

Principles for collaborative risk communication: Reducing landslide losses in Puerto Rico

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ABSTRACT

Landslides are frequent and damaging natural hazards that threaten the people and the natural and built environments of Puerto Rico. In 2017, more than 70,000 landslides were triggered across the island by heavy rainfall from Hurricane María, prompting requests by local professionals for landslide education and outreach materials. This article describes a novel collaborative risk communication framework that was developed to meet those requests and shaped the creation of a Spanish- and English-language Landslide Guide for Residents of Puerto Rico. Collaborative risk communication is defined here as an iterative process guided by a set of principles for the interdisciplinary coproduction of hazards information and communication products by local and external stakeholders. The process that supports this form of risk communication involves mapping out the risk communication stakeholders in the at-risk or disaster-affected location—in this case Puerto Rico—and collaborating over time to address a shared challenge, such as landslide hazards. The approach described in this article involved the formation of a core team of government and university partners that expanded in membership to conduct collaborative work with an informal network of hazards professionals from diverse sectors in Puerto Rico. The following principles guided this process: cultural competence, ethical engagement, listening, inclusive decision making, empathy, convergence research, nested

mentoring, adaptability, and reciprocity. This article contributes to the field of risk communication and emergency management by detailing these principles and the associated process in order to motivate collaborative risk communication efforts in different geographic and cultural contexts. While the work described here focuses on addressing landslides, the principles and process are transferable to other natural, technological, and willful human-caused hazards. They may also serve as a roadmap for future partnerships among government agencies and university researchers to inform the cocreation of science education and outreach tools.

Key words: Hurricane María, natural hazards, landslides, collaborative risk communication, science education, public outreach, convergence, interdisciplinary teamwork

INTRODUCTION

Hurricane María made landfall in Puerto Rico as a Category 4 hurricane on September 20, 2017. Following on the heels of Hurricane Irma, Hurricane María was the archipelago's deadliest hurricane in more than a century.¹ High-intensity rainfall triggered more than 70,000 landslides, damaging infrastructure and disrupting lives.² The highest concentration of landslides occurred in the island's mountainous interior,³ where many roads were blocked, impeding search and rescue efforts and the distribution of

postdisaster aid. In rural areas, many of the residents impacted by landslides were elderly and had to clean up dirt and debris without family support because members of the younger generation had previously moved away from rural communities.⁴

The widespread impact from the hurricane and landslides prompted requests by local professionals responding to Hurricane María for improved landslide hazard assessments for the island as well as better science education and outreach materials describing residential landslide risk. The US Geological Survey (USGS) responded to those requests by launching new science efforts with the University of Puerto Rico Mayagüez (UPRM) to better understand the hazards posed by landslides, including a digital database of landslides from Hurricane María and a high-resolution landslide susceptibility map of Puerto Rico.^{2,5} The USGS also leveraged a longstanding academic partnership with the Natural Hazards Center at the University of Colorado Boulder to create education and outreach materials about landslides. The USGS and Natural Hazards Center, in turn, partnered with faculty and students from the Department of Geology at UPRM to

create these educational materials. Researchers and students who were involved in the scientific assessment also worked on the collaborative risk communication project described in this article to develop Spanish- and English-language versions of the *Landslide Guide for Residents of Puerto Rico* (Figure 1).

The core team from the USGS, Natural Hazards Center, and UPRM collaborated with planners, emergency managers, geologists, and meteorologists from Puerto Rico. These collaborators were in dialogue with the core team over the course of a year and contributed written content, photos, and constructive feedback to improve the risk communication materials. The core team and collaborators operated within an even broader ecosystem of risk communication stakeholders in a variety of relevant disciplines, many of whom shared local knowledge or were involved with distributing the landslide educational materials. (See Appendix table for a list of collaborators and stakeholders.) Importantly, UPRM's role on the core team shifted a significant portion of project ownership from a group of researchers located on the US mainland to a faculty member and students in Puerto Rico. This

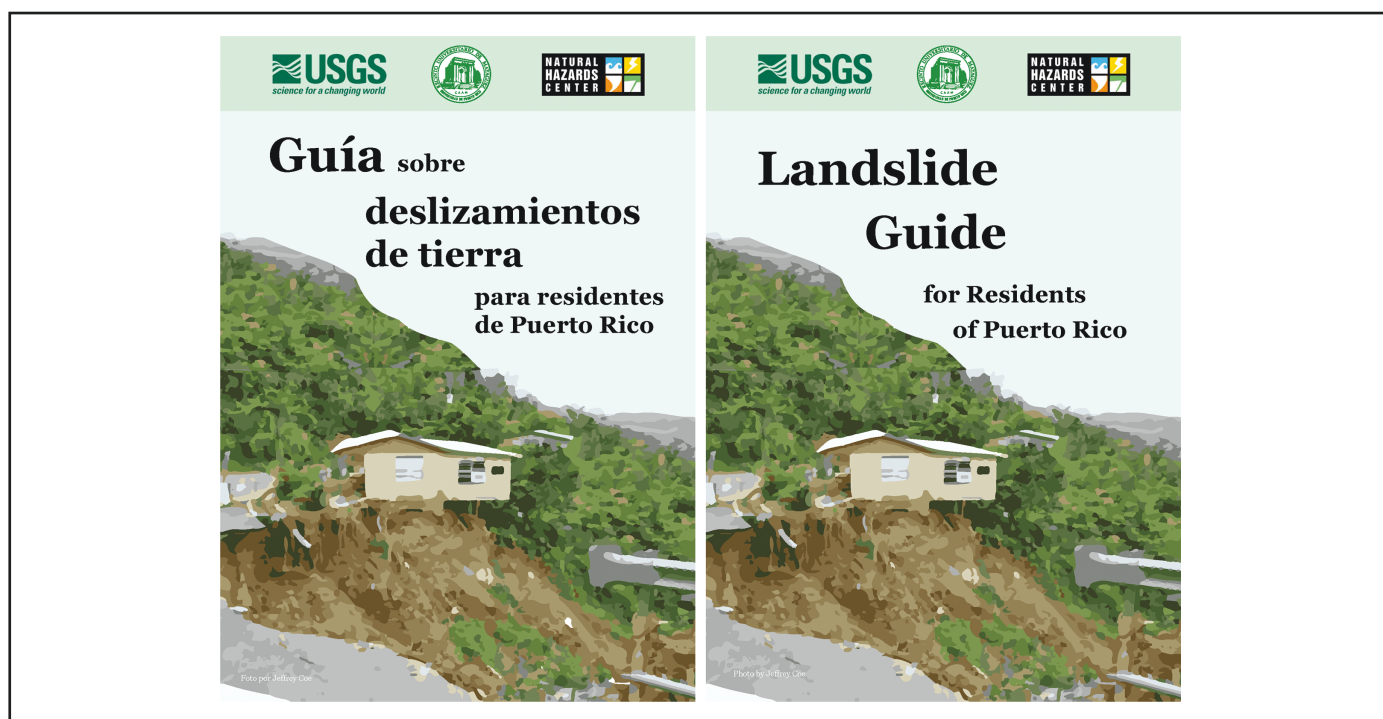


Figure 1. Covers of the *Landslide Guide for Residents of Puerto Rico*, in Spanish and English.

ultimately helped to ensure the educational products were culturally and linguistically aligned with the needs of our audience and partners in Puerto Rico.

