy situations (Spanish General Directorate of Traffic): https://www.dgt.es/comunicacion/noticias/todo-lo-que-necesitas-saber-para-circular-bajo-la-lluvia/.* | Keywords: | *Infrastructure, car, motorcycle, automobile, road, highway, construction.* |

2. Emergencias de tráfico

2.2. Emergencias en carretera	Fase 3: Actuación

Mensaje 54

INFORMACIÓN DEL CENTRO DE COORDINACIÓN DE EMERGENCIAS DE LA GENERALITAT VALENCIANA SOBRE ALERTA POR LLUVIAS

NO CRUCE CON SU VEHÍCULO puentes, túneles y pasos de nivel que no ofrezcan condiciones de paso seguras.

- Si tiene dudas sobre la resistencia y seguridad de estas estructuras, opte por detener su vehículo y realice un cambio de sentido siempre que sea seguro.
- Si se encuentra atrapado/a en alguna de estas estructuras, llame de inmediato al 1·1·2.

| Otros recursos: | • *Recomendaciones de conducción ante situaciones de lluvia (Dirección General de Tráfico): https://www.dgt.es/comunicacion/noticias/todo-lo-que-necesitas-saber-para-circular-bajo-la-lluvia/.* | Palabras clave: | *Infraestructura, coche, moto, automóvil, camino, carretera, construcción.* |

Fig. 11 Message Card for Phase 3: Action/Section 2: Traffic emergencies/Topic Area 2.2. Road emergencies

3. Flooding and storms

3.1. Waterlogged areas	Phase 3: Action

Message 55

INFORMATION FROM THE EMERGENCY COORDINATION CENTER OF THE VALENCIAN GOVERNMENT ON RAIN ALERT

DO NOT WALK THROUGH areas where there is WATER ACCUMULATED OR IN CIRCULATION.

- A flooded area can hide dangerous objects and holes you could sneak into, such as uncovered sewers.
- If it is strictly necessary to cross one of these areas, help yourself with a long object to know the height of the water and detect dangerous areas.

| Other resources: | • x | Keywords: | *Flood, overflow, waterlogging.* |

3. Anegamiento y tormentas

3.1. Zonas anegadas	Fase 3: Actuación

Mensaje 55

INFORMACIÓN DEL CENTRO DE COORDINACIÓN DE EMERGENCIAS DE LA GENERALITAT VALENCIANA SOBRE ALERTA POR LLUVIAS

NO ATRAVIESE A PIE zonas donde haya AGUA ACUMULADA O EN CIRCULACIÓN.

- Una zona inundada puede ocultar objetos peligrosos y agujeros en los que podría colarse, como alcantarillas sin tapa.
- Si es estrictamente necesario atravesar una de estas zonas, ayúdese de algún objeto alargado para conocer antes la altura del agua y detectar zonas peligrosas.

| Otros recursos: | • x | Palabras clave: | *Crecida, avenida, inundación, desbordamiento, anegamiento.* |

Fig. 12 Message Card for Phase 3: Action/Section 3: Flooding and storms/Topic Area 3.1. Waterlogged areas

4. Landslides and rockfalls

4.1. Natural environment	Phase 3: Action

Message 60

INFORMATION FROM THE EMERGENCY COORDINATION CENTER OF THE VALENCIAN GOVERNMENT ON RAIN ALERT

Maintain caution against possible LANDSLIDES that may occur on the road.

- If you are on a road affected by a landslide, call 1·1·2 immediately and do not cross or remain in the danger zone.
- Whenever it is safe, try to make a U-turn and move away from the area having previously called the emergency services reporting the deprediment.

| Other resources: | • x | Keywords: | *Hillside, stone, road, rural, circulation, rock.* |

4. Deslizamientos y desprendimientos

4.1. Medio natural	Fase 3: Actuación

Mensaje 60

INFORMACIÓN DEL CENTRO DE COORDINACIÓN DE EMERGENCIAS DE LA GENERALITAT VALENCIANA SOBRE ALERTA POR LLUVIAS

Mantenga la precaución ante posibles DESPRENDIMIENTOS DEL TERRENO que puedan tener lugar en la carretera.

