Risk communication during sismo-volcanic crises: the example of Mayotte, France

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Abstract

a supprimé: successes and limits

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a supprimé: On 10 May 2018, an active seismic crisis began on French island of Mayotte, which a year later will be shown to be related to offshore volcanic activity. It affects a vulnerable territory exposed to risks of many kinds (poverty, violence, lack of basic resources). In the absence of known events in human memory, the population is naive with regard to seismic and volcanic hazards. The concern is therefore very strong. In spite of a large number of , the communication set up by the main actors of the risk chain does not answer the population's concern. To understand why, we analyse a large corpus of the textual communications (press releases, web pages, scientific bulletins, reports, etc.) issued by the authorities and scientists from May 2018 to April 2021. We draw lessons on the communication strategy put in place in the first three years of the crisis; and we issue recommendations for improvement in the future, in Mayotte, but also elsewhere in contexts where comparable geo-crises may happen. We notably stress the importance of ensuring that communication is not overly technical, that it aims to inform rather than reassure, that it focuses on risk and not only on hazard and that it provides clues to possible risk scenarios.¶

Population information is a fundamental issue for effective disaster risk reduction. As demonstrated by numerous past and present crises, implementing an effective communication strategy is however not a trivial matter. This paper draws lessons from the seismo-volcanic “crisis” that began in the French overseas department of Mayotte in May 2018 and is still ongoing today.

Mayotte’s case study is interesting because: i) although the seismo-volcanic phenomenon itself is associated with moderate impacts, it triggered a social crisis that risk managers themselves qualified as "a communication crisis", ii) risks are perceived mostly indirectly by the population, which poses specific challenges, in particular to scientists who are placed at the heart of the risk communication process, iii) no emergency planning or monitoring had ever been done in the department of Mayotte with respect to volcanic issues before May 2018, which means that the framing of monitoring and risk management, as well as the strategies adopted to share information with the public, have evolved over time.

Our first contribution is to document the gradual organisation of the official response. Our second contribution is an attempt to understand what may have led to the reported "communication crisis". To that end, we collect and analyse the written information delivered by the main actors of monitoring and risk management to the public over the last three years. Finally, we compare its volume, timing and content with what is known of at-risk populations information needs. Our results outline the importance of ensuring that communication is not overly technical, that it aims to inform rather than reassure, that it focuses on risk and not only on hazard and that it provides clues to possible risk scenarios. We finally issue recommendations for improvement of public information about risks, in the future, in Mayotte, but also elsewhere in contexts where comparable geo-crises may happen.

1. Introduction

As recalled by the Sendai Framework for Disaster Risk Reduction, population information is a fundamental issue for effective disaster risk reduction (UNISDR, 2015, article 18.g.). Some researchers even consider that a disaster is a result of a crisis or a breakdown in the communication process (e.g. Gilbert, 1998). Implementing an effective communication strategy is however not a trivial matter. As pointed out by previous studies, and as exemplified by the current COVID-19 crisis, there are numerous pitfalls (see Lagadec, 1993; Lindell, Prater and Perry 2006 or Rodriguez et al., 2007 for overviews). Deciding what content, format and medium to use to share information is a first challenge. The information held by the actors in charge of risk management is often partial, sometimes contradictory, especially at the beginning of a crisis when there are many unknowns; the information available - and especially the information produced by scientists - can be difficult to translate into operational terms when there are large uncertainties; actors might also have difficulties in sharing information and/or in coordinating (see Doyle and Paton, 2018; Donovan, Bravo and Oppenheimer, 2012; Donovan and Oppenheimer, 2012; Fearnley and Beaven, 2018 for application on volcanic risks). Reaching the population at-risk is a next challenge. Traditional channels (press releases, public conferences, mass media) may allow reaching a majority of people, but might not help reaching minorities whose habits, customs, and sometimes day-to-day language, differ (Lindell and Perry, 2004). And, it is not enough for a message to reach people, it must then be understood, believed and confirmed to have a chance to induce the expected response (e.g. Mileti and Sorensen, 1990; Mileti, 1999; Lindell and Perry, 2004). This implicitly raises the issue of trust and of the perceived credibility and legitimacy of information providers (see Haynes, Barclay and Pidgeon, 2008 for a reflection on the importance of trust in the management of volcanic risks).

The present paper contributes to the effort made by human and social sciences to build knowledge on risk communication processes. It draws lessons from the seismo-volcanic “crisis” that began in the French overseas department of Mayotte in May 2018 and is still ongoing at the time of writing. It focuses on “public information” i.e. on the information shared by the actors in charge of monitoring and risk management with the public. The corresponding processes are sometimes called “external” communication processes, “internal” communication referring to the exchanges taking place between the actors (e.g. Becker et al., 2018).

Mayotte’s case study is interesting because, although the seismo-volcanic phenomenon itself has been associated with moderate impacts (see section 2), it triggered a social crisis that the risk managers themselves qualified as "a communication crisis" (see section 3). The situation has eased in part nowadays but scientists and authorities are still regularly taken to task, especially on social media (see section 5). Mayotte’s case study is also interesting because, with the exception of felt seismicity, deep sea dead fishes occasionally found by fishermen, and gas bubbling in a few spots on land, risks are perceived mostly indirectly by the population at risk. As Skotnes, Hansen and Krovel (2021) point out, risk and crisis communication about "invisible" hazards poses specific challenges. While trust is a key factor in communication in general, it becomes all the more crucial when one must rely entirely on the knowledge and experience of others to make decisions. The seismo-volcanic phenomena at stake here are not, strictly speaking, “invisible” (not in the sense of chemical or radiological pollution for instance) but everything one knows about it comes from scientific observation and interpretation. This puts scientists at the heart of the risk communication processes. Public information emerges thus in Mayotte, more than ever, as an end product of a complex interface between science, policy and society. Decrypting this interface's mechanisms and dynamics is necessary to help actors, including scientists, better understand their role and its limits[1].

Scientists and authorities have complementary roles to play with respect to population information. The local and national authorities are in charge of informing populations at risk about the nature and evolution of the threat and about the measures put in place to manage or reduce it. Scientists have a key role to play in helping the other stakeholders of the “risk chain”, including the at-risk population and the wider public, to comprehend scientific information as the latter is often too technical for non-specialists (e.g. Newhall, 1999; Fearnley and Beaven, 2018). This role is essential to maintain the legitimacy and credibility of the information on which public decisions are based, scientists being generally more trusted than their official counterparts (e.g. Eiser et al.,

[1] As emphasized by Jasanoff (2004), although science is produced by a specific method in a specific social context, it is influenced by the broader social and political context in which scientists themselves are embedded (this is especially true in risk management contexts when scientists intervene not as researchers but as experts). And science in turn influences the way societies order themselves and organize their response.

2008 on the predictors of trust and Donovan, 2021 for an overview of the challenges faced by experts in crisis contexts).

In Mayotte, as far as seismo-volcanic risk is concerned, a disaster has not yet occurred - the seismic crisis, although worrying for the population, has not caused significant damage. But many questions remain unanswered concerning the potential effects of the current activity in the short or medium term (see section 2). Today's challenges are therefore those of scientific research to understand, monitoring to alert, and prevention and preparedness to reduce potential impacts, improve emergency management, and foster individual and collective resilience. As a recent report commissioned by the French ministry in charge of risk management (*ministère de la Transition écologique et solidaire*) reminds us, the involvement of the population is crucial for the success of the process as a whole (Courant et al., 2021). There are, however, several indications that Mayotte's inhabitants have not been satisfied with the way information has been shared about the current event (see section 3). Although, as we will demonstrate later on, there has been a persistent effort by risk managers and monitoring experts to share information with the public. The issue hence arises of understanding what may have led to the reported "communication crisis". We propose here to compare the information delivered by the main actors of monitoring and risk management to Mayotte's inhabitants with what is known of at-risk populations information needs.

First, we provide a brief overview of what is known about Mayotte's geological setting and the ongoing seismo-volcanic activity (section 2). We then relate some elements of the political and social context that contributed to transform a telluric phenomenon with relatively minor consequence into a situation of crisis (section 3). The corpus and methodology used in our analysis are described in Section 4. Section 5 describes the successive stages of organisation of the monitoring and risk management response. As no emergency planning or monitoring had been done in the department of Mayotte with respect to volcanic issues before May 2018, the framing of the official response has evolved significantly over time. Documenting this evolution was a significant part of our work. It led us to distinguish four main phases (1, 2, 3, 4) that are presented chronologically in section 5. Because public information strategies have not always evolved coincidently with monitoring and risk management frameworks, communication issues are discussed separately in section 6. Analysis of the volume, timing and content of the written documents used by authorities and scientists to share information with the public leads us to distinguish three main phases of communication (A, B, C). In section 7, we discuss our results and issue recommendations to improve future communication strategies. We believe that the lessons learnt from the relatively long-lasting case study of Mayotte (3 years), in a relatively unprecedented context (mostly submarine phenomena, leading to "invisible" risks, whose study requires significant resources and technical innovation), can usefully nourish the reflection carried out in the literature about risk communication and, more generally, disaster risk reduction.

2. Mayotte's geological setting and what is known today about the ongoing seismo-volcanic activity

Mayotte belongs to the Comoros archipelago, a chain of four main volcanic islands that extends ~E-W between the east African coast and the northern tip of Madagascar (Figure 1). Recent studies link the formation of these islands to an E-W zone of diffuse transtensional right-lateral shear at the immature boundary between the Somalia and Lwandle plates (e.g. Famin et al. 2020, Feuillet et al. 2021, Tzevahirtzian et al. 2021). Following this interpretation, the Comoros volcanism occurs along en échelon NW-SE tensional fractures affecting the lithosphere in a context of NE-SW extension (Famin et al., 2020; Feuillet et al., 2021). The location and genesis of this volcanism would be mostly due to lithospheric deformation (Michon, 2016; Famin et al., 2020; Feuillet et al., 2021; Tzevahirtzian et al., 2021) rather than to an hotspot trail as previously proposed by several authors (e.g. Emerick and Duncan, 1982; Class et al., 2009). Volcanism and formation of the Comoros islands started at least ~10 Ma ago (e.g. Emerick and Duncan, 1982; Michon, 2016). The Karthala volcano in the westernmost island of Grande Comore (Bachélèry et al., 2016) is still active today. It is monitored by the Karthala Observatory of the CNDRS (Centre National de Documentation et de Recherche Scientifique, in Moroni) in collaboration with the Institut de Physique du Globe in Paris and the University of La Réunion. In Mayotte, recent volcanism is documented with eruptive products as young as ~4 ky inland (e.g. Pelleter et al., 2014), and actual at the "new volcanic edifice" (NVE) discovered in May 2018 (Feuillet et al. 2021). Recent analysis of seismic receiver functions by Dofal et al. (2021) points to a thinned continental crust beneath Mayotte with a former continental moho at 17-19km depth, underlined by a 9-10km fast layer interpreted to result from magmatic underplating (Dofal et al., 2021). According to these authors, the magmatic reservoir feeding Mayotte's new volcanic edifice would be located below the interface between the underplated magmatic layer and the underlying mantle lithosphere.

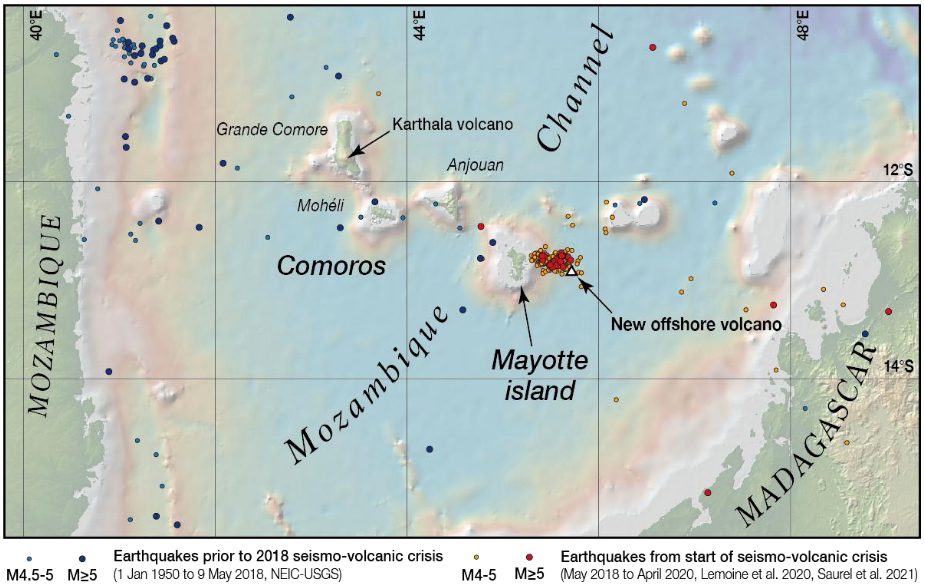

Figure 1. Location of Mayotte, easternmost island of the Comoros archipelago. Blue dots: epicenters of seismic events prior to seismic crisis that started on 10 May 2018 (Magnitude ≥4.5, Jan. 1950 to 9 May 2018, USGS catalog); Red (magnitude ≥5) and orange (4 ≤ magnitude < 5) dots show earthquake epicenters with well-constrained hypocentral depth from 10 May 2018 to April 2020 - locations from Lemoine et al. (2020) between May 2018 and March 2019 and REVOSIMA catalog between April 2019 and April 2020 (Saurel et al., 2021). Most earthquakes of the ongoing seismic crisis as well as the new offshore volcanic edifice discovered in May 2019 (Feuillet et al., 2019, 2021) are located 10-50km east of Mayotte island. To avoid problems with mislocated events on this map we excluded epicenters with 10km fixed depth, and only plotted the ones with well-determined hypocentral depths. Topographic and bathymetric visualisation is from GeoMapApp (www.geomapapp.org - CC-BY).

The ongoing activity started on the night of 10 to 11 May 2018 with an earthquake of magnitude ML4.3 felt by the population. Seismicity intensified on 15 May 2018 with several earthquakes of magnitude > 4, all largely felt, and an event of magnitude ML5.8 (MW 5.9) (Lemoine et al., 2020). Although diminishing over time, seismic activity has continued since and is still active at the time of writing, >3.5 years after its beginning. Prior to May 2018, regional instrumental seismicity near the islands (blue dots in Figure 1) was moderate, with the largest magnitudes recorded between M_b 5 and 5.5.