This article describes a novel collaborative risk communication framework that our team developed in the process of completing this project. Collaborative risk communication is defined here as an iterative process guided by principles for the interdisciplinary coproduction of hazards information and communication products by both local and external stakeholders. This approach to risk communication uses a cyclical process of collaboration, cocreation, and feedback on risk communication materials and activities over an extended period of time. Collaborative risk communication builds upon several existing frameworks for risk communication,⁶⁻⁹ while emphasizing adaptability and convergence research to address compound hazards and disasters.¹⁰ This article contributes to the literature on risk communication and stakeholder engagement by: (1) defining and illustrating the key tenets of collaborative risk communication and (2) describing the nine principles that guided our work as we coproduced landslide education and outreach materials with and for residents of Puerto Rico. Although we focused on collaboration with emergency managers, mitigation practitioners, disaster researchers, landslide hazard experts, and risk communicators in Puerto Rico, we argue that the principles and process explained here can serve as a roadmap for future partnerships among those working to reduce hazards risk in many different contexts.

Risk communication

Risk communication is integral to effective emergency management. The initial motivation for risk communication research arose in response to research on risk perception in the field of psychology in the 1960s and 1970s, which distinguished between perceptions of risk held by scientists and nonscientists.¹¹ Risk communication was seen as a mechanism for closing the gap between rational, scientific assessments of risk and common heuristics used by the public.^{6,11,12} For this reason, early conceptions of risk communication involved a one-way transfer of knowledge from experts to the public.¹³

Over time, risk communication research and practice has moved from a focus on risk assessment and improving public understanding of risk to a focus on engaging at-risk populations as partners in more democratic educational and decision-making processes.^{13,14} Components of this type of risk communication include symmetric communication, mutual benefit for all parties,¹⁵ and a strong emphasis on participatory processes and two-way exchange between information providers and receivers.^{6,16} In these instances, risk communication is defined as “a dialog conducted to help facilitate a more accurate understanding of risks among people and, related, the decisions they may make to manage them.”^{14pp1245-1246}

Recent scholarship has encouraged shifting the emphasis from communicating risk itself to communicating about preparedness actions—what Wood et al.⁹ call “communicating actionable risk.” This work also emphasizes the dual value of *information observed* such as seeing preparedness actions taken by those around you, and *information received* such as guidance about a particular hazard and preparedness actions one can take.^{9p601}

For risk communication involving the general public and vulnerable populations, Campbell et al.^{17p2} underscore the need to adhere to three common and long-standing principles: “Communicate through familiar and trusted messengers; provide clear, actionable information; and tailor messages and information pathways for target audiences.” Best practices recommended by others include: maximizing the use of trusted local media channels, developing risk communication products through collaborative partnerships with local organizations,¹⁸ understanding the needs and priorities of partners,^{18,19} and ensuring the risk communication process and products are context-specific.^{13,20} Risk communication research has also demonstrated that effective disaster preparedness campaigns require multiple vectors of credible and consistent information delivered by trusted messengers.^{9,21-23} Moreover, such strong and trusting relationships between multiple local and external partners are vital to establishing and maintaining effective risk communication channels.^{16,24}

Despite growing use of the label “two-way” to describe risk communication, skepticism remains among some scholars regarding whether certain initiatives have invested the required time and effort necessary to develop trust and most effectively communicate risk.^{13,14} Indeed, multidirectional risk communication has been touted for more than three decades,²⁵ but it remains difficult to carry out successfully, perhaps because the field of risk communication has lacked clear models and guidance for how to do so. Such multidirectional risk communication is particularly challenging in the context of scarce resources, limited budgets, compound disasters, political division, and rising public mistrust of officials and scientists.^{14,24,26} As the United States grows more ethnically diverse and more socially and economically stratified, it is ever more urgent to understand how different populations who are exposed to a range of hazard threats may receive, respond, and contribute to risk communication.¹⁷

Landslides in Puerto Rico

Landslide risk in Puerto Rico is a function of high landslide susceptibility⁵ and frequent intense rainfall²⁷ exacerbated by certain building and land use practices, such as construction on steep slopes or historical deforestation.²⁸ The spatial distribution of exposure to landslides in Puerto Rico has roots in the historical, social, political, and economic arrangements that limited access to land and housing and perpetuated poverty in the interior mountains.²⁹ This has left poorer, rural residents of Puerto Rico with greater landslide risk.

The single deadliest landslide in US history, the Barrio Mameyes landslide near Ponce, occurred on October 7, 1985 during a three-day period of heavy rainfall.^{30,31} The slide, which happened prior to widespread public awareness campaigns about landslide hazards, killed an estimated 130 people and destroyed 120 homes built on a hillside without planning or regulation.³⁰ Subsequent research found that improper septic collection and water distribution operation likely contributed to the slide movement.³²

Rainfall associated with tropical cyclones has caused extensive landslide occurrence as well. The

deadly San Ciriaco Hurricane, which made landfall in Puerto Rico on August 8, 1899, caused landsliding in Utuado and the mountainous interior of Puerto Rico.¹ More recently, intense rainfall associated with Hurricane Hugo in 1989 triggered hundreds of landslides in the eastern part of the island.³³ The more than 70,000 landslides that occurred during Hurricane María stand as the most ever recorded on the island.

Effective household response to landslides, hurricanes, flooding, earthquakes, and other natural hazards in Puerto Rico is dependent on the level of awareness of potential threats, available resources, and actions that can be taken to reduce the associated risk.²⁸ Research examining the effectiveness of risk communication campaigns in Puerto Rico has noted that the provision of flood hazard information through pamphlets is not sufficient to mitigate such risk,³⁴ and the success of public health messaging was increased by delivering information through many forms of media to reach larger audiences.³⁵ Recommendations for landslide risk communication focus on education targeted towards children, in particular.³² Among adults, risk perception of landslides in Puerto Rico has often been overshadowed by concern for other natural hazards such as hurricane winds, flooding, and earthquakes, which are often considered less predictable or more destructive.²⁸

Landslide hazards and collaborative risk communication

In this section, we elaborate on a project designed to increase focus on landslides as a prevalent but sometimes underestimated hazard in Puerto Rico. We proceed by describing the process for creating the first product, the *Landslide Guide for Residents of Puerto Rico*, which is an illustrated booklet available in print and digital formats in English and Spanish; it also serves as the foundation for a suite of related landslide risk communication products, such as videos and online interactive story maps (<https://hazards.colorado.edu/puertorico>).

In establishing the process for collaborative risk communication, our core team relied on a set of principles for stakeholder engagement and envisioning, coproducing, and distributing these education and

outreach materials. As elaborated below, a broad range of literature in emergency management, risk communication, and disaster research provides the foundation for each of the principles. In addition, we turned to the growing body of research on disaster research ethics³⁶⁻³⁸ as well as cultural competence in disaster research and practice^{39,40} to inform our process. The principles underpin a relationship-based and collaborative approach to risk communication, informed by tenets of environmental education that have been advocated for by Indigenous scholars.⁴¹ Further, our work is grounded in respect for the social, historical, and geographic context of Puerto Rico and seeks to advance landslide risk reduction efforts on the island.

THE PROCESS

This project relied on three initial approaches to inform the creation of the *Landslide Guide*. First, we developed an annotated bibliography of risk communication research related to landslides in Puerto Rico. Second, we conducted a systematic review of existing landslide education and outreach materials. Finally, we cocreated an engagement strategy based on relationship building and informal interviews with risk communication professionals and residents of Puerto Rico who live in areas of high landslide susceptibility. Through a combination of these three information-gathering methods, we combined and refined our inputs for a first draft of the *Landslide Guide*.