- Si se encuentra en una carretera afectada por un desprendimiento, llame de inmediato al 1·1·2 y no atraviese ni permanezca en la zona de peligro.
- Siempre que sea seguro, intente realizar un cambio de sentido y alejarse de la zona habiendo antes llamado a los servicios de emergencia informando del desprendimiento.

| Otros recursos: | • x | Palabras clave: | *Ladera, piedra, camino, rural, circulación, incidente.* |

Fig. 13 Message Card for Phase 3: Action/Section 4: Landslides and rockfalls/Topic Area 4.1. Natural environment

Fig. 14 Message Card for Phase 3: Action/ Section 5: Assistance and rescue of people/Topic Area 5.2. Outdoor emergencies

Fig. 15 Message Card for Phase 3: Action/Section 6: Evacuation of people/Topic Area 6.1. Evacuation from dwellings

Fig. 16 Message Card for Phase 3: Action/Section 7: Animal protection/Topic Area 7.2. Urban and rural environment

8. Essential resources and supplies — S+EM

8.1. Food and water	Phase 3: Action

Message 79

INFORMATION FROM THE EMERGENCY COORDINATION CENTER OF THE VALENCIAN GOVERNMENT ON RAIN ALERT

During the emergency, TRY TO CONSUME ONLY BOTTLED WATER and avoid tap water.

- Prioritize bottled water over other water sources.
- Keep in mind that during an episode of heavy rainfall tap water may become contaminated and unfit for consumption.

Other resources:	• Recommendations for the use of food in case of emergency (Centers for Disease Control and Prevention): https://www.cdc.gov/es/disasters/foodwater/prepare.html.	Keywords:	Hydration, hydric, pollution, resources.

8. Recursos y suministros básicos — S+EM

8.1. Agua y alimentación	Fase 3: Actuación

Mensaje 79

INFORMACIÓN DEL CENTRO DE COORDINACIÓN DE EMERGENCIAS DE LA GENERALITAT VALENCIANA SOBRE ALERTA POR LLUVIAS

Durante el tiempo que dure la emergencia, PROCURE CONSUMIR ÚNICAMENTE AGUA EMBOTELLADA y evite la del grifo.

- Priorice el agua embotellada de que disponga para su ingesta.
- Tenga en cuenta que durante un episodio de lluvias intensas el agua corriente puede contaminarse y no ser apta para su consumo.

Otros recursos:	• Recomendaciones para el uso de alimentos en caso de emergencia (Centro para el Control y la Prevención de Enfermedades): https://www.cdc.gov/es/disasters/foodwater/prepare.html.	Palabras clave:	Hidratación, hídrico, contaminación, recursos.

Fig. 17 Message Card for Phase 3: Action/Section 8: Essential resources and supplies/Topic Area 8.1. Food and water

1. Personal safety — S+EM

1.1. Household environment	Phase 4: Recovery

Message 85

INFORMATION FROM THE EMERGENCY COORDINATION CENTER OF THE VALENCIAN GOVERNMENT ON RAIN ALERT

In case you have been evacuated or your HOME has been damaged, DO NOT RETURN TO IT until the AUTHORITIES indicate it.

- If you do not have information about returning to your home, call 1·1·2 or access [link].
- Failure to comply with the instructions of the authorities on the return to housing can put at risk your life, that of your family and that of those who try to help you.

Other resources:	• Enlace correspondiente.	Keywords:	House, household, evacuation, resettlement.