In May 2018, Mayotte's area was poorly instrumented. The ability to identify and precisely locate the earthquakes improved gradually with the development of the network of seismic stations (Bertil et al., 2021; Saurel et al. 2021). The inclusion of underwater stations (OBS for Ocean Bottom Seismometer) from February 2019 (Feuillet et al., 2021, Saurel et al., 2021), and the use of refined seismic velocity models (Lavayssière et al., 2021; Saurel et al., 2021), were determinant to this respect. The study of the seismicity since the OBS deployment allowed to locate two clusters of seismicity: a dense "proximal cluster" located close to Mayotte's eastern coast, and a "distal cluster" located about 30 to 40km east of the islands extending eastward in the direction of the new volcanic edifice (Feuillet et al. 2021, Saurel et al. 2021, Lavayssière et al. 2021). According to Lemoine et al. (2020), these two clusters are active since the end of June 2018, while, from May to June 2018, the earthquakes occurred in a more distal cluster, shallower and closer to the new volcanic edifice. This earlier cluster would have included the large earthquakes that marked the beginning of the crisis. Distal clusters are interpreted to result from the fracturation and diking processes that allowed magma migration from the deep magma chamber to the new volcanic edifice (e.g., Cesca et al., 2020; Lemoine et al., 2020; Feuillet et al., 2021; Lavayssière et al., 2021). The proximal cluster is composed of deep (~35-50km) seismic events that might be linked to the deformation induced by a deflating deep reservoir (e.g., Feuillet et al. 2021, Lavayssière et al. 2021). It also contains less deep events (20-35km) that might be due to stress perturbations around a shallower (~25km) reservoir, as suggested by the location of very long period seismic events (Feuillet et al. 2021, Lavayssière et al. 2021). Being close to the islands, it is this proximal seismic cluster, and the magmatic processes related to it, and their uncertain evolution, that present the real significant hazard.

Inhabitants have mainly experienced the ongoing activity through felt earthquakes. More than 20 earthquakes with magnitudes 5+ were recorded during the first month of the crisis, from 10 May to mid-June 2018 (Bertil et al., 2021), while ~1900 events with magnitudes >3.5 happened during the first year (Cesca et al., 2020; Lemoine et al., 2020). About 140 of these earthquakes were reported as felt by the population in the LastQuake crowdsource-based information app of the Euro-mediterranean Seismological Center (EMSC-CSEM, 2021). There was a sharp decrease in the number of felt earthquakes after June 2018, in line with the decrease in the number of instrumentally recorded earthquakes and of their average magnitude (e.g. Lemoine et al. 2020, Bertil et al. 2021). EMSC-CSEM catalog reports only ~4 felt events per month until the end of 2018, and then a moderate recovery in the number of felt events between February and June 2019 (~9 felt events per month on the average) (the red curve in Figure 3 summarizes this information).

3. The social and political context of Mayotte's seismo-volcanic "crisis"

Geoscientists are accustomed to speaking of seismic-volcanic "crises," although the use of the term "crisis" is not always relevant to disaster risk management definitions. However, in the case of Mayotte, the observed activity did indeed give rise, at least in the first months, to a crisis situation that required the intervention of the authorities in charge of civil protection and crisis management. We relate here some elements of the political and social context that contributed to this.

● A vulnerable territory

Mayotte, which became a French Department in 2011, is a particularly vulnerable territory. It is marked by great poverty and high social inequality (Roinsard, 2014). In a population of 256 000, 77% live under the poverty line and over 30% are unemployed, 48% are foreign (and often undocumented), 30% have no access to clean drinking water, and four in ten live in informal housing (Données 2017 – INSEE, 2021). Mayotte's multiculturalism is a wealth that proves difficult to manage when the situation requires informing the widest possible audience: 95% of the population is Muslim (ministère des Outre-mer, 2016), 45% is from the Comoros (INSEE, 2021), and while French remains the official language, about 37% of the population do not speak it (Données 2017 – INSEE, 2017). Oral culture is the dominant one and the most commonly spoken languages are Shimaore and Shibushi. There is no real integration between the traditional culture of the villages and the more westernized culture of large cities (Lambek, 2018). According to Regnault (2011), "three quarters of the *Mahorais* - rural or, at least, still very attached to their village - live a culture other than the "westernized" culture of the cities" (*trad. by the authors*). The relationship with state authorities is complicated by the island's colonial past, but also by a sense of disappointment among the population, who expected more rapid changes to bring the island up to French standards after departmentalization (Roinsard, 2019). Since 2011, Mayotte has been regularly shaken by social crises. The most recent one, which brought the economy to a standstill for two months in the spring of 2018, was just ending as the first earthquakes began (Roinsard, 2019; Mori, 2021). Lastly, the absence in living memory of seismic and volcanic events in Mayotte meant that part of the inhabitants were relatively naïve about such risks (although people coming from the neighboring Comoros islands may have experienced previous seismic and volcanic crises as four eruptions occurred in 2005, 2006 and 2007, see Morin *et al.*, 2016).

● A recurring complaint about a lack of information

The intensity and duration of the initial seismic crisis surprised not only the population but also the authorities and scientists. On 16 May 2018, the director of the scientific institution locally in charge of seismic monitoring (the *Bureau de Recherche Géologique et Minière, BRGM*[2]) qualified the activity as "*exceptional beyond anything recorded in Mayotte*" (AFP dispatch picked up by many media, e.g. Le Point (2018), 16 May 2018). A few days later, the prefect of Mayotte[3] talked about "*an abnormal and persisting activity*" (*Le Journal de Mayotte*, 19 May 2018). A month later, in an interview given to the French national press, the director of BRGM Mayotte declared: *"Unfortunately, we are in the unknown"* (15 June, Le Figaro, 2018b).

Although the earthquakes were of moderate intensity, they affected vulnerable buildings and their multiplication caused the appearance of cracks leading some municipalities to close schools (Sira et al., 2018). Local observers reported strong anxiety among inhabitants, many people leaving their houses to sleep outside (Mori, 2021, Fallou & Bossu, 2019; Fallou et al.,

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[2] The Bureau de Recherche Géologique et Minière (BRGM) is a public industrial and commercial institution dedicated to geological resources and placed under the joint supervision of the ministries in charge of ecology, research and economy. It is the only expert earth-sciences institution with a local branch in Mayotte. It is in charge of seismic monitoring in the area when the current crisis begins.

[3] In France, each department is governed by a prefect, appointed by the president. The prefect is responsible for risk and crisis management at the departmental level in coordination with the mayors, who are responsible for risk and crisis management in their municipalities.

2020; it was also currently reported in our interviews). They also testified of a general feeling of confusion linked to the unfamiliar nature of the hazard, and to a lack of information. A group of citizens created a Facebook feed called "Signalement tremblement de terre de Mayotte" (STTM), aimed at reporting felt events and at sharing experiences. The success of the feed, which soon gathered more than 10,000 members (about 4% of the population), attested to the existing thirst for information. The posts exchanged at that time show a lack of confidence in the authorities' willingness to take charge of the situation: *"Earthquakes that sometimes exceed magnitude 5, cracks in buildings, fires, landslides, etc.... and no real reaction from the state apart from information on the magnitude of the tremors already felt."* (excerpt from STTM Facebook group, 26 May 2018); "*How much do you want to bet that in a year nothing will have been done? As soon as the crisis passes we*[4] *play the watch hoping that the next one will come when we leave the island. That's how the administration has managed Mayotte for decades.*" (excerpt from STTM Facebook group, 27 May 2018). On 5 June 2018, the deputy of Mayotte in the French national assembly warned the government against the consequences of a lack of public information leading to the spread of *"false information fueled by fantasies that have the effect of increasing people's anxiety, generating a state of panic and even psychosis"* (Ali, 2018). Eight months later, in February 2019, members of the STTM facebook feed published an open letter urging the state, local elected representatives and scientists to provide more information about the ongoing activity (Picard, 2019). Although this group is not really representative of the sociology or the demography of Mayotte's population, it soon became a serious interlocutor for the local authorities, and the prefect invited its most visible members to the discussion table in 2019 (Journal de Mayotte, 9 August, YD, 2019). It remains today one of the public arenas where information about the seismic-volcanic crisis is followed with the most attention.

It took a whole year between the beginning of the seismic crisis and the official declaration, in an interministerial press release dated from 16 May 2019 (*ministère de la Transition écologique et solidaire, ministère de l'Enseignement supérieur, de la recherche et de l'innovation, ministère des Outre-mer, ministère de l'Intérieur*, 2019), of the discovery of the new volcanic edifice. The event closed a year of questioning about the possible origin of earthquakes. The unexpected *"birth of a new volcano"* (BBC - Science in Action, 2019) caused enthusiasm in the national and international scientific community, and in the media (e.g., Andrews, 2019; Minassian, 2019; Wei-Haas, 2019; Devès et al., 2022). The discovery has been described as "exceptional": first, because of the large volume of lavas involved, more than $5\ km^3$ (Feuillet et al., 2021) - corresponding to the largest eruption ever observed with modern techniques (Cesca et al., 2020; Feuillet et al., 2021; Thordarson & Self, 1993) - and, second, because of the submarine nature of the activity - marking the beginning of an exciting scientific adventure to develop new techniques of observation. The local press welcomed this sudden interest in Mayotte's actuality (Devès et al., 2022), the volcano being presented as a more positive way of talking about the *101st department* than the usual references to its social misery (*Journal de Mayotte*, 28 May 2018). But "discovering" the volcano is insufficient to characterize the associated threats. In this sense, the advance in knowledge showed itself to be frustrating for the inhabitants, for the authorities, and for journalists alike (Devès et al., 2022). In June 2019, STTM's facebook feed members were still complaining about the official communication: *"Say nothing, explain nothing... Can only create confusion...*

4 "We" refers here to the civil servants coming from metropolitan France to work in the overseas department of Mayotte.

a supprimé: (10 to 20% of the population according to official sources, pers. com.)

a supprimé: *Whether or not we know what's going on at more than 3,000 meters deep, there are facts that are there.*

a supprimé: since the Laki eruption in 1783-1784

Questions that go around in circles because we don't have the answers! When there is neither answer nor explanation ... One can only wonder ... Why this? What interest or motivation do they have in not giving the information ... They would like the population to worry: they couldn't do better! The sickly inability of administrations to communicate …" (excerpt from Facebook group STTM, 20 June 2019).

4. Material and methods

The present research is part of a research project entitled MAY'VOLCANO dedicated to the study of the circulation of knowledge between scientists, risk and crisis management actors, the media and the population of Mayotte during the current seismo-volcanic crisis. This paper aims at providing a first analytical view of the public information process, and of its potential limitations.

The empirical data for the research presented here were collected between 10 May 2018 and 1 April 2021, covering more or less the three first years of the ongoing seismo-volcanic "crisis". The work was organized in three tasks: 1) documenting and understanding the organisation of the monitoring and risk management response and its evolution over time, 2) documenting and understanding the organisation of the process of public information and its evolution over time, and 3) examining the process of public information with regard to what is known of at-risk population information needs. The first two tasks were done in parallel. In the following, we describe the empirical data and the methods used to complete each of these tasks. The corresponding results are presented in section 5 (task 1), 6 (task 2) and 7 (task 3).

4.1. Documenting and understanding the organisation of the "official response" and its evolution over time

Our first task was to capture and understand the organisation of the "official response". By "official response", we mean the decisions and actions taken by the local and national authorities in charge of risk and crisis management and by the scientific experts in charge of monitoring the ongoing seismo-volcanic activity. As emphasized in the introduction, the framing of that response evolved significantly over time and it was important to be able to document and describe these evolutions before addressing the issue of public information.

The methods chosen were participant observation, semi-structured interviews, collection and analysis of written archives. The fact that three of the authors worked at the Institut de Physique du Globe de Paris (IPGP), which is currently in charge of monitoring the activity, facilitated contact with experts. The involvement of the first author in previous research projects associating crisis management officials facilitated contact with authorities.

Participant observation was done within the framework of a day-to-day cohabitation with scientists at IPGP, within the scientific council of the REVOSIMA since February 2020 (when the first author was invited to join) and, between January and June 2021, within a working group coordinated by the interministerial delegation for major risk reduction in overseas territories (the

a supprimé: The announcement of the birth of the volcanological and seismological observation network of Mayotte (REVOSIMA) in June 2019 only partially meets expectations.

a supprimé: **2.1. A two step-methodology combining quantitative and qualitative approaches**

We focus on the first three years of the Mayotte seismic-volcanic crisis, more precisely from 10 May 2018 to 1 April 2021. We build our analysis on the following methodology and datasets.

We searched the archives and in particular the web archives of the scientific and state institutions involved in the monitoring and management of the crisis. We collected and analyzed all the documents made public by the authorities and scientists during these first three years such as press releases, scientific bulletins, news on websites and public notes (table 1). Hereafter, we are citing scientific bulletins and websites as references (including their URL when existing) while authorities' press releases are given in the supplementary dataset (ministerial press releases as well as those from the Préfecture of Mayotte). We also included the academic papers published during our 3 years period of study (Cesca et al., 2020; Famin et al., 2020; Feuillet et al., 2021; Lemoine et al., 2020; Tzevahirtzian et al., 2021). We coded this dataset by date of publication and by publishing institution/author, and quantitatively analysed it to show the time evolution of the publication rate by the different actors of the risk management (see Figure 4). Using the catalog of the felt seismicity provided by EMSC for the period from May 2018 to April 2021 (EMSC-CSEM, 2021), we compare this publication rate to the number of earthquakes felt by Mayotte citizens and its evolution in time (Figure 3, 4). This analysis was made using the R software package. This allows us to quantitatively put the scientist's and authorities' communication effort in perspective with the evolution of the geophysical signal that directly affected the population.