The annotated bibliography and our review of existing landslide education and outreach materials helped us identify key scientific insights and mitigation recommendations (Appendix). Available information about landslides is voluminous, and no single education and outreach booklet could cover the full range of topics. In order to identify the most critical issues to be covered in the educational materials we planned to develop, we identified and analyzed examples of existing landslide communication products that addressed issues similar to our needs. We used a spreadsheet to cross reference the information gleaned from each existing product, such as format, target audiences, phases of the disaster cycle addressed, eg, preparedness, mitigation, etc., and recommendations.

This allowed us to assess what other landslide risk communicators found most important, and to identify creative methods for sharing information. This initial review helped us to identify major landslide-related issues to discuss in subsequent informal interviews.

In order to create useful landslide education and outreach materials, we needed to develop relationships with a diverse array of professionals who had expertise in landside science, risk communication, emergency management, land-use planning, and other allied fields. Because the goal of our project was not academic research and we did not want our collaborators to feel like research subjects, we chose to take a less formal approach to information gathering. We began building a network by having conversations and conducting informal interviews, drawing upon referrals within participants' social networks. Colleagues at the USGS provided our first introductions to people with whom they had established contact during the response to Hurricane María, including the Puerto Rico Seismic Network. Those participants introduced us to other professionals they believed had relevant knowledge, and so on. In the process, we learned about the concerns of the local population related to landslides, including information about the culture, language, and behavior that could inform the content and presentation of the educational materials we were developing.

Although the seeds for this project were planted in October of 2017, we began engaging with professionals and formally building our network in October 2018. Follow-on trips were made in December 2018 and February 2019 to expand the network. Often, we received help coordinating focus groups or meetings from a local collaborator. Through these early interactions, we developed partnerships, learned about previous and ongoing efforts to address landslide hazards, visited recent landslide sites around the island, and came to understand the complexity of landslide mitigation and preparedness in Puerto Rico.

Throughout the next year of the project, we invested substantial time and effort in engaging with the network of stakeholders to inform the content and format of the guide and other related risk communication products. To do so, the four members of the core

team who are not based in Puerto Rico made many trips to the island, spending a total of 123 person-days in Puerto Rico between October 2017 and February 2020. Informational interviews with planners, emergency managers, and other risk communicators that were conducted during those trips and by the three members of our core team who live in Puerto Rico highlighted the need to expand beyond the creation of a risk communication pamphlet in order to reach a broader audience. This insight is consistent with recommendations of related risk communication efforts in Puerto Rico.³⁶ Additional feedback from the growing network helped us see that the guide would need to function in two ways: (1) as a vetted repository of coproduced information and advice about landslides, and (2) as a starting point for the risk communication process. Even so, we recognized that the guide was merely a first step for communicating about landslide hazards through additional channels and formats.

As the project progressed, our core team also spoke with residents and homeowners, some of whose homes were impacted or threatened by landslides. Their perspectives were gathered through informal conversations, nonresearch informational interviews, and group meetings, informing the practical information ultimately included in the guide. We also spoke with approximately 60 individuals through house visits, community engagement events, and stakeholder meetings. Our team captured the conversations by taking detailed meeting notes or writing postmeeting summaries when it felt inappropriate to take substantial notes during conversations. We would subsequently debrief on key themes that were emerging. When we began to hear similar responses from many different stakeholders, we felt comfortable that we had sufficient information to move forward, a point that qualitative researchers describe as reaching “saturation.”⁴²

Maintaining relationships and continuing to gather information was time-intensive but ensured the *Landslide Guide* and any subsequent products would ultimately be aligned with stakeholder needs. For example, many people we spoke with identified specific landslide education products they could use in their existing activities, such as audio recordings that

could reach older populations who regularly listen to the radio. In addition to the invaluable feedback provided, we anticipated that the professionals we met as part of our networking activities would serve as vectors for sharing the *Landslide Guide*. For that to happen, we needed to provide material that could be incorporated into their existing risk communication activities.

Creating the Landslide Guide

The *Landslide Guide* is distinct from other available landslide communication tools in that it is visual, created in Spanish and translated to English, tailored to Puerto Rico, grounded in the latest science, and designed to emphasize actions individuals can take to reduce risk. We incorporated content from standout examples of existing landslide guides, publications about previous landslides and risk communication in Puerto Rico, USGS reports about the island’s geology and previous landslide events, and educational materials about other hazards affecting Puerto Rico. Some of the best landslide guides we found from other projects had graphics that were engaging and easy to understand, and we wanted to follow that model. When reviewing other landslide guides, it also became apparent that we needed to be explicit about our audience and selective about the information included. There is simply too much information about landslides, much of which is highly technical, to communicate everything relevant through a single guide.

The process of collaborative risk communication helped us to narrow down the information included in the guide in a systematic way while seeking feedback regularly. The development of the *Landslide Guide* was therefore highly iterative and involved frequent interactions with our collaborators across Puerto Rico during each stage of the project. It involved regular meetings and a series of 18 drafts of the guide produced over the course of 14 months. Work among the core team was organized via weekly meetings, which allowed us to develop a plan for creating the guide. Two project collaborators, the Puerto Rico Seismic Network and Caribbean Tsunami Warning Program, provided our UPRM undergraduate student team members access to office space and digital media

editing software. Not only were these resources key to the creation of the guide, but the frequent personal interactions also provided additional pathways for stakeholder input.

Continuing to engage stakeholders from multiple organizations across the island, we invited reviews from members of our extended network. Input from physical and social scientists, planners, government employees, emergency managers, and residents of at-risk communities was incorporated into a complete draft through a stepwise review process that involved the review of multiple versions of the guide. Each new reviewer, or set of reviewers, therefore received a more polished draft. Reviewers described the need to broaden the audience of the guide by replacing as much text as possible with graphics to improve

accessibility and to make it more visually engaging for readers. The evolution of the guide's content and the final publication reflects a consensus view on the most effective way to present information on landslide risk and cost-effective mitigative actions for Puerto Rico (Figure 2).

We also utilized input from the network of risk communication professionals to identify the landslide information that would be of greatest use to those professionals in their work managing earthquakes, tsunamis, extreme weather, and other hazards. Reviewers contributed information that helped shape the content of the guide as well as images and professional and personal experiences with landslide hazards. Final technical review was completed by university faculty and landslide scientists from the