1. Seguridad personal — S+EM

1.1. Ámbito doméstico	Fase 4: Recuperación

Mensaje 85

INFORMACIÓN DEL CENTRO DE COORDINACIÓN DE EMERGENCIAS DE LA GENERALITAT VALENCIANA SOBRE ALERTA POR LLUVIAS

En caso de haber sido evacuado/a o de que su VIVIENDA haya sufrido daños, NO REGRESE A LA MISMA hasta que las AUTORIDADES LO INDIQUEN.

- Si no dispone de información sobre la vuelta a su vivienda, llame al 1·1·2 o acceda a [link].
- No cumplir con las indicaciones de las autoridades sobre la vuelta a la vivienda puede poner en riesgo su vida, la de su familia y la de quienes intentan ayudarle.

Otros recursos:	• Enlace correspondiente.	Palabras clave:	Casa, hogar, evacuación, desalojo.

Fig. 18 Message Card for Phase 4: Recovery/Section 1: Personal safety/Topic Area 1.1. Household environment

2. Cleanliness and hygiene — S+EM

2.1. Return to the home	Phase 4: Recovery

Message 91

INFORMATION FROM THE EMERGENCY COORDINATION CENTER OF THE VALENCIAN GOVERNMENT ON RAIN ALERT

Start CLEANING THE HIGHEST AREAS OF YOUR HOME and leave outside those objects and belongings that have become unusable.

- If the weather permits, open the doors and windows of your home to speed up the drying process.
- If possible, use fans and dehumidifiers to remove excess moisture.

Other resources:	• Tips for Safe Cleaning After a Disaster (CenterS for Disease Control and Prevention): https://www.cdc.gov/es/disasters/cleanup/facts.html.	Keywords:	Flushing, sanitation, cleaning, sweeping, scrubbing, shrinking.

2. Limpieza e higiene — S+EM

2.1. Vuelta a la vivienda	Fase 4: Recuperación

Mensaje 91

INFORMACIÓN DEL CENTRO DE COORDINACIÓN DE EMERGENCIAS DE LA GENERALITAT VALENCIANA SOBRE ALERTA POR LLUVIAS

Comience la LIMPIEZA DE SU VIVIENDA por las zonas más altas y deje en el exterior aquellos objetos y enseres que hayan quedado inservibles.

- Si la situación meteorológica lo permite, abra las puertas y ventanas de su vivienda para acelerar el proceso de secado.
- Si le es posible, utilice ventiladores y deshumidificadores para eliminar el exceso de humedad.

Otros recursos:	• Consejos para la limpieza segura después de un desastre (Centro para el Control y la Prevención de Enfermedades): https://www.cdc.gov/es/disasters/cleanup/facts.html.	Palabras clave:	Baldeo, salubridad, aseo, barrer, fregar, achicar.