However, to understand people's feeling of a lack of communication and how the communication has been managed by the scientists and authorities as the crisis developed, we also needed more qualitative approaches: i.e. qualitative analysis of the content of the different documents. We thus studied the content of all the documents in the above dataset and the way it has evolved in time. We also aimed to identify the main stages of scientific monitoring and to understand how the circulation and transfer of knowledge has been managed by the different actors. With this objective, we conducted semi-structured interviews with scientists from the main institutions in charge of the geophysical monitoring of the crisis (7 interviews lasting from 1 to 3 hours within BRGM, IPGP, CNRS and REVOSIMA) and with local and national risk managers (6 interviews lasting from 40 minutes to 2 hours within the Préfecture of Mayotte, the DIRMOM, the Ministries of Research, Environment and Interior[MD6]). We asked questions about the actors involved in the monitoring and their role, about the procedures, contents and formats used to exchange between them, with the media and th ... [1]

Délégation interministérielle aux Risques majeurs en Outre-mer, DIRMOM) who developed a sensibilisation campaign (using videos) about the seismic and tsunami risks in Mayotte.

15 semi-structured interviews were conducted with the persons who were identified as pivotal to the overall monitoring and risk/crisis management process: 8 with scientists directly involved in the organisation of monitoring (sometimes at different moments of the crisis), 7 with risk or crisis managers acting at the local, national or inter ministerial levels. Two of these persons were interviewed twice, before and after the creation of the REVOSIMA which allowed us to gain a better insight into the associated changes. Most interviews were conducted via visioconference because of the restrictions due to the COVID-19 pandemic. During the interviews, we asked questions about the actors involved in monitoring, risk and crisis management, about their role, about the procedures, contents and formats used to exchange information, between them, with the media and the public. We also asked more specific questions about the communication process (see section 4.2). All interviews were recorded (with the agreement of the interviewees) and transcribed soon after. The transcriptions were anonymized when used for discussion between the members of the team (only the first author has access to the original files as she was the one conducting the interviews). Citations taken from interviews for illustration in the present paper are anonymized to respect interviewees' confidentiality. We also provide our own English translation. The interviews were analyzed qualitatively with the aim to understand the organisation of the official response and its evolution. The chosen method places emphasis on the meaning rather than the quantification of the materials.

Regarding the collection of archives, we collected public press releases, public scientific bulletins and official reports. Interviewees often spontaneously shared the materials they used to communicate and the materials on which they based their decision, such as internal notes and reports. We cite here only the documents that are public.

The work carried out on the basis of those data allowed us to identify the main actors to be considered for studying the process of public information (Figure 2).

INSERT FIGURE 2

Figure 2: Cartography of the actors who played an active role in public information during our period of study.

Two main categories of actors are distinguished according to their function: risk and crisis management or scientific monitoring.

On the risk and crisis management side, the main actors are 1) the *p*refecture of Mayotte, which is the body representing and implementing government policy at the local level, and 2) the ministries concerned with risk prevention (ministère de la Transition écologique et solidaire), civil protection (ministère de l'Intérieur), research (ministère de l'Enseignement supérieur, de la recherche et de l'innovation), and overseas administration (ministère des Outre-mer). The interministerial level is also to be considered because of the active role played by a temporary interministerial delegation called DIRMOM (*Délégation interministérielle aux Risques majeurs en Outre-mer*) whose task was to improve coordination between ministries on the topic of major risk reduction in the French overseas. The delegation was in activity between April 2019 and June 2021. The end of our study period therefore corresponds approximately to the end of the

DIRMOM's activity, at the dawn of a possible reorganisation of interministerial coordination on major risk management overseas. In the French system, mayors are usually key actors of risk and crisis management. But, in the case of the seismo-volcanic crisis of Mayotte, it soon appeared that public information was mainly being orchestrated at the departemental and national levels (anonymous from interviews conducted in June 2020, April, June and September 2021). The explanation that was given to us by interviewees is that the initial crisis overwhelmed the capacity of response of local mayors requiring the intervention of the prefecture of Mayotte, with the support of the national level.

On the monitoring side, the number of actors involved has evolved significantly over time. In summary[5], the Institut de Physique du Globe de Paris (IPGP), the School and Observatory of Earth Sciences in relation with the École et observatoire des sciences de la terre / Institut de Physique du Globe de Strasbourg (hereafter referred as EOST), the Bureau de Recherche Géologique et Minière (BRGM) and the Institut Français de Recherche pour l'Exploitation de la Mer (IFREMER) have been directly involved in monitoring, although in different ways over time. They are the main partners of the REVOSIMA network. The latter, born in June 2019, is operated by the IPGP from its closest observatory of the Indian Ocean region, i.e. the Observatoire

- [5] The Bureau de Recherche Géologique et Minière (BRGM) and the Institut Français de Recherche pour l'Exploitation de la Mer (IFREMER) are public industrial and commercial institutions dedicated to, respectively, georessources and marine resources placed under the joint authority of the Ministries in charge of ecology, research and, respectively, economy or agronomy. The National Institute of Geographic and Forest Information (IGN) is a public administrative establishment placed under the joint authority of the Ministries in charge of ecology and forestry.

- The Institut de Physique du Globe de Paris (IPGP) is an institution for higher education and research in geosciences which is in charge of certified observation services in volcanology, and seismology through its permanent volcanological and seismological observatories like the one in La Réunion island (OVPF for Observatoire Volcanologique du Piton de la Fournaise). It operates the Volcanological and Seismological Monitoring Network of Mayotte (REVOSIMA).

- The School and Observatory of Earth Sciences (EOST) is an institution under the supervisory authority of the University of Strasbourg and the CNRS (French National Center for Scientific Research) in charge of education, research, and observation in Earth Science. The IPGP and EOST equip and maintain global geophysics networks that monitor seismic activity (GEOSCOPE network) around the globe. EOST is sometimes referred to as the Institut de physique du Globe de Strasbourg (IPGS), the two bodies having intimate links. The EOST pilots the BCSF-RéNass, Bureau central sismologique français - Réseau national de surveillance sismique, which is in charge of centralising, archiving and distributing national seismic data. The BCSF-RéNass issues a bulletin after each event and collects public testimonies of felt earthquakes (www.franceseisme.fr). It also provides assistance to the public authorities by sending a task force of seismologists (GIM for Groupe d'intervention macrosismique) to estimate impacts after significant earthquakes in French territories.

- The French National Centre for Scientific Research (CNRS) is an interdisciplinary public research organisation under the administrative supervision of the French Ministry of Higher Education and Research. A significant part of French researchers belong to CNRS and work within laboratories which are placed under the joint authorities of the CNRS and the local university. The National Institute for Universe Sciences from CNRS (INSU) has the mission to develop and coordinate French research in astronomy and Earth sciences, as well as ocean, atmospheric, and space sciences.

- The European-Mediterranean Seismological Centre (EMSC) runs an Earthquake Alert System for potentially damaging earthquakes in the Euro-Mediteranean region. As BCSF-RéNass, EMSC collects testimonies through its Lastquake application (e.g., Bossu et al., 2019). Within the hour following the occurrence of an earthquake, EMSC publishes a web page with its epicentre and magnitude, and the collected testimonies.

volcanologique du Piton de la Fournaise (OVPF) in Reunion Island, and with the support of the antenna of BRGM in Mayotte. The Bureau central sismologique français - Réseau national de surveillance sismique (BCSF-RéNass), the European-Mediterranean Seismological Centre (EMSC) and the National Institute of Geographic and Forest Information (IGN) centralise, distribute or provide data.

4.2. Documenting and understanding the organisation of the process of public information and its evolution over time

The ultimate goal of this research being to examine the process of public information, it required documenting and understanding how the above-mentioned network of actors organized its "external" communication (Becker et al., 2018) and how it evolved with time. We used the same methods as those mentioned in section 4.1. In addition to the questions listed earlier, we also asked the interviewees what were the role of the various actors with respect to public information, what role they played at an individual scale, what were the most important moments for them with respect to public information and to give their view on the effectiveness of that information regarding risk reduction. We also took note of the media most commonly used to share information with the public and decided to systematically collect the documents that were available (either online or with the help of the interviewees).

We searched the archives and in particular the web archives of the scientific and state institutions involved in monitoring and risk management. We collected all the written documents. By the end of our period of study, we had collected 320 items including press releases, scientific bulletins, news on websites and public notes (Table 1). Hereafter, we are citing scientific bulletins and websites as references (including their URL when existing) while authorities' press releases are given in the supplementary dataset (press releases are typically from the prefecture of Mayotte but there are also a few press releases from the government and from ministries). We did not consider the numerous automatic bulletins emitted by REVOSIMA (daily automatic bulletins are emitted since march 2020), BCSF-RéNass and EMSC but we included the report published by the BCSF-RéNass's Groupe d'intervention macrosismique (GIM) and a web article from the EMSC aiming at providing a global view of the seismic crisis. We also included in our database the five academic papers (one was a preprint version of a submitted paper) dedicated to the crisis that were published during our period of study (Cesca et al., 2020; Famin et al., 2020; Feuillet et al., 2021; Lemoine et al., 2020; Tzevahirtzian et al., 2021) and commented by the press and/or the members of STTM facebook group. We also took into account the contribution of individual researchers who issued key analyses at crucial times during the crisis (Briole, 2018).

Each item was downloaded, stored in pdf under a specific ID, and then read independently by 2 to 3 researchers who completed a table with information about format and content. Disagreements were discussed and solved collectively. We took note of the ID, the date of publication, the URL (when existing), the publishing authors/institutions, the title, the public it aimed to, the number of words, the presence or absence of illustrations and the nature of these illustrations (scientific, local, etc.). We also took note of the main topics covered by the text and of the list of actors that were mentioned. This dataset was used to quantify the volume and timing of public information, and to undertake a qualitative analysis of content.

To complete our understanding of the public information process, we also explored Facebook publication feeds when they existed (i.e. for OVPF-IPGP, REVOSIMA and prefecture of Mayotte) but without aiming for exhaustiveness as it was difficult to achieve without adequate tools.

Using the catalog of felt seismicity provided by EMSC (EMSC-CSEM, 2021), we compared the publication rate to the number of earthquakes felt by Mayotte citizens and its evolution in time (Figures 3 and 4). This allowed us to put the scientist's and authorities' communication effort in perspective with the evolution of the geophysical signal that directly affected the population.

4.3. Examining the process of public information with regard to what is known of at-risk population information needs

The combination of these data (archives, interviews, notes of participant observation, written documents used by the actors to share information with the public) provided the basis for examining the public information process with regard to what is known of at-risk populations' information needs. The latter is inferred from the existing literature on risk communication (which is abundant on this particular topic, see section 7), while bearing in mind the social and cultural context of Mayotte.

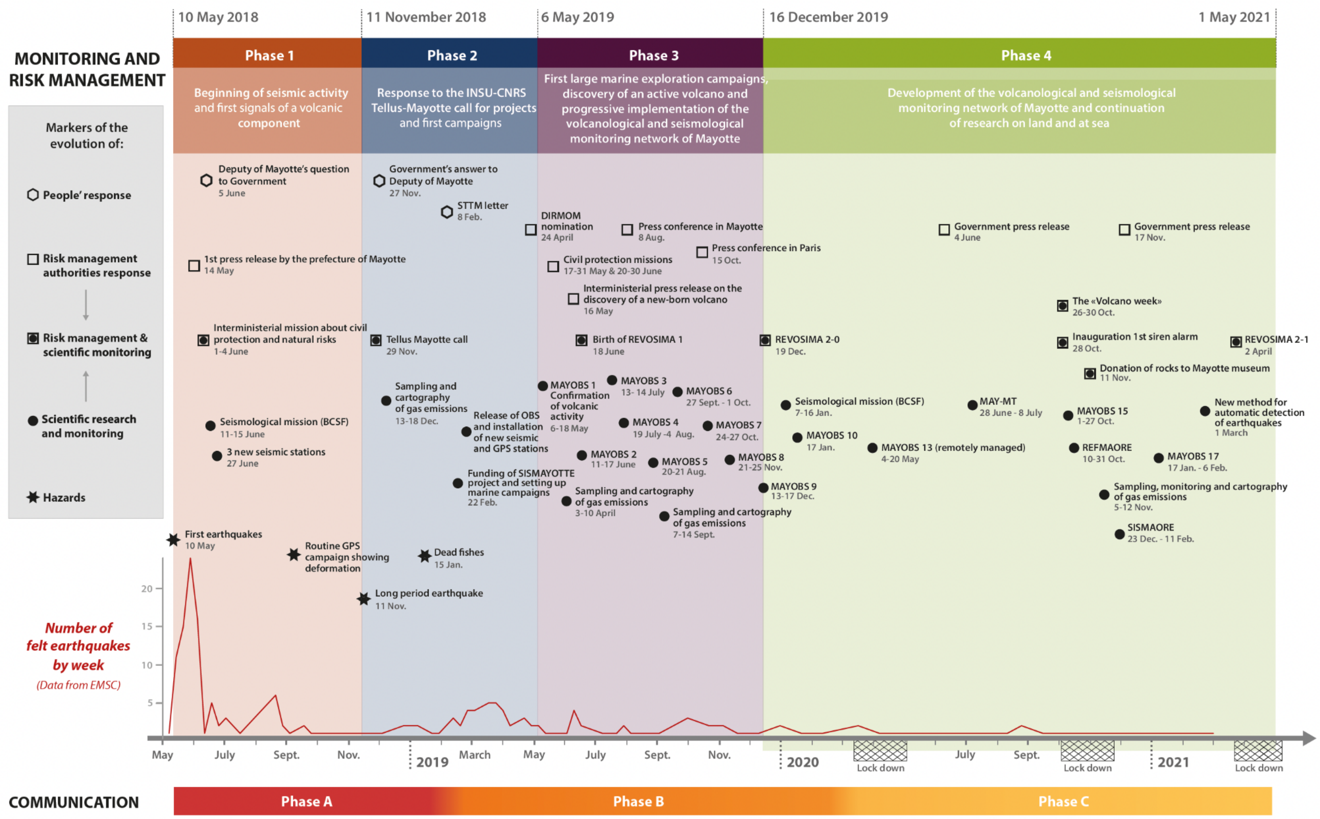
We also explored STTM's Facebook publication feed but, again, without aiming for exhaustiveness as it was difficult to achieve without adequate tools. Hereafter, we use excerpts from STTM facebook posts to illustrate some of our statements. We anonymised these citations, and provide our own English translation (anonymised French original versions of the facebook posts are given in supplementary dataset).