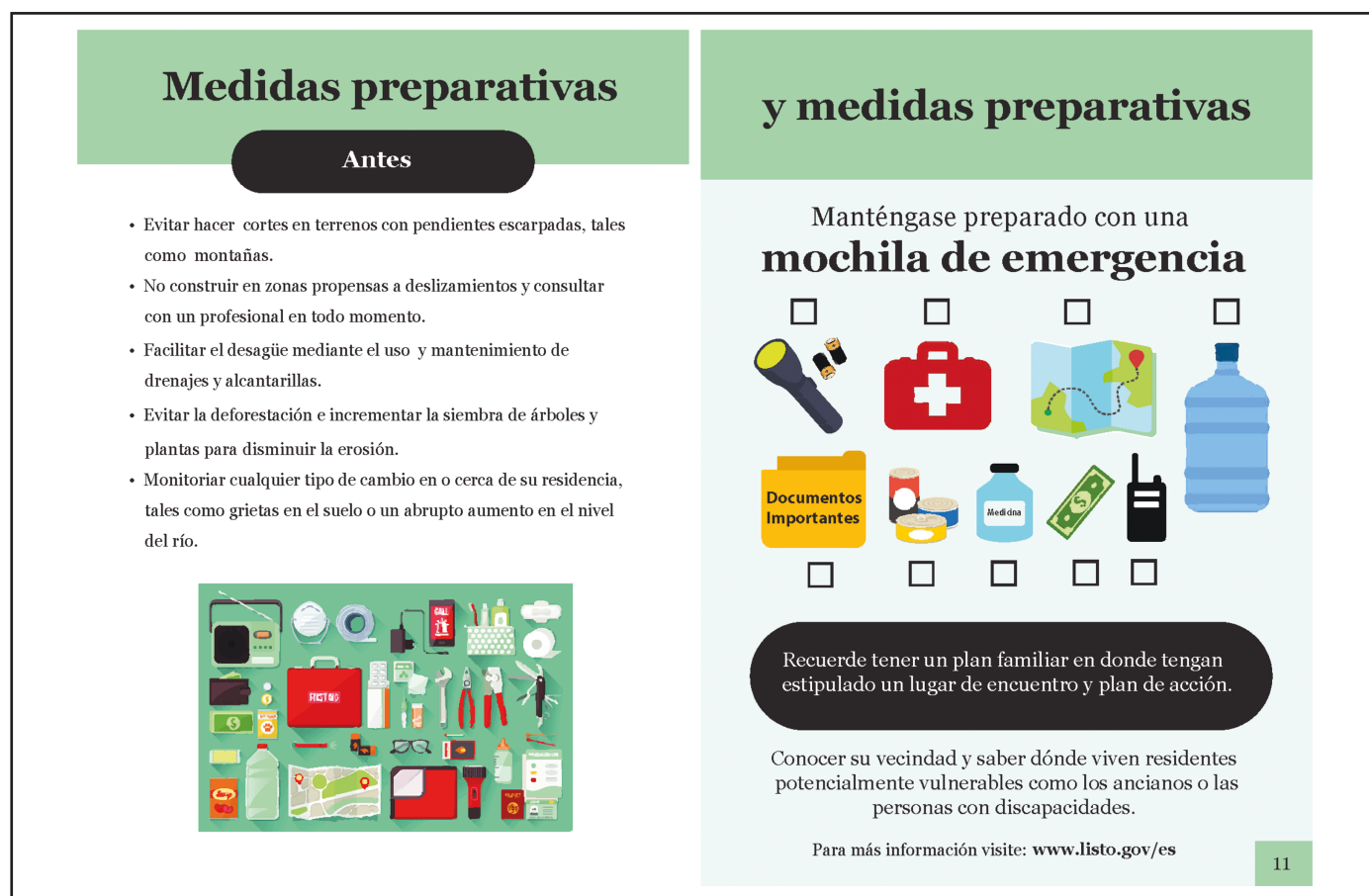


Figure 2. First version and final version of the *Landslide Guide*. Left panel depicts a first draft of the “Preparedness Measures” page with heavy use of text. Right panel shows the graphics created for the final version in response to suggestions and requests from stakeholders.

USGS to ensure the scientific integrity of the information provided. The time needed to employ this iterative process of review and revision was substantial, but the approach provided a means to engage the network of professionals in cocreation of the guide without demanding a burdensome commitment from any one person.

Developing a communications plan and distributing the guide

In order to effectively reach the broadest audience with available resources, the team developed a communications plan to inform the print and digital distribution of the guide. The objectives were to maximize electronic distribution of the guide through the existing network of reviewers and collaborators and to identify key audiences of additional stakeholders potentially willing to share the guide through their networks. One thousand copies of the Spanish-language guide were also printed in Puerto Rico for distribution to audiences that preferred or required a physical copy.

We identified several “disaster risk reduction champions,”^{22,43} and their efforts greatly expanded the reach of the guide. For example, about a month prior to publication and release, a notable Puerto Rican meteorologist gave our team an opportunity to present the guide to her television and online audiences. This interview allowed us to test the reception of the guide and provided another opportunity for feedback from a different audience. She has continued to promote the project, reaching millions of followers through her social media accounts with posts about the *Landslide Guide* after it was released.

Many other stakeholder groups provided outlets and championed the education and outreach materials. For example, a project collaborator and consultant at the Puerto Rico Planning Board requested materials to train inspectors on landslide hazard identification. We also participated in webinars and a youth science camp delivered by the Puerto Rican science museum EcoExploratorio. The Federal Emergency Management Agency (FEMA) requested presentations by our team to engage emergency managers in municipalities around the island and throughout

the mainland United States via a FEMA-supported webinar series. We have also presented the guide at workshops and conferences, and the undergraduate research assistants were hosted by the television network Univision to discuss the guide and landslide hazards in Puerto Rico.

Creating derivative products

After finalizing the *Landslide Guide*, our team began creating derivative products to address the requests of risk communication professionals and reach a broader audience. The full range of open access landslide risk communication products developed in addition to the guide—available in both Spanish and English—includes:

- A presentation slide deck, including speaker notes for each slide;
- An illustrated animation with a voiceover for use on social media;
- A story map explaining the context behind the *Landslide Guide*, including visualizations of landslide density in Puerto Rico based on USGS data;
- Recorded webinars explaining the *Landslide Guide*;
- Written scripts that can be read on radio or television; and
- K-12 educational materials including a slide deck, worksheets, and guided science experiment.

These products were generally developed in Puerto Rican Spanish and later translated to English, as was done with the *Landslide Guide*. We understood from our interviews that younger generations in Puerto Rico prefer to consume information from social media, whereas older residents often listen to the radio or rely on local presentations from NGOs, emergency managers, and others. As such, we tried to ensure that the

range of derivative products would reach a wide cross section of the Puerto Rican population.

The *process* of creating the *Landslide Guide* as well as these derivative products is shown in Figure 3. This roadmap is meant to illustrate the major milestones along the way and the key partnerships that made this effort possible.

The time and effort dedicated to the *Landslide Guide* and derivative products have paid off in terms of expanding the projects' reach. For example, 500 people have attended our presentations, and, collectively, there have been more than 18,000 views of our recorded video presentations and interviews on social media. We have also received a dozen requests from stakeholders for presentations about landslides. To date, 700 print copies of the guides have been distributed to residents by our team or through our risk communication partner organizations. Posts on social media about the *Landslide Guide* have received thousands of likes, comments, or shares, and commenters often thank us specifically for providing this information in Spanish. Indeed, our extended network of risk communicators has helped the USGS communicate

time-sensitive hazards information for Puerto Rico in Spanish related to both earthquakes and hurricanes.

PRINCIPLES OF COLLABORATIVE RISK COMMUNICATION

The following core principles informed this collaborative project and the process described above: cultural competence, ethical engagement, listening, inclusive decision making, empathy, convergence research, nested mentoring, adaptability, and reciprocity (Table 1). Together, these principles help illuminate how to engage in collaborative risk communication while harnessing the power of interdisciplinary, cross-cultural teams. It is important to underscore that these principles all operate simultaneously and reinforce one another throughout the risk communication process. They help address questions of how to build and sustain the successful relationships that enable multidirectional exchanges involved in collaborative risk communication.

Cultural competence

Cultural competence is one of nine core principles that we used to guide our efforts in Puerto Rico.