Fig. 19 Message Card for Phase 4: Recovery/Section 2: Cleanliness and hygiene/Topic Area 2.1. Return to the home
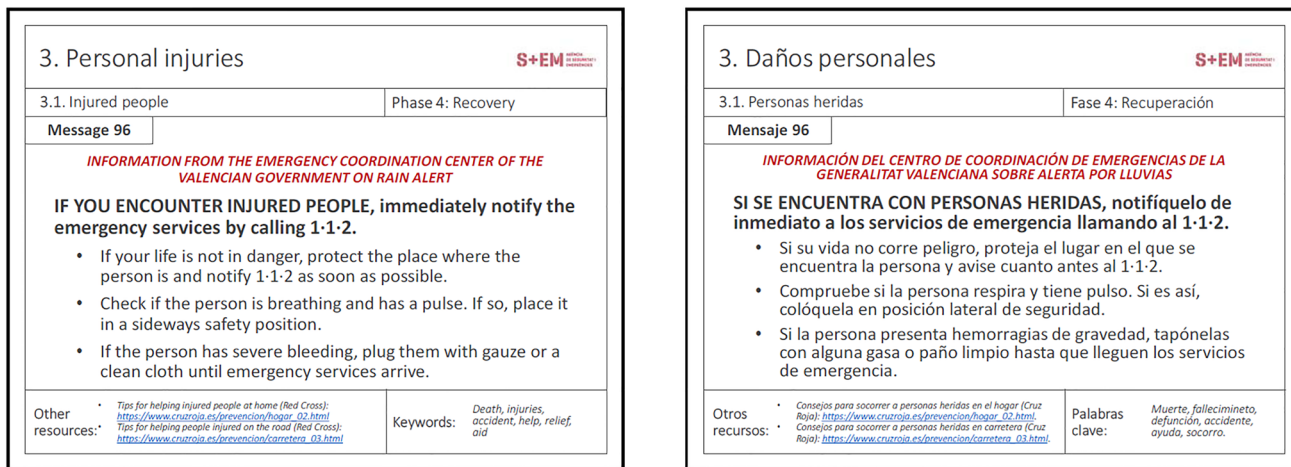
Fig. 20 Message Card for Phase 4: Recovery/Section 3: Personal injuries/Topic Area 3.1. Injured people
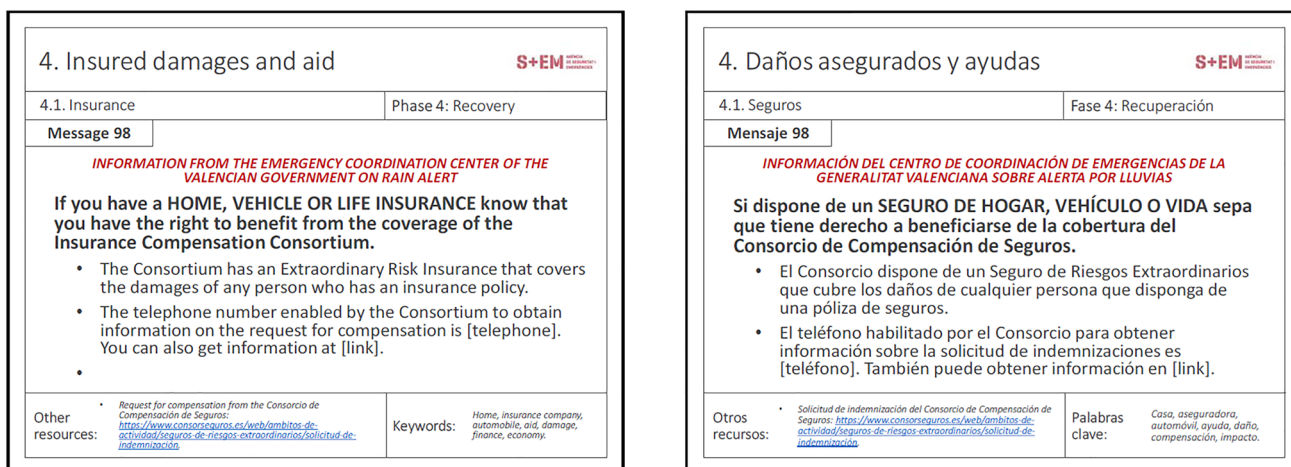
Fig. 21 Message Card for Phase 4: Recovery/Section 4: Insured damages and aid/Topic Area 4.1. Insurance

general alert systems, there is a recognition of the need for communicative adaptation to the particularities of the local contexts and the diverse type of hazards. As Sorensen (2000: 119) puts it "a 100% reliable warning system does not exist for any hazard." In this sense, warning systems are a complement to alert systems, given their capacity to incorporate a wider range of topics, objectives (awareness, preparation, capacitation, etc.), and communicative resources.

Despite their strategic importance, most emergency services across the world have not yet developed warning message catalogs or libraries. However, there is currently a growing demand for the design and implementation of protocols for the standardized production of this kind of content. The methodological proposal and results presented in this paper address this by creating a catalog of warning messages for flood events based on the particularities of this hazard as well as the needs expressed by the population in

the calls received by the 112 services during the disastrous flood event of 2019 in Vega Baja (Alicante, Spain). This bottom-up approach was aimed at ensuring the coherence of the warning messages with the particular way in which the event developed in the case study and provides a procedure that can be re-applied in other contexts and events.