5. The organisation of the "official response" and its evolution

As no emergency planning or monitoring had ever been done in the department of Mayotte with respect to volcanic issues before May 2018, the framing of the official response has evolved significantly over time. Here we provide a description of its gradual organisation. We distinguish four main successive phases (1, 2, 3, 4). The first phase goes from the recording of the first earthquakes to the recording of the first unambiguous signals of a volcanic component. The second phase corresponds to the mobilization of scientists, and funding agencies in relation to ministries, to get the financial means to instrument the area. The third phase runs from the first measurement campaigns to the proof of the volcanic activity which signed the official setting up of the seismo-volcanic monitoring network of REVOSIMA. The fourth phase begins with the official creation of REVOSIMA and ends with our windows of study. Figure 3 summarizes the key events that marked each of these four phases. In addition to the events linked to monitoring, we also discuss some key events in the response of scientists, authorities and inhabitants of Mayotte.

a supprimé: Description of the phases of the crisis from a monitoring and risk management perspectiveThe seismic crisis starts on the night of 10 to 11 May 2018 with an earthquake of magnitude M_L4.3 being felt by the population. It intensifies on 15 May 2018 with several earthquakes of magnitude M_L greater than 4 and an earthquake of M_L5.8 (M_W 5.9) that slightly damages buildings (Lemoine et al., 2020). One month after the beginning of the crisis, 140 earthquakes with magnitudes M_L>4 have been recorded (Lemoine et al., 2020). For weeks, the people of Mayotte feel several earthquakes a day. During the first month of the crisis, the EMSC catalog (EMSC-CSEM, 2021) reports ~10 to 20 felt earthquakes per week (i.e. seismic events with at least 4 online citizen testimonies, which EMSC call "felt reports"). Mayotte citizens testify largely after earthquakes of the largest magnitudes: EMSC catalog lists ~200 to more than 500 felt reports for each M_L>5 events that occurred in May and June 2018. Between May 2018 and May 2019, the seismic networks record about 1900 events with $M_L \geq 3.5$ (Cesca et al., 2020; Lemoine et al., 2020). However, there is a sharp decrease in the number of felt earthquakes after June 2018 (Figure 3), with only ~4 felt events per month until the end of 2018, and then a moderate recovery in the number of felt events between February and June 2019 (~9 felt events per month on the average). The seismic crisis is still ongoing at the time of writing, 3 years after its start.

a supprimé: The following description illustrates the role of these different actors and the timing and context of their involvement phase by phase.


10 May 2018
11 November 2018
6 May 2019
16 December 2019
1 May 2021
MONITORING AND RISK MANAGEMENT
Phase 1
Phase 2
Phase 3
Phase 4
Beginning of seismic activity and first signals of a volcanic component
Response to the INSU-CNRS Tellus-Mayotte call for projects and first campaigns
First large marine exploration campaigns, discovery of an active volcano and progressive implementation of the volcanological and seismological monitoring network of Mayotte
Development of the volcanological and seismological monitoring network of Mayotte and continuation of research on land and at sea
Markers of the evolution of:
People' response
Risk management authorities response
Risk management & scientific monitoring
Scientific research and monitoring
Hazards
Deputy of Mayotte's question to Government 5 June
Government's answer to Deputy of Mayotte 27 Nov.
STTM letter 8 Feb.
DIRMOM nomination 24 April
Press conference in Mayotte 8 Aug.
Press conference in Paris 15 Oct.
Government press release 4 June
Government press release 17 Nov.
1st press release by the prefecture of Mayotte 14 May
Civil protection missions 17-31 May & 20-30 June
Interministerial press release on the discovery of a new-born volcano 16 May
The «Volcano week» 26-30 Oct.
Interministerial mission about civil protection and natural risks 1-4 June
Tellus Mayotte call 29 Nov.
Birth of REVOSIMA 1 18 June
REVOSIMA 2-0 19 Dec.
Inauguration 1st siren alarm 28 Oct.
REVOSIMA 2-1 2 April
Donation of rocks to Mayotte museum 11 Nov.
Sampling and cartography of gas emissions 13-18 Dec.
MAYOBS 1 Confirmation of volcanic activity 6-18 May
MAYOBS 3 13- 14 July
MAYOBS 6 27 Sept. - 1 Oct.
Seismological mission (BCSF) 7-16 Jan.
MAY-MT 28 June - 8 July
MAYOBS 15 1-27 Oct.
New method for automatic detection of earthquakes 1 March
Seismological mission (BCSF) 11-15 June
Release of OBS and installation of new seismic and GPS stations
MAYOBS 4 19 July -4 Aug.
MAYOBS 7 24-27 Oct.
MAYOBS 10 17 Jan.
3 new seismic stations 27 June
MAYOBS 2 11-17 June
MAYOBS 5 20-21 Aug.
MAYOBS 8 21-25 Nov.
MAYOBS 13 (remotely managed) 4-20 May
REFMAORE 10-31 Oct.
MAYOBS 17 17 Jan. - 6 Feb.
Funding of SISMAYOTTE project and setting up marine campaigns 22 Feb.
Sampling and cartography of gas emissions 3-10 April
MAYOBS 9 13-17 Dec.
Sampling, monitoring and cartography of gas emissions 5-12 Nov.
Sampling and cartography of gas emissions 7-14 Sept.
SISMAORE 23 Dec. - 11 Feb.
First earthquakes 10 May
Routine GPS campaign showing deformation
Dead fishes 15 Jan.
Long period earthquake 11 Nov.
Number of felt earthquakes by week
(Data from EMSC)
20
15
10
5
May
July
Sept.
Nov.
2019
March
May
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Nov.
2020
Lock down
July
Sept.
Lock down
2021
Lock down
COMMUNICATION
Phase A
Phase B
Phase C

Figure 3: Major phases and markers of the response by local and national authorities in charge of risk and crisis management and by scientific experts in charge of monitoring the seismic-volcanic activity in Mayotte. Our period of study extends from 10 May 2018 to 1 April 2021. The lockdown periods that are shown are those of metropolitan France (note that most of the scientific institutions involved in monitoring are located in metropolitan France). Mayotte endured longer lockdowns in spring 2020 and 2021 but there was no proper lock down in autumn 2020.

- **Phase 1: 10 May 2018 to 10 November 2018**

During the **first phase of the crisis**, the French Geological Bureau (BRGM) played a central role. It was the only geo-scientific institution with a permanent office in Mayotte and, at the beginning of the seismic crisis, it was in charge of maintaining the only 3 accelerometric seismic stations installed on the island (known as moderately active). BRGM Mayotte was hence the natural interlocutor of the local and national authorities for decision support. But the situation was difficult as crucial data were missing. Only the largest magnitude earthquakes (M>5) were reported by global seismic networks while the existing local network – the few accelerometric stations in Mayotte completed by few regional stations in Comoros and in Madagascar – did not allow a good record of the surge of moderate magnitude earthquakes felt by the population. Because of this inadequate network, the BRGM operators initially encountered difficulties in accurately locating the earthquakes and assessing their epicentral depths (see section 2).

In June 2018, the persistence of the seismic crisis led to the involvement of new actors. Ministries in charge of civil protection (ministère de l'Intérieur) and disaster risk prevention (ministère de la Transition écologique et solidaire) sent an interministerial mission composed of civil protection experts and seismologists (e.g., Mayotte la 1ère, 2018; Perzo, 2018b). The experts concluded that the impact of the earthquakes mainly resulted in an aggravation of disorders on buildings that were already vulnerable (widening, elongation of cracks) and reported that about thirty people got minor injuries that were indirectly linked with the earthquakes (e.g. falling down stairs to get out of the house). They also outlined that the repetition of shaking had been causing a feeling of anxiety and fear among the population, all the more marked as this seismic swarm phenomenon was unknown in Mayotte until then[6]. Mid-June 2018, a team of seismologists from BCSF-RéNass was sent to *"estimate the levels of damage induced by this seismic swarm according to the vulnerability of the buildings at the date of the field analysis"* (Sira et al., 2018). 3 more seismic stations were installed (two short-period RaspberryShake velocimeters by the BCSF, one broad-band velocimeter in the frame of the 'Sismo à l'École' network). During the summer, scientists from IPGP and EOST helped the BRGM team to monitor the activity[7]. In July, the French scientific community started organising to seek funding to instrument the area, notably at sea. A note was sent to the French National Centre for Scientific Research (CNRS) to attract funding agencies' attention to Mayotte's issues[8].

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[6] The problem of anxiety was addressed with the opening of a toll-free phone number and a psychological support unit at the local hospital (Press release of the prefecture of Mayotte, 19 June 2018)

[7] Until the creation of REVOSIMA, real-time data processing was organized through the voluntary commitment of scientists.

[8] The issue of funding is not simple. The activity being mostly submarine, surveys have to be done mostly offshore using research vessels and heavy human and technical logistics. The funding to be mobilized is typically of the order of several million euros per year. In parallel, one also has to deal with vessel's availability for their work programs are often planned years in advance. However, several scientists we interviewed claim that the rapid mobilization of fifty

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Commenté [2]: A note was added here in response to an external review received by email.
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In September, routine satellite measurements (using Global Navigation Satellite System, GNSS) led by the IGN revealed strong displacement anomalies affecting stations located on the island. Researchers from the Ecole Normale Supérieure (ENS) Geoscience Lab. analyzed the data, tracing the onset of surface deformation back to July 2018 (Briole, 2018). They explained it by the deflation of a huge magmatic chamber located off the coast of Mayotte. The lack of geological observations offshore Mayotte was still preventing a good understanding of the phenomenon but the scientific community urged public authorities to fund geophysical instrumentation and surveys in the region.

- **Phase 2: 11 November 2018 to 5 May 2019**

The **second phase of the crisis** started on 11 November 2018 with a long period earthquake with peculiar characteristics (a very long trend of monochromatic seismic waves, e.g., Cesca et al. 2020, Lemoine et al. 2020). The event, not felt by the population because of its long period character, was recorded by global seismic networks. It was much discussed on social networks and appeared to be mentioned in the international and soon national and local press (see discussion in Lacassin et al., 2020). It supported the volcanic hypothesis (Cesca et al., 2020; Lemoine et al., 2020). Mid-november, a meeting was organised with representatives of the four ministries, scientists and scientific institutional stakeholders like CNRS-INSU. On 29 November, public authorities set up a call for projects to fund observation and research in the area. The call, named *"Tellus-Mayotte"*, was coordinated by the CNRS-INSU and co-financed by the ministry in charge of disaster risk prevention (*ministère de la Transition écologique et solidaire*).

In January 2019, fishermen reported dead deep sea fishes at the surface of the ocean east of Mayotte (Perzo, 2019a)[9]. On 22 January, three projects were eventually selected on the Tellus Mayotte call, involving 11 laboratories and 44 scientists from CNRS, IPGP, EOST, BRGM, Ifremer and IGN. On 22 February, CNRS, IPGP, BRGM and EOST announced the launch of the first major monitoring missions. Between February and March 2019, 6 OBSs were deployed at sea in the frame of these Tellus-Mayotte projects, and new seismic and GNSS stations were installed on land (by OVPF-IPGP, BRGM, EOST). A team from the University of La Réunion associated with OVPF-IPGP carried out field missions to consolidate knowledge of the tectonic and volcanic history of Mayotte.

- **Phase 3: 3 May 2019 to 5 December 2019**

The third phase of the crisis started with the first MAYOBS marine campaigns on the scientific ship *Marion Dufresne* (MAYOBS 1 on 6-18 May 2019 and MAYOBS 2 on 11-17 June). The campaigns were led under the auspices of the CNRS and involved scientists from BRGM, IPGP, EOST, IFREMER, the University Clermont Auvergne, the University of La Rochelle with the support of IGN, the national center for space studies (*Centre national d'études spatiales*, CNES) and the service hydrographic and oceanographic marine observations (*Service hydrographique et océanographique de la marine*, SHOM). The OBSs deployed in February were retrieved and new ones were released. The data allowed relocating the earthquakes and

thousand euros in funding would have provided enough knowledge by the end of summer 2018 to confirm the volcanic origin of the seismicity. So there is a debate about the agility of the scientific and administrative governance in organizing the monitoring response as quickly as possible.

[9] It is the first time the existence of dead deep sea fishes were made public.

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a mis en forme : Police :9 pt, Couleur de police : Automatique specifying the location of the seismic swarms (Deplus et al., 2019; Feuillet et al., 2019, 2021; Jacques et al., 2019; Saurel et al., 2019). Scientists also acquired high-resolution marine geophysical data, studied the water column and carried out rock dredging operations on the seafloor. An ongoing deep sea volcanic activity was discovered with a new ~800m high underwater volcanic edifice, confirming the already suspected volcanic hypothesis. The discovery was announced by an official press release signed by four ministries (e.g., *ministère de la Transition écologique et solidaire, ministère de l'Enseignement supérieur de la recherche et de l'innovation, ministère des Outre-Mer, ministère de l'Intérieur,* 2019) and relayed by the scientific institutions involved in the campaign on their websites.

Numerous other marine campaigns followed, allowing to refine progressively the understanding of the phenomenon (see Feuillet et al. (2019) to access the MAYOBS campaigns' reports). On 18 June 2019, an interministerial meeting set up a scientific and technical committee to monitor the activity and officialized the creation of the Volcanological and Seismological Monitoring Network of Mayotte (REVOSIMA) with the implementation of *"a monitoring of volcanological and seismological activity in real time and continuously"* (IPGP, 2019b, published on 27 August 2019, translation by the authors). Several phases were envisaged for the implementation of this network. In a first phase, the REVOSIMA (called REVOSIMA 1 by the actors) was supported by a 2.5 million euros fund in order to establish a monitoring network and to guarantee a scientific follow-up of the phenomenon with the implementation of new oceanic campaigns aiming at deploying and recovering OBS. The monitoring mission was entrusted to the IPGP, already in charge of the other French volcanological and seismic observatories. IPGP decided to operate this network through the Observatoire volcanologique du Piton de la Fournaise (OVFP-IPGP) in co-responsibility with the BRGM and its regional direction in Mayotte. The REVOSIMA's mandate was outlined as follows to: *"i) monitor the seismo-eruptive dynamics on land and at sea, in particular in connection with offshore campaigns and underwater instrumentation to monitor the possible migration of seismicity and volcanism, ii) monitor marine deformation and submersion, iii) characterize and monitor gravitational instabilities and tsunami hazard, iv) improve knowledge of the tectonics and geodynamic context of Mayotte, v) monitor the geochemistry of volcanic fluids."* (IPGP, 2019b, published on 27 August 2019, translation by the authors). In October 2019, a "pickathon" was organised by the REVOSIMA's scientists in order to speed up the process of seismicity relocation.