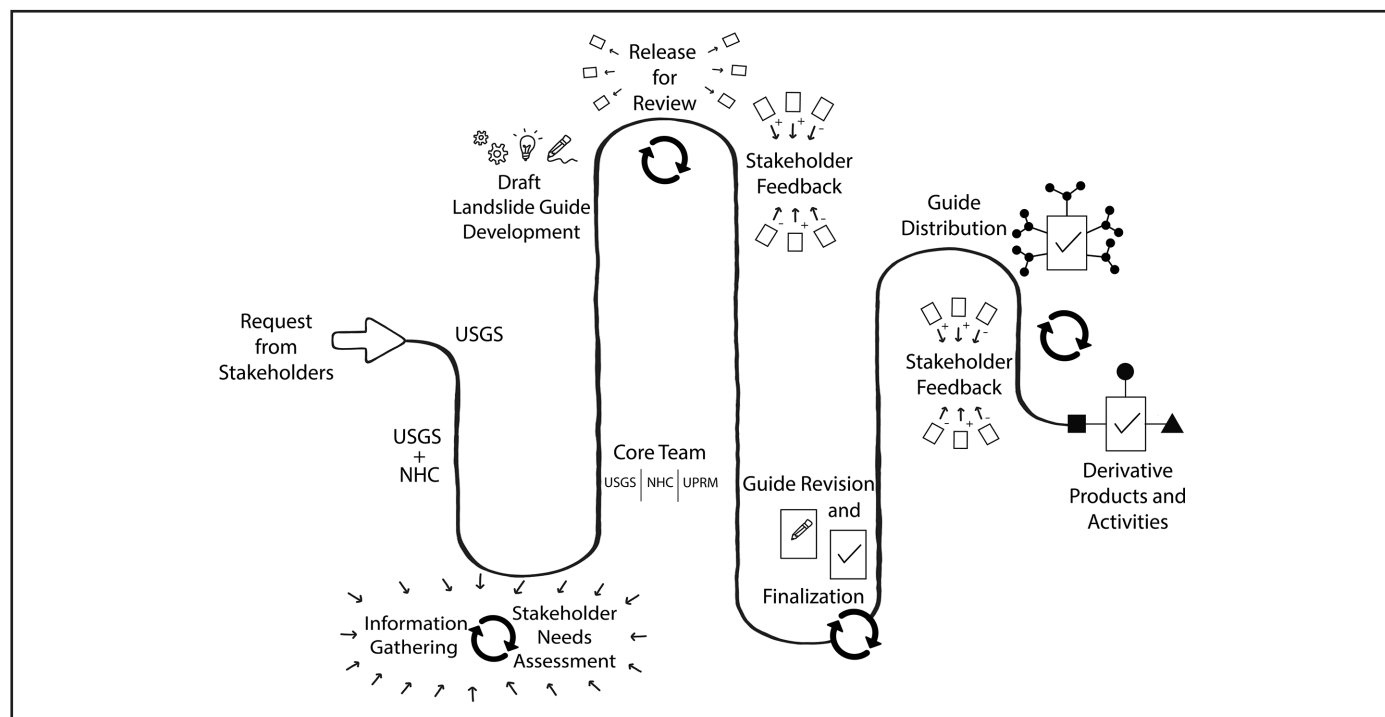


Figure 3. Roadmap illustration of the process used to develop the *Landslide Guide*, starting on the left. Circles with arrows represent iteration of activities.

Table 1. Principles of collaborative risk communication

Cultural competence	Aligning the project with social, cultural, historical, political, and environmental contexts to provide greatest benefit
Ethical engagement	Building collaborative working relationships based on what is just, equitable, and morally sound for all involved
Listening	Seeking regular feedback in recognition of the knowledge and capacities of local populations
Inclusive decision making	Encouraging and utilizing input from all those who come into contact with the project, including creating a nonhierarchical team structure
Empathy	Recognizing, respecting, and validating the unique experiences of people involved with or affected by the project
Convergence research	Approaching research through the lens of a specific and compelling problem and working toward solutions that require extensive integration across disciplines
Nested mentoring	Mentoring of current and next-generation professionals through reciprocal relationships
Adaptability	Anticipating and making changes as needed in response to new information and current events
Reciprocity	Finding meaningful, tangible ways to give back to those who contribute to a project through a practice rooted in gratitude

Cross et al.^{44p13} define cultural competence generally as: “A set of congruent behaviors, attitudes, and policies that come together in a system, agency, or among professionals and enable that system, agency, or those professionals to work effectively in cross-cultural situations.” With respect to collaborative risk communication, we define cultural competence as the proactive and ongoing process of aligning our project with social, cultural, historical, political, and environmental contexts to make the risk communication process and products relevant, appropriate, and beneficial to those exposed to landslide hazards.

Disaster researchers and emergency management practitioners commonly work in geographic and cultural contexts that are unfamiliar to them, so cultural competence is critical for outside professionals to ensure their actions do not exacerbate inequality or further harm affected populations.^{40,45} Because four of the seven members of our core team do not live in Puerto Rico, cultural competence was important for aligning our perspectives and communication with the local cultural context. Three of the non-Puerto Rican members of our team are proficient in Spanish, and each person made a concerted effort to understand the unique culture and environment of Puerto Rico by immersing ourselves in Puerto Rican media, reading books by local authors, listening to podcasts, and visiting cultural and historical sites during time spent on the island.

As indicated previously, one of our policies was to develop the education and outreach materials in Puerto Rican Spanish first, then to translate to English as needed. This stands in sharp contrast to traditional science communication practice on the US mainland, where most of the guidance about hazards is written or created in English first, then (sometimes) translated to other languages. Most of the population in Puerto Rico speaks Spanish as their primary language, so creating content in Puerto Rican Spanish at the outset was an important aspect of our risk communication efforts. This approach ensured our educational materials would be as relevant and intuitive as possible to our intended audience.

Collaborative efforts among professionals and students in Puerto Rico and with the external stakeholders helped accelerate what Wu et al.⁴⁰ have described as a stepwise process for developing cultural competence, where researchers and practitioners move from cultural awareness, to knowledge, to sensitivity, to competence. Strong rapport among team members supported regular, open communication that guided the project towards alignment with the local cultural context. These relationships provided avenues for direct and immediate feedback about adjustments that needed to be made to the education and outreach materials and the process used to develop them.

Ethical engagement

Research ethics is a broad term that refers to a set of principles, or ethical standards, that govern the conduct of scientific research and practice and, above all else, “protect the dignity, rights, and welfare” of those involved.⁴⁶ Recent publications have called for greater attention to ethics in disaster research.^{47,48} Browne and Peek^{36p82} observe that ethical concerns span the entire lifecycle of long-term disaster research projects. Likewise, risk communication projects often involve ethical uncertainties and asymmetrical relationships among participants, who vary in their levels of influence over risk, access to risk information, and initiation of risk communication messaging.⁴⁹ Such asymmetries in risk communication create the potential for ethical dilemmas that can threaten to upend research projects and practical interventions.³⁶

In response to the complexity of engaging ethically in diverse communities, the field of risk communication has moved toward centering core principles of risk communication while adapting them to ensure that audiences and stakeholders from across the whole community are involved. This entails asking about “political, ethical, and other issues that may shape people’s attitudes toward risk and their capacity to take steps to reduce it.”^{17p11} Thus, the principle of *ethical engagement* in risk communication seeks to proactively acknowledge and address imbalances among collaborators and participants in a risk communication process while moving toward more just and equitable approaches to community involvement.

We sought to use ethical engagement as the first and final reference points for any major decisions in our project. At a minimum, ethical boards and other institutional oversights require researchers to “do no harm.” By centering ethics in our practice, our team sought to move beyond such basic institutional review board requirements. This meant, in practice, that we regularly asked questions like, Is this ethical? Ethical for whom? Is this just and fair? How can we ensure that our own ethical principles and the values of others are inherent in the processes and the products that we are creating? By asking these

types of questions about our work, our goal was to infuse ethical decision making throughout our entire engagement process and to make the most ethically informed decisions possible.³⁶

Ethical engagement is critical across the disaster lifecycle—from preparedness to response to recovery to mitigation. During postdisaster periods in particular, however, centering ethics becomes paramount as researchers and practitioners may be regularly interacting with disaster-affected people who are coping with varying forms of trauma and loss.⁴⁷ We were made keenly aware of this dynamic in Puerto Rico, as our collaborators and project participants not only expressed challenges related to the ongoing impacts of Hurricane María but also described the economic inequality, social disinvestment, and chronic hazards such as heat and flooding that made recovery slower and more difficult. While we could not address every issue, centering ethics helped us to see through a more holistic and principled set of lenses.