Also, this catalog of warning messages adds value to the advice and recommendations found in the specialized literature due to two main features: (1) The systematic and functional structure and textual content formulation of the warning messages. This project claims that warning message catalogs are an essential strategic resource for comprehensively identifying areas of action, organizing information into topic categories, standardizing the development of messages, and ensuring that they communicate appropriately. Such systematization can enhance the scope and effectiveness of the warnings issued by emergency services. Also,

this type of standardized database aims to facilitate the work of the emergency services at critical times in which speed of communication and action is key to ensuring an effective response with a positive impact in reducing material and human damages. The research team has been especially careful in creating an internal structure for the catalog that facilitated its use by the emergency agencies or risk managers. This system was also essential to ensure the exhaustiveness of the topics. The analysis of 4,078 calls received by the 112 services, together with the review of the messages produced by diverse agencies, have allowed the identification and categorization of the demands of affected populations as well as the prioritized topics tackled by different emergency centers, with a resulting catalog of 20 sections, 55 topic areas, and 99 messages. (2) Coverage of the entire disaster cycle, organizing the messages into its main phases. The prerequisite of exhaustiveness and systematicity imposed a diachronic design of the catalog that covered the different stages of the disaster's life cycle. Unlike alert systems, this catalog focuses on both, the pre-disaster phase with advice on how to prepare households and individuals for the disaster, and during and post-disaster phases with useful information to facilitate effective response, and the return to normality and recovery of the affected population.

Clearly, the pilot nature of this study necessarily involves limitations that must be considered. This was a problem-oriented project commissioned by an emergency agency with the very specific need and demand of creating a warning messages catalog for a particular territory and natural hazard (floods). Therefore, the resulting catalog provided by this project needs to be interpreted as a necessary first step for the improvement of warning systems in the Valencian Region, and one of a series of strategies implemented by the regional authorities in the aftermath of the 2019 event. However, this pilot experience should be complemented with further research.

The limitations of this pilot research have been thoroughly pondered and are planned to be addressed in an future extension of this research, with the incorporation of the following improvements: (1) It is convenient to extend and complete the testing of the catalog in three main aspects: (a) given its pilot nature, this catalog was written in Spanish and consequently tested only among the native Spanish-speaking population. However, the socio-demographic diversity of the case study makes translation to and testing in other languages necessary in order to ensure full coverage of the relevant target population; (b) testing was carried out on the basis of a recent event of which the population—and the participants in the testing actions—still have a fairly clear memory. It will be necessary to test the messages in flood-prone areas that still have not suffered from a recent major flood event; (c) also, it is recommended to increase the heterogeneity of the testing groups, with a stronger focus on vulnerable populations. (2) Further research needs to also cover the particularities of other types of flood events, such as flash floods or coastal flooding. (3) Definitive results about the effectiveness and incidence of this catalog can only be achieved once the emergency authorities apply it to a real event, for which it will be necessary to create an ad-hoc evaluation system. (4) This catalog was designed to be used in diverse online outlets and mobile-telephone systems. It would be convenient to adapt the messages to the specific characteristics of the different communication platforms (push notifications, sms, diverse social media, alert and warning apps, etc.).

Lastly, it should be noted that the procedure presented in this article, although designed to address emergency factors occurring specifically in flood events, can be used to develop warning message catalogs for other hazards. Therefore, beyond the particular end-product provided with the creation of this catalog in the selected case study, the most important contribution of this study in the field of emergency communication is the proposal of a context-adapted replicable method for the comprehensive, systematic, and functional development of warning messages for environmental risks and other stressful events.

Declarations

Competing interests The authors declare no competing interests.

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