- **Phase 4: 16 December 2019 to 1 April 2021**

The fourth phase of the crisis corresponds to the progressive development of the volcanological and seismological monitoring network which allowed the progress of research on land and at sea (there has been more than eight research and monitoring campaigns since december 2019). In December 2019, a new interministerial meeting ratified the perpetuation of the surveillance network and the release of 4.5 million Euros funding. REVOSIMA 2 was launched at the beginning of 2020. In January 2020, seismologists of BCSF-RéNass came back to Mayotte to trace the evolution of damages due to the earthquakes from June 2018 and a second pickathon was organised to relocate seismicity. From March 2020 onwards, the actors had to deal with disruptions due to the international pandemic of COVID-19. A double maritime campaign (MAYOBS 13-1, MAYOBS 13-2) was nevertheless organized in May with the support of the French Navy. The second campaign was remotely operated by scientists from IFREMER, IPGP,

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BRGM and CNRS located in metropolitan France. It was followed, in June, by a magnetotelluric campaign (MAY-MT) and, in October, by a seismic-refraction campaign (REFMAORE), both coordinated by BRGM. The oceanographic campaigns have continued at a steady pace since then, despite the second and third COVID-19 lock downs. The only notable change, at the end of our study period, was the improvement of the automatic earthquake location method announced by REVOSIMA in March 2021.

6. The organisation of the process of public information and its evolution

Table 1 lists the preferred publication format and the volume of communication issued by the main actors in charge of monitoring and crisis and risk management during our period of study. Figure 4 shows that the number and frequency of publications has varied greatly over time and among actors. Public information was particularly intense during the first six weeks of the crisis and continued with some regularity throughout 2018. The average number of communications per day was 6,8 during the first phase of the crisis (phase 1), compared to 1,3 (phase 2), 1,2 (phase 3) and 1,0 (phase 4) during subsequent phases. Over 90% of all press releases and scientific bulletins issued by authorities and scientists during our period of study are dated from 2018 i.e., during the period qualified by Fallou et al. (2020) as an “information vacuum”. This finding deserves an in-depth analysis to understand the discrepancy between the initial high communication rate and the perceived lack of information. Hence, hereafter, we analyze in detail not only the frequency but also the content and modalities of public information and its evolution over time. Three main phases are distinguished (A, B, C) that are discussed in relation to the phases 1, 2, 3, 4 describing the evolution of the monitoring and risk management response (Figures 3 and 4).

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Table 1. Format and volume of the documents made public by the main actors of scientific monitoring and risk and crisis management during our period of study. As discussed in the text, we only count a report and a web article for, respectively, the BCSF-RéNass and the EMSC, and not their automatic reports. We do not count the automatic bulletins from REVOSIMA. We include the five academic articles dedicated to the understanding of the phenomena occurring in Mayotte that were published during our study period.

	Scientific bulletins	**Press releases**	**News on website**	**Public notes**	**Academic papers**	***TOTAL***
Scientific monitoring						
BRGM	104		22			**126**
REVOSIMA	40	1				**41**
IPGP		1	15			**16**
IFREMER			10			**10**
Researchers				4	5	**9**
EOST			8			**8**
CNRS/CNRS-INSU		2	1			**3**
IGN			1			**1**
EMSC			1			**1**
BCSF-RéNaSS	1					**1**
Risk management						
Prefecture of Mayotte		100				**100**
Ministries/Governement		4				**4**
TOTAL	**145**	**108**	**58**	**4**	**5**	**320**

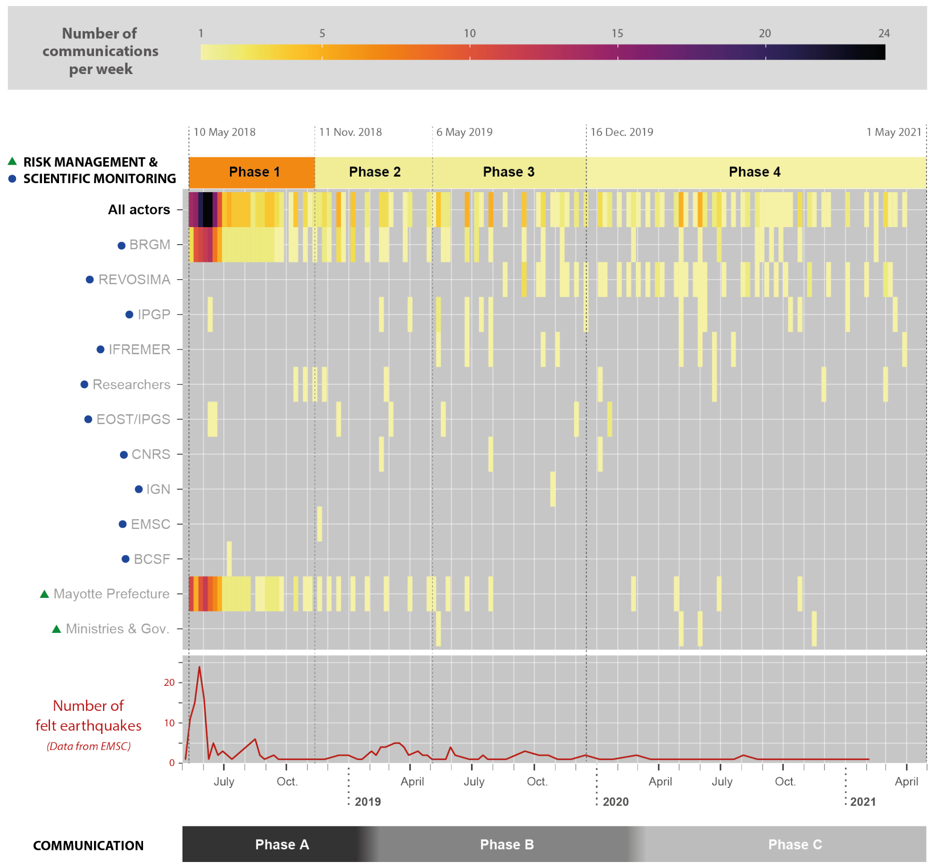

Figure 4. Number of documents made public per week by the main actors of monitoring and risk and crisis management. The average number of documents published per day is indicated for each of the phases identified in Figure 3.

- **Phase A: from the beginning of the crisis to February 2019**

Between the beginning of the seismic crisis and February 2019, the modalities of communication did not vary much. The local stakeholders in charge of monitoring and risk and crisis management, BRGM and the prefecture of Mayotte, were the main contributors. Other scientific actors, such as the IPGP and the EOST who were gradually getting involved in monitoring from the first months of the crisis, were only communicating punctually to report on the geodynamic context of the activity and/or on their involvement in the collect and treatment of data: e.g. on 11 June 2018, EOST announced the dispatch of the macroseismic response mission

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(GIM) to Mayotte (EOST, 2018a); on 12 June, IPGP published an information brief on the ongoing crisis in Mayotte (IPGP, 2018).

The first communication to the public was a press release from the prefecture of Mayotte on 14 May 2018. Referring to the monitoring undertaken by the BRGM since 10 May 2018, it mentioned a *"swarm of earthquakes"*, distinguished it from seismic aftershocks and recalled the safety instructions to be followed in case of earthquakes. Three press releases were published on 15 May that listed the time and magnitude of felt earthquakes and specified that *"all the earthquakes [took] place in the same sector (around 50km off Mayotte) and, although located at sea, [were] too weak to generate a tsunami"*. Confronted with the repetition of felt earthquakes, the prefect of Mayotte activated a crisis unit on 16 May 2018. From then on, the Prefecture published press releases on a daily basis (sometimes more) while the BRGM, switching to "crisis monitoring", published daily reports[11]. As testified by several interviewees, during that first phase of the crisis, the local branch of BRGM was put under strong pressure *"to be able to inform, almost 'day and night', the authorities on the magnitude, on the location of the earthquakes, a more precise location than the one announced by the international networks which were not reliable because of their distance"* (anonymous, interview in May 2020).

During the first weeks of the crisis, the scientific reports and official press releases followed one another within a few hours. BRGM published its bulletins on the BRGM website[12], while the prefecture sent press releases to the press and published them on Facebook. These official press releases generally reproduced the elements communicated by the BRGM. They remained often very technical, recalling the number of earthquakes recorded per day, their magnitude, the time at which they were detected and their distance from the island (the reports mentioned uncertainties of the order of 10-15 km). The prefecture's press releases could contain additional elements about impacts (injuries, building damage) and often recalled safety instructions. They also provided information about the decisions taken by the prefecture to support the inhabitants of the island (e.g. the setting up of a toll-free phone number and the opening of a psychological support unit ; the demand for (and arrival of) a support mission of civil protection and risk management in June 2018).

Mid-June 2018, the BRGM published a Frequently Asked Questions (FAQ) on its website explaining the state of knowledge and the main uncertainties. But, as written a few months later by the ministry in charge of civil protection (*ministère de l'Intérieur*) in its answer to the deputy of Mayotte, *"the most inventive explanations have found an echo in part of the population (conspiracy, actions of evil spirits, etc.) and communication is proving difficult. The state has obviously been concerned about this situation since the beginning of the event, and everything possible is being done to inform the population in a reliable manner"* (Question à l'assemblée nationale n°8992, 27 November 2018, Ali, 2018). Among the incorrect explanations that had emerged, a popular one was that the earthquakes were caused by oil exploration off the coast of Mayotte (Fallou et al., 2020; Mori, 2021). The hypothesis of a volcanic cause had also surfaced:

[11] https://www.brgm.fr/fr/actualite/dossier-thematique/volcan-seismes-mayotte-brgm-fortement-implique
[12] *id.*

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a supprimé: This unusual seismic activity surprises the local experts. In an interview given to the French national press, the director of BRGM Mayotte declareds: *"Unfortunately, we are in the unknown"* (15 June, Le Figaro, 2018b).
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it was discussed on the websites of national scientific laboratories (EOST, 2018b; IPGP, 2018) and in the local press (e.g., YD, 2018) as early as May-June 2018.

From the end of june 2018, the number of communications decreased with the decrease in seismic activity (2 BRGM bulletins per week from 29 June 2018). In September 2018, BRGM announced that *"the swarm [was] still running [but that] the lull observed since the end of June [justified] the change from "crisis" monitoring to "routine" monitoring"* (bulletin of 17 Sept, BRGM, 2018a). From then on, BRGM published bulletins twice a month, with exceptional bulletins in case of felt earthquakes. In October 2018, analysing the routine GNSS measurements led by the IGN, a geophysicist from the Ecole Normale Supérieure suggested that the seismicity could be related to the deflation of a deep magma chamber. These results were published in the form of notes on the public website of the laboratory in October, November and December 2018 (Briole, 2018). In the opinion of several scientists we interviewed, the *"wild"* (sic) publication of his results played an important role in raising awareness of the importance of this seismic crisis among the scientific community and authorities in charge of risk management. On 7 November 2018, a press release from the prefecture of Mayotte mentioned that the IGN measured a shift of the island eastward as well as a *"slight downward shift"*. The risk implications were not specified but it was the first time the volcanological component was officially mentioned, 6 months after the hypothesis circulated among experts and in the press. The infrasound signal of November 11, 2018, which occurrence supported the volcanic hypothesis, gave rise to intense discussions among the international scientific community (Lacassin et al., 2020). It was mentioned by the BRGM in a news item summarizing current knowledge on the understanding of the ongoing activity published on its web site on 17 December 2018 (BRGM, 2018b) .

From January 2019, the frequency of BRGM bulletins continued to decrease to reach a frequency of one bulletin every 20-30 days.

- **Phase B: from February 2019 to February 2020**

On 8 February 2019, following the initiative of the STTM group of Mayotte, 140 inhabitants of Mayotte signed an open letter addressed to the prefect of Mayotte, the local administration, the BRGM and the local media. Pressing them for more information (Picard, 2019, on change.org), they wrote: *"You are not unaware that, for almost 9 months, a large majority of "your" population has been living in anxiety, incomprehension ... Even anguish! The most "basic" questions in terms of security of people, conduct to hold and even projection in the near future ... Are found without any answer! You are certainly convinced that you are doing the maximum so that the panic does not reach your "constituents"? BUT this is not the reality on the ground."* Expectations were particularly high toward scientists, who were expected to provide explanations and guidance with respect to risk scenarios. But, in the absence of offshore observations, the scientific advances were still poor.

February 2019 was an important tipping point, however, as the scientific community finally received the funding to work in the area. On 22 February 2019, CNRS issued a press release with the laureates of the Tellus-Mayotte call for tenders (CNRS, 2019). With the launch of the Tellus Mayotte program, communication opened up to new scientific actors. IPGP and EOST announced their involvement in the up-coming missions on their website. BRGM scientists

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published the first public catalog of the seismic data collected since the beginning of the crisis (Bertil et al., 2018; Lemoine et al., 2019).

BRGM continued to publish a monthly bulletin dedicated to the monitoring of the seismicity but communication from the prefecture of Mayotte became more episodic. It focused on relaying BRGM's situation points (with the list of events - among which the felt ones - in the past months) and on announcing the arrival of Tellus Mayotte scientific campaigns. The volcanic hypothesis was eventually put forward in the official communication. The press release of 3 April 2019 mentioned a *"scientific volcanological mission"* aiming at *"consolidating knowledge of the tectonic and volcanic history of Mayotte and at highlighting the tectonic structures of the island by means of dating of magmatic rocks, or analyses of the composition of soil gases"*.