Listening

The principle of listening was central to this project. Collaborative risk communication calls for listening to local stakeholders from the start and developing the project from the ideas and feedback shared. Our commitment to listening emerged both from our commitment to the practice and from prior cautionary tales. Indeed, in a variety of postdisaster contexts, problems have arisen when outsiders did not take the time to listen to local people.⁵⁰ Thus, listening to the stories of local people and fellow collaborators is essential to ensuring that interventions are effective and appropriate for the local context.^{51,52} Listening focuses on ensuring that every individual involved in the project is heard so that their contributions can help shape and advance the project’s mission.

In collaborative risk communication, listening provides a mechanism for multidirectional communication and an understanding that all perspectives are valued. In essence, listening can help counteract power imbalances and the tendency of one-way risk communication that privileges scientific over local knowledge. Collaborative risk communication involves taking the time to identify, meet with, and

hear local voices, and then adapt the project to reflect their requests and contributions. It prioritizes recognizing the knowledge and experiences of others. Listening as a principle also means asking questions and being prepared to receive critical and constructive feedback to help enhance project deliverables.

Seeking out and working to understand the perspectives of local risk communication professionals, urban planners, emergency managers, and residents was a critical part of crafting the *Landslide Guide*. By starting the project with months of informal interviews, meetings, and focus groups, we created opportunities to listen and gathered key perspectives that informed the concept for the guide. Conversations with professionals and residents throughout Puerto Rico helped define a list of desirable characteristics for the guide and associated materials. For example, we heard from stakeholders that the guide needed to be scientifically accurate and culturally relevant to Puerto Rico. We learned that it needed to be cocreated, endorsed, and used by a wide variety of stakeholders throughout the island.

Our team originally considered creating two separate guides about landslides, one for residents and one for emergency management professionals. However, listening to emergency managers, planners, scientists, and other stakeholders, made evident that a single guide could serve the needs of both audiences. Residents could learn directly from the pages of a guide, while hazards professionals could use it as a tool for dialogue to engage community stakeholders and exchange knowledge. Emergency managers indicated that they could use the guide as a reference and starting point for reaching different audiences, combining its recommendations with their knowledge of Puerto Rico and emergency management. Through this process of listening and tailoring our products to local needs, we demonstrated respect for local knowledge and experience. As a result of these efforts, several stakeholders have incorporated the guide and related products into their ongoing outreach activities.

Inclusive decision making

Inclusive decision making refers to the democratic process of steering a project by proactively

incorporating input from all stakeholders. This approach draws upon definitions of inclusive risk governance⁵³ as well as participatory research approaches,⁵⁴ which recognize an expansive range of knowledge types and encourage reflexivity in decision-making processes. In this project, the principle of inclusive decision making involved encouraging constructive feedback and responding to input from all those who became involved. While we sometimes received conflicting feedback—and, therefore, could not follow every recommendation—we remained committed to inclusive decision making and thoughtful action at all times.

Inclusive decision making, like listening, relies on demonstrating respect for each person's knowledge, experience, and perspective, regardless of any social or professional status. In terms of the dynamics within our core team, each member had varying levels of experience and was at a different career stage. Nevertheless, each team member's ideas were treated as equally valid and were incorporated when feasible into project-related decisions. As a matter of practice, none of our senior members made a decision without consulting other members of the core team and local stakeholders in Puerto Rico.

When a decision needed to be made, our core team did so through a bottom-up process of consensus, consolidating the input from our extended network. Because local team members in Puerto Rico had the best context for what decision would be appropriate regarding many issues, it made sense for our Puerto Rico-based team members to lead the consensus-based decision-making process. Reaching consensus involved combining different types of expertise, including: the lived experience and situational awareness of undergraduate research assistants in Puerto Rico; field research and scientific expertise on landslide hazards; and the decades of experience of senior team members related to risk communication and project management.

Because of the hierarchical systems that structure our work environments in academia and government, the principle of inclusive decision making needed to be reinforced regularly throughout the project to ensure all team members felt confident and welcome to voice their ideas and concerns. Any time

we faced major turning points in the project activities, our options for next steps were generated among the whole team, including input from colleagues in our extended network; then, next steps were decided upon as a collective. The principle of inclusive decision making established a flat structure, rather than a top-down hierarchy, in terms of how the team worked together and steered the project.

Empathy

Empathy is a cornerstone of our model of collaborative risk communication and, recently, it has been recognized as a key component of other models of risk communication.^{8,55} We define the principle of empathy as recognizing, respecting, and validating the unique experiences of people involved with or affected by the project. These stakeholders include those with whom we communicate about risk, those with whom we collaborate, and members of our core project team.

Empathy helps risk communicators meet people where they are. In the Crisis and Emergency Risk Communication (CERC) model, for example, empathy is not just a means to improve risk communication, it is an end goal associated with providing reassurance and reducing emotional turmoil.⁸ Though empathy is not included in all stages of the CERC model, we argue that empathy can improve the entire risk communication cycle.

As we developed landslide risk communication materials, our project team recognized that empathy was crucial to understanding the type of information we ought to provide. As members of our project team interfaced directly with residents whose homes were cracking because they were situated on active landslides, the problem we were tackling was no longer abstract—it was personal. Many of the people who we met were still living in their homes despite the possibility of catastrophic failure of nearby landslides, and those who had been directly affected by landslides expressed a sense of loss, anxiety, and frustration. A strong sense of empathy for these emotions motivated our team to do as much as possible to respond to expressed needs and desires.

Building and practicing empathy facilitated stronger working relationships within our network

of collaborators. We recognized that many of these professionals work tirelessly to decrease risks to the people they serve. Some of our collaborators included, for example, a local emergency manager who is called when landslides block roads and access to hospitals; planning officials responsible for advising on the geology of zoning; weather forecasters entrusted with providing timely and life-saving information to the public; and university professors, who were often juggling teaching courses and research with responding to the needs of their students and local communities. Each of these partners had different responsibilities and demands on their time, but they all shared a common desire and sense of responsibility for the well-being of others. Meanwhile, these professionals were often dealing with the cascading effects of compound natural hazards and disaster fatigue in their own lives and households.

As our recognition of struggles and strengths improved, empathy was a core operating principle for our efforts. Our team is composed of people of various ages, ethnicities, gender identities, geographic locations, career stages, disciplines, and personal experiences with disasters. Our team members in Puerto Rico are both hazards professionals as well as survivors of multiple disasters, including Hurricane María. In order for everyone to work collaboratively, empathy was a necessary practice. It enabled us to foster mutual respect among a loosely networked group of people from different backgrounds. Empathy also guided our response to unexpected situations and compounding disasters that arose in the course of our work together, including the 2020 Puerto Rico M6.4 earthquake and associated seismic sequence, chronic flooding across Puerto Rico, and the global COVID-19 pandemic that affected us all.⁵⁶ Empathy took the form of checking in with team members and collaborators on a personal level and creating space for those concerns to take precedence over our work together or any competing deadlines. More generally, empathy provided a strong motivation to participate in collaborative risk communication and established a foundation to navigate complex circumstances while cocreating with diverse teams and networks.