One year after the beginning of the seismic crisis, it was time to take stock of the situation. In a press release published on 10 May 2019, the Préfecture of Mayotte reviewed the actions undertaken, both from a scientific and risk management point of view, during the past year, and concluded that *"the latest data collected by the experts and the modeling of the phenomenon suggested a volcanic origin, possibly linked to a large-scale underwater eruption, or even to an origin combining both tectonic and volcanic phenomena"*. When the scientists of the MAYOBS campaign arrived at the dock on 16 May 2019, they were accompanied with an interministerial press release (e.g., *ministère de la Transition écologique et solidaire, ministère de l'Enseignement supérieur, de la recherche et de l'innovation, ministère des Outre-Mer, ministère de l'Intérieur,* 2019) announcing the discovery of a newborn volcano at the origin of the abnormal seismicity endured by the Mahorais for the past year. The government, through the voice of four of its ministries, commited to reinforce monitoring and prevention measures[14]. IPGP relayed the press release on its web site on the very same day (IPGP, 2019a), IFREMER, EOST and BRGM followed soon after. The announcement was relayed on Twitter, with a spectacular picture of the underwater volcanic edifice and the rising plume above it (Lacassin, 2019), which raised the interest of international scientists and of media such as National Geographic, Science, or the BBC (BBC - Science in Action, 2019; Pease, 2019; Wei-Haas, 2019). The prefecture and vice-rectorate of Mayotte launched a competition among primary and secondary schools to name the new-born volcano[15].

There were similar surges of communication after the return of the next marine campaigns MAYOBS 2 to 4 in June and July 2019, but much less communication afterwards[16]. The effort of communication resumed again in May 2020 after the MAYOBS13 campaign.

From the discovery of the underwater volcanic activity, the prefecture of Mayotte and the BRGM were no longer the only two central actors regarding public information. On 28 May, 2019,

[14] The press release indicates that the government has defined the following action plan: 1) Complete as soon as possible the monitoring system and install the scientific devices that are necessary to continuously monitor the phenomenon; 2) Complete, through appropriate missions, the scientific knowledge; 3) Immediately update the knowledge of the risks presented by this phenomenon and the potential impacts for the territory of Mayotte; 4) Strengthen without delay the planning and preparation for crisis management ; 5) Regularly inform the population, in conjunction with local elected officials.

[15] The name chosen for the new volcanic edifice was finally made public in December 2021. It did not match the names originally proposed by the children. It is not possible to explain the reasons for this in this paper, as it would require extending our study period. However, it can be noted that the entire process was not consistent with the need to engage people more actively in the recognition of this new source of hazard.

[16] Reports and press releases following MAYOBS campaigns are listed on this dedicated IPGP web page: https://www.ipgp.fr/fr/revosima/rapports-communiques-de-presse-missions-mayobs

BRGM published its latest seismic bulletin on its own and the prefecture of Mayotte published its latest press release only dedicated to the seismic crisis. Monitoring falled in the hand of the newly born REVOSIMA. Communication was then discussed at a more centralised level by the DIRMOM who reported directly to the cabinet of the Prime Minister. The prefecture worked closely with the DIRMOM to elaborate new communicational tools such as information leaflets. Early August, the Prefect organized a press conference during which scientists presented the results of the last campaigns to elected officials and local dignitaries.

The creation of the REVOSIMA was eventually announced one year and four months after the start of the seismic "crisis" in the end of August 2019, during a visit from the minister of the Overseas (*Ministre des Outre-mer*) (*Journal de Mayotte*, 27 August 2019). The first web news concerning the creation of REVOSIMA was published on the IPGP website (IPGP, 2019b). Entitled *"Volcanological and Seismological Monitoring Network of Mayotte"*, it presented the mandate of the IPGP and its partners in monitoring the seismic-volcanic crisis in Mayotte. REVOSIMA issued its first scientific bulletins at the end of August 2019. Several bulletins were issued approximately at the same time ((one bulletin for July and two for August 2019) creating an apparent surge of communication on Figure 4. From then on, two scientific monitoring bulletins were published every month (it was reduced to one per month in March 2020)[17].

A scientific conference was organized at IPGP in Paris on 15 October 2019. It aimed to present scientific advances, and to discuss the challenges of its future monitoring. It was followed by a public conference and a question-and-answer session in the presence of state representatives and of the media. It was covered by national media, interested by the unprecedented nature of the activity (e.g., Vey, 2019), and the local press, proud to see a local scientist invited (Perzo, 2019b). In October 2019, the Préfecture set up a *"stakeholder committee"*[18] aimed at bringing together *"all the notables, heads of department, politicians, around a table"* and to whom scientists would be expected to present, about every six months, *"the assessment of the crisis and the scientific findings"* (anonymous, interview in May 2020). In November 2019, the prefecture organised public meetings in several municipalities of Mayotte but with a sparse audience (a few tens of people, anonymous, interview in May 2020).

In December 2019, the American Geophysical Union fall meeting hosted a special session dedicated to the Mayotte new volcano discovery where the scientific results from the first MAYOBS campaigns were presented (e.g., Deplus et al., 2019; Feuillet et al., 2019; Jacques et al., 2019; Saurel et al., 2019). From our interviews, we understood that some tensions emerged between the authorities and the scientists about one of the communications (Poulain et al., 2019), which mentioned a delay of a few minutes between a triggering event due to the volcanic activity and the arrival of a tsunami on land. The authorities did not want such information to be communicated without having thought beforehand about the protection measures to be put in place. The decision was taken to not show the poster (interview in June 2020). At the end of 2019, EOST also announced the arrival of the second mission of the BCSF-RéNaSS macro-seismic

[17] All REVOSIMA bulletins and reports are listed and accessible from the following IPGP web page: https://www.ipgp.fr/fr/revosima/actualites-reseau

[18] According to our interviewees, this committee has not been very active since its creation. One or two meetings were organized

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At the end of 2019, EOST also announceds ... [11]

intervention group in Mayotte. The continuation of REVOSIMA decided at the December 2019 interministerial meeting was not really announced, at least publicly.

In January 2020, a team of French and German researchers, not members of REVOSIMA, published in *Nature Geoscience* the first academic paper analysing the evolution in time of the seismicity and its relation with the ongoing volcanic activity (Cesca et al., 2020). This paper, mostly based on seismic data acquired by worldwide seismic networks, mentioned the discovery of the new volcanic edifice before its publication by the scientists directly involved in the survey campaigns and the close monitoring of the activity. The CNRS and the University of Toulouse, which hosted the second author of this paper, published a press release in French (CNRS & Université de Toulouse III, 2020) bearing a sketch section of the proposed magmatic plumbing system, which was commented by the STTM group: "*So much questions !!! In particular on the position of the magma chamber […] One or Two? 1 or 2 chambers? The island is moving east, towards the supposed chamber near the volcano??? And there's another one just below under the doormat on our front door", "Silly question, but does that portend a big disaster for us?"* (excerpts from STTM Facebook group, 8 Jan 2020)

In January, EOST also announced the results of the GIM mission and of a pickathon organized by the REVOSIMA to get help in relocating earthquakes. In February, the BRGM and the prefecture of Mayotte announced the future launch of seismic-refraction and magnetotelluric surveys (MAY-MT and REFMAROE).

- **Phase C: From March 2020 to April 2021**

From the beginning of 2020, with the perpetuation of REVOSIMA, the number of actors communicating diminished. REVOSIMA refocused the communication effort. From March 2020, the frequency of its scientific bulletins became monthly and automatic bulletins were released every day online. The monthly bulletins, consisting of about ten to twenty pages, were particularly appreciated by the scientific community because they contained details on scientific hypotheses, instruments, methods and results as well as the related uncertainties. Despite a first summary page aimed at popularizing the contents of the bulletin, they remained nevertheless difficult for the lay public to access as it was testified of by discussions within the STTM group: *"Gee.... a REVOSIMA bulletin of 21 pages, we didn't expect so much.....I don't understand everything, so I count on THE scientists to tell me if there is something new..."*, and in response, *"Sorry but I can't stand these bulletins anymore! I force myself to read them ? Why : 89 % of repetitions and reminders of the facts ... I haven't read this one yet (the 25th) ! I think that the objective is reached ! To make the "average" readers like us run away ! Impossible a short, sharp and clear bulletin ??? Saying : "since the last time…"* (excerpts from STTM Facebook group, 5 Jan 2021) and again, "Silly question, but does it mean a big disaster for us? I have no knowledge on this subject..." (excerpt from STTM Facebook group, 8 Jan 2021) Shorter exceptional bulletins were issued in case of felt earthquakes. REVOSIMA monthly and daily bulletins and exceptional press releases (in case of felt earthquake) were the main supports for information until the end of our period of study. They were made accessible to the public on a dedicated facebook feed and were regularly commented on, in the STTM facebook group as well as in the local press. The prefecture continued to inform the population about new scientific campaigns.

The COVID 19 pandemics, the related lockdowns and travel restrictions complicated the scientific survey of the crisis. A part of it had to be remotely managed, including the MayOBS13-

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2 bathymetric survey in May 2020, operated by a commercial survey vessel while the scientific team worked on it from their homes. The objectives of these missions were announced by a press release from the Préfecture of Mayotte (2 May 2020) relayed on the websites of REVOSIMA partner institutions (IPGP, IFREMER, BRGM). The information was backed up by a governmental press release (6 May 2020) which recalled *"the state's permanent commitment to protecting the population of Mayotte"* and stated that, as such, *REVOSIMA "[continued] to carry out its land and sea monitoring missions, including in the current health context, with all due precautions"*. Two information leaflets were also issued that described the release and recovery of OBS (MAYOBS 13-1) and the acquisition of underwater acoustic data (MAYOBS 13-2). While surprisingly, no press release followed the MayOBS 5 to 12 missions, REVOSIMA issued in May 2020 a detailed report about MayOBS13 results (REVOSIMA, 2020), which was relayed on the websites of partner institutions (IPGP, BRGM, IFREMER) on 4 June 2020. The same day, the government published a press release summarizing the main scientific results and thanking all the staff for their commitment in these missions.

Two more scientific papers were published in June 2020, one on the volcanological and seismotectonic context of the seismo-volcanic crisis (Famin et al., 2020), the other one, led by BRGM scientists, analysed the seismic and GNSS data from the first year (2018-2019) of the seismo-volcanic episode (Lemoine et al., 2020). A preprint preliminary version of the latter was publicly available in February 2019 (Lemoine et al., 2019).

The following months were marked by more scattered communications from the REVOSIMA partner institutions (in addition to the monthly REVOSIMA bulletin), aiming to summarize the knowledge acquired since the beginning of the crisis (e.g. “two years of seismic crisis and the birth of an underwater volcano in Mayotte”, August 25th, Paquet, 2020). There was a new surge of communication in October 2020 with the preparation of the MAYOBS-15 campaign. IPGP presented the campaign’s objectives on its website on 13 October, 2020 and published a preliminary assessment of the mission on 29 October (IPGP, 2020). The prefecture of Mayotte issued a press release presenting MAYOBS-15 results on 28 October. Some of the scientists of the campaign remained in Mayotte to participate in the "volcano week". Organized by the prefecture of Mayotte, in close collaboration with the DIRMOM and REVOSIMA, this "volcano week" aimed to raise awareness of the volcano among the inhabitants of Mayotte. Local personalities and scientists took turns talking about the ongoing telluric crisis. The scientists presented their understanding of the ongoing volcanic activity without dwelling on the possible scenarios. Only the tsunami risk was presented in some detail. Alternative scenarios were shared to the public recalling that a working group was already working to identify possible evacuation routes and that a program had been launched to work on a network of sirens and, in the longer term, a mass alert system by telephone operators. But the information shared during that week remained quite light on the overall topic of risks and the reactions posted live on the facebook feed of the prefecture during the presentations were pretty skeptical. The tsunami risk was commented in the local press as being eventually "quite limited" (Journal de Mayotte, 2 November, YD, 2020). Two presentations by scientists from REVOSIMA were also organized by the education authority for high school students and 160 science teachers in Mayotte. During the same week, the prefect of Mayotte inaugurated the first tsunami warning siren in Dembeni and scientists symbolically handed over volcanic rocks to the Museum of Mayotte. The government

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issued a press release on 17 November 2020 that reviewed the results of the MAYOBS-15 campaign and the outputs of the "Volcano Week."

In January 2021, IPGP announced to be the laureate of a major instrumentation project in Mayotte (Programme Investissement d'Avenir 3, MARMOR project). Led by IFREMER, the project brings together the core partners of REVOSIMA and prefigures a restructuring of the governance of research and observation in the region. This change in governance will be all the more important in the months to come as the DIRMOM's mission ended at the beginning of May 2021, leaving room for a reorganisation within the state services themselves. This reorganisation is underway at the time of writing and is therefore beyond the scope of this paper. However, it is interesting to note that our study period, which covers the first three years of the crisis, corresponds to the first major stage of volcanic risk management in Mayotte.

In March 2021, the researchers involved in the first MAYOBS campaigns and in REVOSIMA publicly released a preprint of their paper submitted to Nature Geoscience (Feuillet et al., 2021). This paper was initially submitted to Nature in September 2019, then transferred to Nature Geoscience in June 2020, but remained confidential until March 2021. It was still under review after revision at the time of writing. The preprint described the new offshore volcano and its activity, the evolution of the crisis from the initial deep fracturation processes to the upward migration of magma across the lithosphere, and discussed the geodynamic context, but did not discuss future scenarios of evolution and related hazards. Local press summarized its main results using a lithospheric-scale cross-section from the preprint that illustrated the processes at work and the location of the seismicity and of magma chambers (YD, 2021). On 15 March 2021, the online media from the *Cité des Sciences et de l'Industrie* (a science museum in Paris) published a webdoc summarizing in a popularized way all main results obtained so far on the Mayotte seismo-volcanic crisis (Minassian, 2021), providing a whole set of new visuals on the activity. Until then, according to the journalists we interviewed, the coverage of the event was indeed made very hard by the absence of direct images of the activity. Two main types of images were used in the official communication as well as in the media: pictures showing oceanographic vessels or a group of scientists at work and the image showing an underwater plume above the new volcanic edifice that was made during the first MAYOBS campaigns (Lacassin, 2019 ; Feuillet et al., 2021).