Convergence research

Hazards researchers and practitioners have long recognized that rising disaster losses demand new approaches to risk reduction. Convergence, with its focus on deep integration across disciplines and research driven by a specific and compelling problem and the potential for novel solutions, offers one such possibility.⁵⁷ In their effort to bring a convergence framework to the hazards and disaster field, Peek et al.^{10p1} define convergence research as: “An approach to knowledge production and action that involves diverse teams working together in novel ways—transcending disciplinary and organizational boundaries—to address vexing social, economic, environmental, and technical challenges in an effort to reduce disaster losses and promote collective well-being.” Our core team was poised from the start to adopt a convergence-oriented approach to our efforts. Our team and extended network of collaborators included a broad range of disciplinary backgrounds relevant to landslide hazards, including geology, sociology, urban planning, emergency management, and meteorology. We also worked across organizational and geographic boundaries.

What bound us together in this project was our common focus on the specific and compelling challenge of landslide risk in Puerto Rico and our commitment to addressing the underlying drivers of that risk. Such “problem-driven” and “solutions-based” approaches are a hallmark of convergence research, which often requires new processes for encouraging deep disciplinary integration, communication, and collaboration.¹⁰ For our team, this entailed aligning and integrating our different languages (Spanish and English), scientific vocabularies (geoscience, social science, urban planning), networks (government, academic, private sector, nonprofit, and media), and understandings of risk. Our common commitment to one another and to the process of convergence to address vexing challenges bound us together and drove us to overcome disciplinary and organizational divides.

In addition, adopting a convergence mindset meant that our team focused on the root causes of landslide-related losses as well as potential solutions. We worked as diligently to characterize challenges as

we did to address them. This meant, in practice, that each time that we identified a driver of landslide risk, we would ask what could be done about the problem—from the perspective of emergency management, academic research, or mitigation practice. This problem-focus and solutions-orientation helped us to develop more realistic approaches for potentially responding to the myriad challenges we had identified.

Nested mentoring

Nested mentoring is a practice in which project team members learn from one another’s personal and professional experiences to support the learning and development of each team member and improve collaboration that is necessary for convergence (also see Bronner et al.⁵⁸). It shapes the structure of a team by embedding multiple layers of mentoring relationships within it, such that early career team members have opportunities to learn from more experienced team members, and vice versa. Nested mentoring facilitates a multidirectional exchange of knowledge and experience, which also aligns with best practices for risk communication.

Among our core team, these nested mentoring relationships typically consisted of students and other early career team members learning from more experienced team members. Still, everyone recognized there was a possibility for multidirectional sharing of knowledge, information, and experience that underpinned the growth of individuals and the team as a whole. These relationships helped honor the different types of expertise that each team member brought to the project. Structuring our work this way ensured that one outcome of the project, in addition to producing landslide materials, would be training the next generation of disaster researchers and practitioners. It also enhanced the mentoring capabilities of all team members.

We used nested mentoring to support and elevate the voices of the early career members of our team. For instance, after learning from and practicing with more senior team members, the undergraduate research assistants presented this work at their first scientific conferences as well as at meetings that centered the voices of students involved in research

after Hurricane María. Nested mentoring helped team members understand how this project contributed to each individual's future goals. For example, we chose activities that would provide the undergraduate and graduate student team members with experiences that could support their application to graduate programs or internships in their fields, and we ensured that more senior team members were able to complete and submit required project deliverables on time.

Nested mentoring supported successful *internal* processes that advanced our *external* collaborative risk communication efforts. By aligning project-based efforts with the individual goals of each team member, we were able to generate a wider suite of products than we had initially envisioned. By showing a common commitment to one another, we were able to sustain motivation and enhance team member satisfaction as we simultaneously built more robust partnerships with one another as well as across the network we were developing.

Adaptability

Adaptability in collaborative risk communication reflects the ability and forethought necessary to work with a dynamic set of circumstances that might alter the trajectory of the project. Research on community engagement for disaster management has emphasized the need for flexible and adaptable approaches,⁵⁹ recognizing that rigidity decreases the ability to creatively overcome obstacles to project implementation. Working in Puerto Rico over the course of three years, we found our project affected by additional natural hazards, political turnover, and ongoing economic crises. Our team had to be prepared to adapt as needed to both new information and to these current events. The structure of our team enabled the flexibility and adaptability that this project required.

The principle of adaptability proved particularly important immediately before the planned launch of the *Landslide Guide* in early 2020. The Southwest Puerto Rico Earthquake Sequence started in late December 2019 and included the M6.4 mainshock on January 7, 2020. The mainshock and associated earthquakes damaged many homes and buildings in the southwest part of the island.^{60,61} Members of our team worked

directly on the federal and local government response to the unfolding seismic sequence. The earthquakes also triggered landslides in the form of rockfalls, one of which briefly blocked a highway connecting southwest Puerto Rico to the capital city San Juan, where many residents commute for work and other needs. There was a renewed sense of urgency and demand for landslide hazard education and outreach materials amid the earthquakes, and we recognized the need to act quickly. We accelerated the public release of the *Landslide Guide* to make it available to residents and emergency managers in Puerto Rico as of February 2020. We were able to adjust our timeline because we had created a Communication and Outreach Plan well in advance of our anticipated launch date. In it we had already identified our relevant audiences and the channels for distributing the *Landslide Guide*.

As the earthquakes continued and our team planned events in Puerto Rico, COVID-19 brought most travel to a halt. Puerto Rico mobilized in March of 2020 to stop the spread of COVID-19 with strict curfews and public health communication campaigns. For our project, limitations on in-person risk communication activities forced us to reimagine the distribution of the landslide materials to prioritize digital formats for the foreseeable future. We sought out and established new partnerships for online risk communication about landslides. For example, our Puerto Rico-based team members initiated a new partnership with the local science museum. This and other such ongoing and emergent partnerships allowed us to connect with our extended network to verify how each of their organizations was adapting to conditions amid the pandemic and to learn how they wanted to receive the coproduced landslide materials.

Reciprocity

The principle of reciprocity encourages a mutual exchange and benefits for all participants involved in research or a collaborative process.⁶² We understand reciprocity to involve maintaining relationships and finding tangible ways to give back to those who contribute to the project. Giving back can be accomplished through a variety of mechanisms over time, for example, by offering verbal expressions of

thanks, volunteering to assist collaborators with their projects, giving gifts, providing food, or compensating people for their time.

Expressing gratitude is one important form of reciprocity. Given the importance of gratitude, we embedded this practice in all our team's interactions. Opening meetings with expressions of gratitude came to define our project culture and these actions shaped our work together as a team. We found that actively valuing individual contributions helps foster a positive atmosphere that motivates hard work and preserves the momentum of education and outreach efforts. Molding the project into a vehicle to elevate local voices on hazards and risk communication, particularly those of our student team members and volunteer collaborators, had the added benefit of empowering and increasing the cohesiveness of our core team and extended network.

In addition to expressing gratitude, we also had project-related funds to support many activities. This meant that we were in a position to, for example, purchase food for in-person meetings, reimburse travel expenses for project partners, and compensate our research assistants for their efforts. Although our team did not have limitless resources, we tried to channel those that we did have toward our stakeholders in ways that aligned with their requests and needs that we observed.

We prioritized giving credit to the members of our team and network of collaborators in our project deliverables. Similarly, we provided either a Natural Hazards Center affiliation or USGS Volunteer status to the students and early career members of our project team. A commitment to reciprocity led us to provide all of our risk communication products for free and in many formats, including presentations, videos, classroom lectures, TV interviews, and copies of the guide in print and online. We have continued to seek out ways to complement and amplify the work of our collaborators and to ensure that their efforts are recognized, respected, and valued.