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7. Examining the potential limits of the process of public information with regard to what is known of at-risk populations' information needs

The previous sections aimed at documenting and understanding the organisation and evolution in time of the official response (section 5) and, more specifically, of the process of public information (section 6). We showed that the communication strategy adopted by the local and national authorities in charge of risk and crisis management and by the scientists in charge of monitoring became more structured and more centralised from the summer 2019, with the establishment of a dedicated monitoring body (REVOSIMA) and the support of an interministerial delegation dedicated to major risk reduction in overseas territories (*Délégation interministérielle aux Risques majeurs en Outre-mer,* DIRMOM). We also showed that the number and frequency of public communications had been significant over time, testifying of a constant commitment of these actors to, first, understand and monitor the crisis and, second, communicate their progress publicly. The question that arises then is: how to explain the reported perception of a lack of information among the population? (see sections 3 and 6; Fallou et al., 2020; Devès et al., under review)? Here we attempt to answer that question by comparing what we learnt about the public information process in Mayotte with what is known, in the litterature, of at-risk populations' needs.

The question of at-risk populations' information needs has nourished disaster research for more than 40 years. Excellent summaries of this research exist (e.g. Drabek, 1986; Mileti and Sorensen, 1990; Tierney, Lindell and Perry, 2001). Many studies have focussed on how people process and respond to risk communications in emergencies, but the lessons learnt also apply to emergency preparedness efforts - which is the current issue in Mayotte. Lindell et al. (2006) provide a practical summary of what should be known by practitioners in order to design a successful communication strategy. They insist on the fact that people must, first, *receive* information, second, *heed* available information (i.e. pay attention to it) and, third, *comprehend* the information. They broke down information processing into eight stages corresponding to a few typical questions that people ask before making decisions. We summarize these questions below while indicating in brackets the expected outcomes to progress toward protective actions: 1) Is there a real threat that requires my attention? (expected outcome: threat belief), 2) Do I need to take protection action? (protection motivation), 3) What can I do to achieve protection? (decision set), 4) What is the best method of protection? (adaptative plan), 5) Do I need to take protective action now? (threat response), 6) What information do I need to answer my questions? (identified information need), 7) Where and how can I obtain this information (information search plan), 8) Do I need the information now? (decision information). These questions can all be found, in one form or another, on the STTM Facebook publication feed in Mayotte. The people who write on that feed have received information about the activity (they were warned by felt earthquakes and received messages from authorities, the media or peers). However, as Fallou et al. (2020) point out, they complain that the information they receive does not allow them to understand the exact

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a supprimé: This section aims at atallows drawing a few lessons by comparing what we learnt on the public information process with what is known of at-risk populations' needs. Our ultimate goal is to, which could help to improve future communication strategies. The question that arises is: why does the population of Mayotte complain about a lack of information when, objectively, the volume of documents made public by the main risk actors is significant, corresponding to a real effort to communicate on their part? We

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nature and extent of the threat, and hence to make decisions to prepare or adapt to the associated risks. Of course, the large uncertainties existing about the activity itself have affected the ability of authorities and scientists to meet these expectations. But, as we will now see, the public information strategy that has developed over time has not avoided some well-known pitfalls of risk communication that would benefit from being corrected in the future.

~~Discussions revolve a lot around scientific knowledge and uncertainties. They are informed by publicly available scientific knowledge, in the form of official releases from local authorities, scientific reports from institutions involved in monitoring, and more generally anything that can be found on the Internet. Fallou et al. (2020) point to the absence of a professional scientist who can help the group to translate and contextualize such information. *"The schools for example, which accommodate some 80,000 students, have been checked by experts (I hope everywhere in Mayotte) but there has not yet been any feedback to the general public. [...] I would like, for example, in the general interest, that according to such and such a structure, we could say to what extent it will resist to such and such a magnitude (including site effects and other local variables) and also how it will resist to the succession of moderate tremors (in swarm, which is obviously our case)"* (excerpt from STTM Facebook group, 27 May 2018).~~

Before to go further, it is important to recall that the inhabitants of Mayotte perceive the existence of offshore volcanic activity only indirectly, mainly through felt earthquakes and, secondarily, through stories told on social media and in the press or reported, for instance, by fishermen who observe dead fishes coming up from deep seas. Numerous studies have shown that experiencing the effects of a hazard increases the attention paid to information about that hazard (e.g., Sorensen, 2000). From this point of view, it seems reasonable to consider that the thirst for information of the inhabitants of Mayotte has also evolved during the crisis, in response to the evolution of the seismicity (Figure 3). The beginning of the crisis was marked by repeated and strongly felt earthquakes, which goes hand in hand with a strong demand for information (Fallou et al., 2020). This interest in the topic of earthquakes is further evidenced by a peak in the number of articles published in the local press at the beginning of the crisis (Devès et al., 2021). The number of felt earthquakes decreased thereafter and so did interest in earthquake-related news. This is shown by a significant drop in the number of articles in the local press. Inhabitants of Mayotte report that, today, the risks associated with the seismic or volcanic activity are barely mentioned in everyday discussions (anonymous, interview in November 2021). Indeed, people are exposed to a variety of risks, some of which are more immediate than those associated with the seismic-volcanic crisis: financial insecurity, energy insecurity, risk of being expelled from the country, daily struggle for access to water, food, and among the natural hazards, flooding, which is far more frequent.

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75.1. Two factors determining the evolution of population's need for information¶

a supprimé: In the case of Mayotte, the evolution of the population's need for information seems to be a modulation of two main factors: 1) a need for "basic" information that is typical of all populations at risk and well known to disaster studies (see for instance Lindell et al., 2006; Mileti, 1993), and 2) a need for information that adapts to the level of perceived danger, i.e. to the evolution of the hazard.

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The need for information also changes according to the content of the information that is disseminated. Regarding this issue, we have identified three main phases of communication (A, B, C).

7.1. The technicalist bias

The public communication is overall characterized by a frequent but minimalist and technicalist discourse. This was particularly true from the beginning of the seismic crisis in May 2018 to the launch of the first scientific campaigns in February/March 2019 (phase A). As expressed on STTM Facebook feed, lists of earthquakes with magnitude and location do not really help people understand the nature or the extent of the threat nor the uncertainties linked to its possible evolution (see section 3, excerpt from STTM Facebook group, 26 May 2018). The frequent use, by scientists as well as by authorities, of specialist terms such as *"risk", "seismic constellation", "magnitude", "intensity",* etc. is another difficulty for those who receive that information. Devès et al. (under review) show that such terms are reproduced in local newspapers without definition or explanation of context. Among the scientists we interviewed, most argue that "it's not worth worrying people about things that are still hypothetical so [given the uncertainties] we chose to remain very factual" (anonymous, interview in May 2020). But did this *"factual"* communication allowed people to understand *"the big picture"*, i.e. what was happening and what could happen next? We tend to believe that it added confusion by delaying the sharing of robust information. The fact that the Préfecture mentioned the volcanic hypothesis 6 months after the local press undoubtedly contributed to the population's feeling of a lack of information, and also facilitated the emergence of complotism. The technicalist and minimalist tone adopted in official communications was also at odds with the statements that were made by scientists and authorities who insisted on the unprecedented and de facto very uncertain nature of the activity (e.g. the press release of 3 June 2018 stating that "seismic activity remains abnormal and continues").

A final example can be given for illustration here. As reported by Fallou et al. (2020), the fact that some of the felt earthquakes were not reported in scientific bulletins fueled a sense of distrust among the population. Scientists in charge of monitoring took care to publish a note explaining the limitations of the seismic network and the difference with international networks (22 May, BRGM, 2018a). This note was reproduced in part in the local press (e.g. Le Journal de Mayotte, 23 May 2018). But the efforts made to explain instrumental uncertainties were challenged by the technicity of the note, hardly translated by the journalists who copied and pasted whole sections of the text (Devès et al., under review). Experts' efforts were also challenged by the publication of real-time data, albeit of lower quality, by web applications accessible to all. The prefecture tried to bridge the gap by communicating immediately after earthquakes of magnitude greater than 5 using the data issued by international networks while recalling that *"the estimates of international measurement centers were relayed [...] [waiting for] the BRGM to refine its results"* and that the latter would be *"more accurate because the sensors [were] located in Mayotte and in the area"* (Press release, 5 June 2018). Although this strategy seems legitimate from a scientific point of view, one can wonder if it really helped people to better understand the nature of the existing uncertainties. Indeed, it may seem paradoxical to say that the data is of poor quality when it is de facto used in official communication without waiting to be improved.

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7.2. The reassuring bias

We showed that, beyond the fact that it remained essentially focussed on the seismic hazard, the first phase of communication was marked by the propensity of the various actors of the risk chain (the authorities, but also the scientists and the local press) to try *"reassuring"* the population in order to *"avoid panic"*. The local *Journal de Mayotte* reported that *"the mayor of Mamoudzou [was] calling people to calm down and not to give in to any form of panic"* (Journal of Mayotte, 23 May, Perzo, 2018a). Coming back onto that stage of the crisis, a scientist explains: "*At the beginning, we talked a lot about the seismic risk to minimize it in the sense that these were only moderate earthquakes, 5.8 was the larger and afterwards we stayed on moderate earthquakes, we communicated quite a lot saying that to have a lot of damage it was necessary to have high enough magnitudes, that it was, maybe, not in the functioning of the system that we knew*" (anonymous scientist, interview in June 2020). After a public press briefing with civil protection experts and seismologists (Perzo, 2018b), the prefecture posted on Facebook and Twitter that "there will be no earthquake of a higher magnitude than what we have already known". And thus, in the local press, one could read that "*Mayotte [was] indeed in a seismic zone, but the tremors [were] not of a nature to worry the scientists*" (Journal de Mayotte, 2 June, Perzo, 2018b).

This attempt to reassure the public by emphasizing the moderate intensity of the threat had negative side effects when it came to talking about the tsunami threat. The first public scientific bulletin, published on 16 May 2018, indicated that "in all rigor and given the limited knowledge in the region, a tremor of magnitude greater than those already observed [could not] be excluded" and outlined that "these earthquakes [did] not produce damage and, although at sea, [were] too weak to generate tsunamis" (bulletin of 16 May, BRGM, 2018a). This was taken up word for word by the officials and the Minister responsible for the administration of overseas territories declared the same day that "there [was] no risk of damage on land, nor a tsunami at sea" (quote from the Ministre des Outre-mer in L'express de Madagascar, 16 May 2018). A few days later, one could read in national newspapers that: "there [were] no risk of subduction, therefore there [were] no risk of a tsunami", although "emergency teams [were] ready to be dispatched from Paris and from Reunion Island where tents and medication [were] stocked", the journalist outlining that "the watchword [was] to reassure the population." (Le Figaro, 21 May 2018). This press excerpt outlines the paradox of a communication that adopts the tone of certainty (*"there is no risk"*) and, at the same time, recognizes implicitly the existence of unknowns (emergency teams are still making ready!). And, a year later, tsunami risk reduction became one of the priorities of risk management authorities focussing part of the latest communication efforts[19].

Communication in the context of large uncertainties has proven to be challenging as contradictions cannot fail to emerge when awareness about the situation becomes more precise. Devès et al., (under review) point out that news accounts, because of the way they are constructed (by juxtaposition of remarks made by different actors) tend to highlight these contradictions. Nevertheless, it remains crucial that authorities and scientists express themselves promptly so as not to allow space for rumor to gather (see Fallou et al., 2020 on Mayotte's case;

[19] The tsunami is one of the first hazards to have given rise to a precise assessment and to the development of concrete preparedness measures (installation of new sirens, definition of evacuation trajectories). Tsunami risk reduction is at the heart of the prevention campaign organized by the DIRMOM in 2021 with videos explaining how to evacuate to higher ground.

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Lagadec, 1993 or Scanlon, 2007 for general views on the topic). The pitfall here lies in the willingness, often shared by all the actors (authorities, scientists, and in the case of Mayotte even local journalists as shown by Devès et al., under review), to *"reassure"* a supposedly *"panicked"* and *"irrational"* population[20]. This desire to reassure the population in order to avoid disturbances of public order is not specific to the case of Mayotte. It has led risk managers' decision making in many other crises – a famous case is that of Katrina in the United States (Rodriguez, Trainor and Quarantelli, 2006) but examples were also discussed in France (e.g., Borraz, 2019) and about telluric phenomena such as earthquake sequences (e.g., L'Aquila, see discussion in Cocco et al., 2015; Jordan, 2013). However, the representations of *"officials [who] must be careful about issuing warnings because of the danger of panic"* and *"victims [who] will be dazed and confused, perhaps in shock, and must be cared for by others"* (Scanlon, 2007: p. 416) have been shown to be *"inaccurate, biased and often exaggerated"* (Rodriguez *et al.*, 2007: p. 482). They corroborate certain myths circulating in society, largely deconstructed by the social sciences (Mileti, 1999). The populations facing extreme situations, rather than becoming confused, passive and irrational, are on the contrary extremely pragmatic and proactive and tend to react by reinforcing social control mechanisms to face danger (Quarantelli, 2008; Solnit, 2010).

Sharing experiences, emotions and information on a Facebook publication feed is an interesting way to collectively manage stressful situations. But, when scientific knowledge is concerned, the ability to select and comprehend information soon becomes a crucial issue (see the excerpt from STTM Facebook group, 8 Jan 2021, section 6). Fallou et al. (2020) report that the members of the STTM Facebook group worked very rigorously at describing the phenomenon as accurately as possible (following the group, you could know whenever an earthquake was felt, with which intensity and what impact from place to place) and at bringing together all the information they could find (sources were official releases from local authorities, scientific reports from scientific organisations involved in monitoring, and more generally anything that can be found on the Internet, see Fallou et al., 2020). Fallou et al. (2020) also point to the absence of a professional scientist who could help the group to translate and contextualize this information. The question arises of the role to be played here by the scientific community. It is true that, given the uncertainties, some questions could not be answered but, as suggested by Lindell et al. (2006), one might have explained earlier what was known and not known, and what could be done to address that lack of knowledge. As noted by Sharma & Patt (2012), recent empirical studies tend to show that *"lay people do understand uncertainty and, under conditions of good communication, even understand probabilistic forecasts. Therefore, there may be value in communicating uncertainty from the point of view of improving the credibility of the message."* This is particularly important as many studies have shown that the experience about the credibility of the message affects the response to warning in the next future event (Lindell et al., 2006; Sorensen and Sorensen, 2018). The recent development in research about uncertainty communication can help designing communication strategies in this respect (see Doyle et al., 2019 for an overview). This requires scientists to adapt their practices because, as concluded by Doyle et al. (2019), *"scientists must first understand decision-maker needs [and we add here that*

[20] Devès et al. (under review) analyse the representation of authorities, scientists and inhabitants in media accounts and show that the place they are ascribed to echoes disaster myths (Quarantelli, 2008). This is well illustrated in the following press excerpt: "Many irrational reactions, faced with which the BRGM explains…" (Le Journal de Mayotte, 23 May 2018)

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at-risk populations are not the least of the decision-makers in case of emergencies], and then concentrate efforts on evaluating and communicating the decision-relevant uncertainties."

7.3. The hazard bias and the lack of risk scenarios

We showed that, from the launch of the first scientific campaigns in February/March 2019 to the creation and perpetuation of the REVOSIMA (phase B), the format and the nature of communication changed. At first, it was distributed among much more actors and then changed scale with a resumption of communication by national actors (major scientific institutions, CNRS, ministries and government through the DIRMOM). But it remained relatively coherent as each of these actors were referring to the joint Tellus Mayotte work program in their communications. The discoveries made during the MAYOBS1-2 and MAYOBS 3-4 missions constituted an important turning point in the content of the information that was shared. From May 2019, communications no longer focussed only on seismic hazard but started drawing a more general explanatory framework attributing earthquakes to an offshore, and unexpected, volcanic activity. But despite this important change, the communication remained centered on hazards rather than on risks, which still does not allow answering the population information needs. Reading the press and the STTM facebook feed, one realizes that people were very excited by the unprecedented scientific mobilisation around their island and expected to learn a lot from scientists. But after the first campaigns, given the extent of the discovery that made fear of potentially high associated risks, the authorities became very cautious about communication. They asked the scientists to refine their scenarios before sharing openly information about risks with the population (we mentioned earlier some tensions in AGU). A scientist reports that *"today [a year after the discovery of the volcano] we are starting to talk about all the risks. But we are talking about it with frilosity. But it is not the scientists who talk about it with frilosity, I think that the authorities have locked up this subject a little."* (anonymous, interview in May 2020). Some of the scientists actually share the frilosity of the risk managers pointing out that *"I prefer to publish, and to get a peer-to-peer validation of my hypotheses, before sharing them publicly [...] I don't want to panic people"* (anonymous, interview in July 2020). Hence, public information tended to settle for highlighting the unprecedented nature of volcanic activity and the prowess scientists had to deploy to study it. Little was said about the possible evolution of the hazard although, as recalled by another scientist, *"we identified [coarsely] the possible scenarios probably from May-June 2019"* (anonymous, interview in May 2020). On STTM Facebook Publication feed, the feeling prevailed that communication did not answer the important questions: *"[…] The state gives up a lot of money and resources... But no respect for the population! No info (the same for 2 years! True!) No listening to people and their requests! No explanation in the villages […] And when they give a conference (scientific or press) it is to repeat the same information over and over!"* (excerpt from STTM Facebook group, 5 Jan 2021).

So far, i.e. three years after the beginning of the seismic crisis, scenarios have only been communicated orally, in the form of a listing of potential hazards, indicating that scientists are still working to refine their assessment of the associated risks. But this strategy is debated among scientists. Some argue that *"these are still scenarios, so we must be very careful [in communicating] [...] I understand that some scientists are a little confused because a lot of work has been done and not all the information has been passed on to the general public, but I think*

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that the general public does not need to know certain information either, because it is all just hypotheses and then you take a sentence out of context and it's panic. I understand that" (anonymous, interview in May 2020). Others respond: *"I think it's better [...] that people are aware that one day there could be a mudslide in their garden or a tsunami than not to know. I know that Mayotte is maybe more complicated because, I don't know, they have other problems but it's not a reason to hide it from [people]..."* (anonymous, interview in June 2020). Between the supporters of a communication based on certainties and quantitative assessment, which is structurally close to the strategy adopted by the authorities, and the supporters of a certain level of academic freedom in communicating hypotheses at work and not just confirmed results, the debate is still open.

Both strategies have advantages and caveats. Davies et al. (2015) argue that *"quantitative risk assessment and risk management processes"* are *"of value at regional or larger scales by governments and insurance companies"* but do not provide *"a rational basis for reducing the impacts at the local (community) level because in any given locality disaster events occur too infrequently for their future occurrence in a realistic timeframe to be accurately predicted by statistics"*. They suggest, instead, that *"communities, local government officials, civil society organisations and scientists could form teams to co-develop local hazard event and effects scenarios, around which the teams can then develop realistic long-term plans for building local resilience"*. As outlined by earlier studies, as providers of the primary information about the hazards, scientists are - whether they like it or not - at the heart of the risk reduction process (e.g. Rodriguez et al., 2017; Donovan, 2021). They cannot wait for the very last quantitative results to share their knowledge, i.e. their hypothesis, their methods and their results (that can be negative ones proving that an hypothesis does not hold). They have a moral, when not legal, responsibility to respond to the demand for information from different audiences (authorities, people likely to be affected, journalists, etc.) and at all times (times of larger or smaller uncertainties). Jasanoff (2005) speaks about *"civic epistemology"* as *"the institutionalized practices by which members of a given society test knowledge claims used as a basis for making collective choices"*. Scientists' role is indeed all the more central as their opinions not only inform, but also legitimize the decisions taken by the authorities in charge of civil protection. Of course, such a posture is not easy to adopt, notably because there is a bounded understanding of the scientific approach in our societies (e.g., Bromme & Goldman, 2014). During our interviews, we were said that the comments posted on STTM hurted some scientists. Referring to the criticisms read on the Facebook of the STTM group, one of them says: *"What they did not understand is that we did not understand what was happening either [...] Because there is no analog [...] We started from an area considered as [inactive]. We find ourselves in an unknown zone to manage a phenomenon without analogue while having to organize missions involving unprecedented means [i.e. large scientific boats that should be booked months in advance] [...] Our role is to make scientific reports [but] I think these have a limited impact [because] there is no one on the ground [who can translate what we do]."* (anonymous, Interview in July 2020). That such knowledge *"translation"* has to be done by concerned scientists actively engaged in science communication and in answering people's concerns, or by professional *"knowledge brokers"* (Hering, 2016), is an open question.

The publication of an article by REVOSIMA researchers on EarthArxiv (Feuillet et al., 2021) in march 2021 gave rise to mixed feelings in the STTM feed. The fact that the publication was not associated with a document in French and addressed to the lay public was not much

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appreciated: *"they are seriously starting to get on my nerves! A choice to address only peers! And damn for a minimum of popularization and "simple" explanations. Afterwards, they are surprised that some and others tell everything, anything! or blame them for their "Height""* (excerpt from STTM Facebook group, 17 March 2021). The intuitive interpretations they made of the article, from the point of view of risks, was rather accurate: *"I learn from this cross-section that the volcano's chimney is 15km from Mamoudzou and not 50, where the underwater volcano is formed. Not reassuring. Moreover, the last activities mentioned are in the main volcano, so very close to us."* (excerpt from STTM Facebook group, 17 March 2021). People have clearly understood that it is not the new volcanic edifice that poses a significant risk to them. They are very concerned about the seismicity located closer to the island, especially since the publication of the cross-sectional diagrams of Cesca et al. (2020) and Feuillet et al. (2021). They ask themselves questions about a future eruption very close, and/or collapse on the outer-reef slope generating tsunamis, which corresponds more or less to the scenarios considered by scientists. To this respect, it seems rather vain not to communicate on scenarios.

7.4. The complexity of multiculturalism

To conclude this discussion, it is important to come back to an essential fact about risk reduction in Mayotte in its communication aspect. Lindell et al. (2006) emphasize that for individuals to effectively adapt their response to a risky situation, they must not only receive information, but also consider and understand it. It is clear that individuals comprehend information only if it is provided in a language they understand, at a time and in a format they are accustomed to use. The above discussion shows that even if information is shared publicly, it is not properly formatted to be understood even by the educated part of the population. Risk communication in multicultural contexts, and on a small island, poses specific challenges (e.g. Lindell and Perry, 2004 or more recently Bolin, 2018 about race, ethnicity and vulnerability; e.g. Koromowski et al., 2018 on the challenges of risk communication on small islands). The fact that written communication to date has been primarily in French, an official language but one that is far from being well understood by the majority of the population, is a major problem. Efforts have been made to translate some of the communication materials, including the seismic safety guidelines, into Shimaoré in May 2020, but this is far from sufficient. Identifying the various habits of the population with respect to communication (not only language but also practices, who listens to who?) would also be important to adapt both format and contents. As pointed out by the Senator of Mayotte, Thani Mohamed Soilihi, orality plays an important role in Mayotte and written formats would gain to be accompanied orally (radio, animated movies but also neighborhood meetings and informal discussions with prominent members of the various social groups composing Mayotte (associations, cadis), etc.) (interview excerpt in the Report of activity of the DIRMOM, May 2019 - July 2020).

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8. Conclusions

As pointed out by Stewart and Lewis (2017), *"scientists' attention to technical accuracy and their emphasis on professional consensus may do little to influence multiple publics whose worries instead root into their sense of place, trust and governance, as well as equity and ethics."* The work done on the circulation of information from its place of production (the laboratory, the boat, the field) to different publics (authorities, media, population) during the first three years of the Mayotte seismo-volcanic crisis supports this observation (also see Devès et al., under review). As outlined by many earlier studies, there are cultural differences between scientists, authorities and at-risk populations (e.g. Newhall, 2017; Haynes et al., 2008 for discussion on volcanic cases). We can only agree with Newhall (2017) when he writes that *"trying to understand and accept the cultural differences among the various groups, and involving users in the scientific process whenever feasible, are the best ways … to develop this thrust"* which *"is essential if that information is to be accepted and used"*.

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The efforts made by the risk chain actors to share information are undeniable, as well as the knowledge built up over time at the cost of a high level of commitment (from the Prime Minister's office to ship technicians). This is reflected in a significant volume of publications that take various forms, from press releases to scientific bulletins, web news or communication events. But the effort is insufficient insofar as it does not allow to reach *"the last mile"* (e.g., Shah, 2006) towards the populations. Many factors come into play here, some of which are well known to the social sciences, and some of which have to do with the complicated relations between metropolitan France and the overseas territories.

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In terms of communication there are several leads to gain efficiency. The first consists in establishing a real strategy of research and expertise dedicated not only to hazard monitoring but more broadly to the reduction of risks, the latter being considered in their technical dimension but also in their human and social aspects. The second lever is to work on the content and formats of information sharing. As emphasized by Oreskes (2015) about seismic risk, *"earthquake safety has never been simply a matter of geophysics, but most earthquake scientists, acting qua scientists, have traditionally understood their job to be to study how, when, and why earthquakes happen, and only to a lesser extent (if at all) how to communicate that knowledge to engineers and officials responsible for mitigation, or to the general public [...] But in the contemporary world, the inter-relationship between knowledge and safety is not easily disentangled. Seismology is no longer simply a matter of geophysics, if it ever was. It involves consideration of ethics, values, and monetary and social costs. [The trial of] L'Aquila shows that scientists can no longer ignore the social factors that affect and even control how damaging a particular earthquake may be. Earthquake prediction is a social science."* The reasoning applies to the assessment of other *"natural"* risks. If scientists' main job is not to communicate, they are nevertheless the only ones able to appreciate the robustness of the science-based information. As such, they are expected to take the time to present it in a way that can help risk managers, elected officials, but also journalists and the wider population to act effectively. From this point of view, it seems important to work at clarifying the frontier between the communication of scientific advances on hazard understanding, and the communication of operational risk management measures. That frontier seems particularly blurry in the case of Mayotte. The advantage of this clarification would be twofold. Allowing scientists to explain their hypotheses, results and uncertainties would lead to an

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improvement of the population's scientific culture while reinforcing the credibility of the scientific expertise. The latter is a pillar of any science-based risk governance process, as one may adhere to decisions made by authorities only if he/she believes their scientific basis to be credible. The adhesion to the scientific approach is thus a prerequisite to the adhesion to the risk reduction approach carried out by the other actors of the chain. The third lever is the association of local personalities, elected officials, local NGOs, to the reflection on the risk scenarios and adaptation strategies. The international Sendai Framework for Disaster Risk Reduction calls for a more integrated practice. The signatory countries reckon that, in order to reduce efficiently the risk of disasters, *"there is a need for the public and private sectors and civil society organisations, as well as academia and scientific and research institutions, to work more closely together and to create opportunities for collaboration […]"* (Sendai framework page 7 - UNISDR, 2015). Following Ismail-Zadeh et al. (2017), Stewart, Ickert and Lacassin (2018) emphasize that the willingness for greater integration defines a *"new social contract between hazard scientists and the wider public [...] that encourages the scientific community to endeavour, alongside their existing technical expertise, to '... support action by local communities and authorities; and support the interface between policy and science for decision-making' (Sendai framework page 22 - UNISDR, 2015)"*. As shown in this paper, this change of expectations creates new challenges for scientists, notably on the issue of communication. We hope that this work will contribute to open new avenues for transdisciplinary research drawing on geosciences, social sciences and humanities that can improve the effectiveness of the science-society nexus for disaster risk reduction.

Data availability

EMSC data on the felt seismicity are available from https://doi.org/10.5281/zenodo.4734032. Instrumental seismicity plotted on Figure 1 is from Lemoine et al. (2020) dataset, and from REVOSIMA catalog (not yet available for distribution, these data will be included in Saurel et al., 2021). Press releases from the prefecture de Mayotte and French ministries are given in supplementary dataset. French version of STTM post excerpts are also given in supplementary dataset. Full verbatim of interviews from which we extracted cited excerpts are not public for confidentiality. All other data used in this paper are available from cited references.

Author contribution

MHD was responsible for the conceptualization of the study, project administration, methodology and writing the original draft of the paper. MHD and RL undertook the revision and editing of the final paper in concert with all co-authors. MHD and GR were responsible for data curation and investigation. RL curated the STTM Facebook threads and selected relevant excerpts. MHD and GR conducted and transcribed the interviews. MHD, RL and GR undertook the formal analysis. MHD and RL carried out the validation. HP, RL and MHD were responsible for the figures.

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Competing interests

The authors declare that they have no conflict of interest.

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