DISCUSSION AND CONCLUSION

We began this article by defining collaborative risk communication as an iterative process guided

by ethical principles for the coproduction of natural hazards knowledge and communication products by local and external stakeholders. Collaborative risk communication is characterized by a cyclical process of collaboration, cocreation, and feedback on risk communication materials and activities over time. This approach builds upon numerous existing frameworks for risk communication⁶⁻⁹ with an eye toward the increasing need for convergence research in the face of compound hazards and disasters.¹⁰

Disaster management stakeholders and practitioners often represent a wide range of disciplines, from physical science and sociology to engineering and planning. Collaborative risk communication enables such diverse and often geographically distributed stakeholders to work together to align understandings of risk and cocreate relevant communication products. Accessible risk communication products are a necessary foundation for informing protective behavior and reducing losses among people exposed to landslides.⁶³ Stakeholders become engaged in a long-term dialogue that enhances understanding of risks as well as options to manage them.⁶⁴

This article demonstrated how we enacted collaborative risk communication in a project we launched following Hurricane María and which resulted in the publication of the *Landslide Guide for Residents of Puerto Rico*. Specifically, we detailed the process used by our team in Puerto Rico to develop landslide risk communication products and described the set of core principles that informed our every effort both internally and externally. These principles—cultural competence, ethical engagement, listening, inclusive decision making, empathy, convergence research, nested mentoring, adaptability, and reciprocity—were used both within our core team and in the broader ecosystem of partnerships that we formed over the years following Hurricane María.

The collaborative risk communication framework places an emphasis on sound science, principled engagement with stakeholders, and justice in disaster research and practice.^{65,66} Puerto Rican scholars have called attention to the archipelago's history of disaster colonialism, demonstrating how past- and present-day disaster policies have too often reinforced

power imbalances and social inequality.⁶⁷⁻⁶⁹ Risk communication processes and products that are developed from a collaborative risk communication perspective can actively counter such asymmetries to reduce disaster losses and support equitable recovery.

Together, the set of principles described in this article offers a framework for carrying out collaborative risk communication projects. We take the position that these principles are integral to enacting collaborative risk communication, which we conceptualize as an *ongoing and mutually reinforcing process*, rather than an end state (Figure 4). This recognition of risk communication as a process became especially important as our project progressed and Puerto Rico experienced multiple compound hazard events that resulted in cumulative disaster exposures.^{70,71} As the risk communication landscape grew more complicated over time, our collaborative risk communication framework allowed us to adjust and adapt both our processes for engagement with partners as well as the products that we were developing.

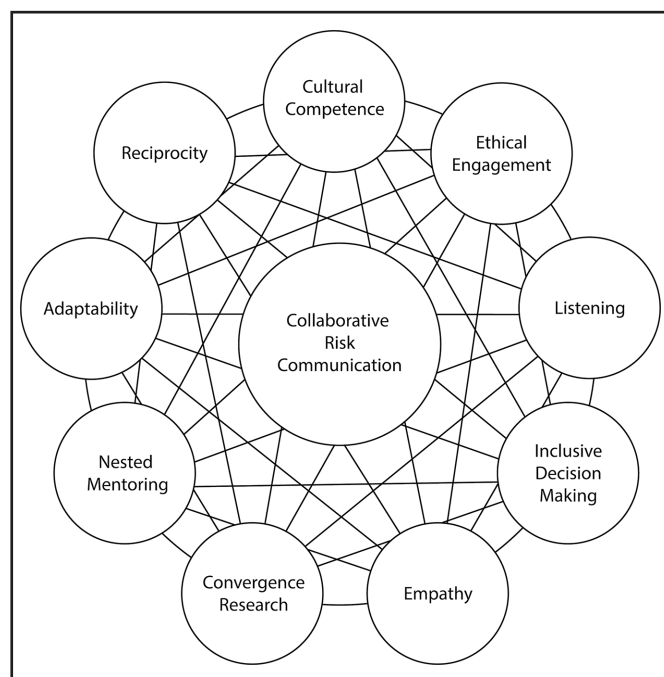


Figure 4. This illustration shows the mutually reinforcing relationships between the nine principles of collaborative risk communication. The principles are not hierarchical and are therefore not intended to be ranked relative to one another.

We came to recognize *time* as an especially important dimension for further consideration in the context of collaborative risk communication. Different levels of engagement and collaboration with counterparts require vastly different time commitments. On a few occasions we realized that too much time had passed since our core team had consulted with some stakeholders, reminding us of the consistent commitment required to maintain strong relationships that facilitate collaborative risk communication. Instead of taking the approach described in this paper, it might have been possible for our core team to develop a landslide guide outside of Puerto Rico, and then consult with Puerto Rican stakeholders only in the final stage. While such an approach might have required less time, fewer partners, and fewer resources, it would not have resulted in a product that was coproduced, vetted, and ultimately coowned by residents and experts in Puerto Rico.

Beyond the production and distribution of the guide, adhering to the principles that allow collaborative risk communication to thrive also requires an investment of time. Therefore, for those who are interested in pursuing this approach, it is important to recognize that slowing down and placing the process before the product is paramount to its success. For this reason, collaborative risk communication efforts should carefully consider such time commitments in advance and establish a realistic project timeline in consultation with collaborators. While developing the *Landslide Guide*, our team had a flexible timeline and sufficient funding to allow the project to evolve over the course of approximately three years. Partnering with local counterparts can lead to vastly improved and more usable communication products, but it calls for allocation of sufficient numbers of people and project resources, both financial and time-related, for effective project planning and management. In the long run, time invested facilitates a process that can generate enduring networks of mutuality and reciprocity rooted in an ethic of care and respect.⁷² The collaborative risk communication process is designed to generate benefits for those involved along the way as well as those served by the final products.

We tried to address as many aspects of landslide risk communication as we could with the resources

we had; however, there are areas we have not yet addressed that we hope will receive attention by researchers and practitioners in the future. For instance, agriculture and private sector building construction are key sectors associated with landslide risk that we have not yet engaged through our project. Reaching those who are most vulnerable will require a continued commitment to nurturing and expanding the coalition of mitigation partners in Puerto Rico.

Although this project focused on reducing landslide losses in Puerto Rico, the principles presented here and the process of collaborative risk communication could be utilized across multiple geographic and cultural contexts. Landslide hazards were our primary focus, but we suggest this process and the principles are applicable across a range of hazard types and landscapes of risk. As emergency managers, scientists, and other professionals look for ways to reduce risk and to effectively communicate about compounding natural hazard threats, we ultimately see collaborative risk communication as a principled approach that can help to build the 21st century constituency necessary to reduce mounting disaster losses.⁷³ We hope that the educational tools and the relationships we have created will support collaborative landslide risk communication long after this current project ends.

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Appendix: Supplementary material	
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Core team	Natural Hazards Center University of Puerto Rico, Mayagüez US Geological Survey
Collaborators	EcoExploratorio Municipal Emergency Managers NOAA Caribbean Tsunami Warning Program NOAA National Weather Service, San Juan Weather Forecasting Office Puerto Rico Highway and Transportation Authority Puerto Rico Planning Board (Junta de Planificación) Puerto Rico Seismic Network San Juan Puerto Rico Science, Technology & Research Trust University of Puerto Rico, Río Piedras
Broader Network of Risk Communication Stakeholders	American Geophysical Union (AGU) Centers for Disease Control and Prevention Federal Emergency Management Agency (FEMA) Geological Society of America (GSA) National Institute for Standards and Technology (NIST) National Science Foundation INCLUDES SURGE RISE Network and Conference Cultural Centers Cooperatives (eg, Cabachuelas) Municipal Governments News Media (eg, Noticentro por WAPA, Univision) Puerto Rican Residents Regional Emergency Managers
*The relative position of contributors within each of the three sections in this list does not imply a hierarchy, rank, or respective level of participation/contribution.	