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Perception of the risk of tsunami in a context of high-level risk assessment and management: the case of the fjord Lyngen in Norway

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Abstract

Background: North Norway, the banks of the fjord Lyngen are highly exposed to a rockslide tsunami hazard. However, the local municipality believes that the coastal community is well-informed about the risk and ready to evacuate, should a warning be issued. Accordingly, the social survey we conducted in this municipality was a matter of exploring three main questions: is the Lyngen population well-informed about the tsunami risk in general and about the potential evacuation time in particular? Is the local population as confident as the local municipality hope? Is there enough information on the tsunami risk for tourists, given their growing number?.

Results: The survey shows that the local population has a clear perception of the tsunami hazard, but that warning and evacuation conditions are not sufficiently well-known, despite the local and national communication work. Moreover confidence in the municipal authorities seems to be imperfect, although confidence concerning hazard surveillance is higher than confidence in the information provided on risk and management. As often, tourists are less informed on natural hazards or evacuation conditions.

Conclusions: The municipal authorities have to improve the information locally delivered. Authorities must also disseminate information to the tourists, especially on a possible evacuation during their stay, so as not to raise anxiety or trigger a decline in the area's touristic appeal.

Keywords: Tsunami, Rockslide, Norway, Risk, Perception, Behaviour, Inhabitants, Tourists

Background

The devastating tsunamis in Indonesia and Japan in 2004 and 2011 illustrate the vulnerability to this natural hazard of coastal communities and tourist regions, where for various reasons, sea level rises very rapidly to abnormally high levels, resulting in the submersion of low-lying coastal areas. As the European tsunami catalogue highlights, the European coast is also prone to tsunamis: for instance, the Mediterranean has been exposed to about one tenth of the tsunamis reported worldwide since 1840 (Tinti et al. 2001) and the tsunami that hit Lisbon, in southwestern Europe in 1755 is widely known (Baptista and Miranda 2009; Mendes-Victor et al. 2009). In another example from northern Europe, historical evidence shows that Norway has witnessed two to three catastrophic tsunamis per century, resulting in a total of 250 fatalities over the last four hundred years (Harbitz et al. 2014). Yet in general there is no real tsunami risk culture in Europe, because of their relative infrequency in this part of the world and their smaller scale (Dawson et al. 2004). As such, the European research project ASTARTE (*Assessment, STrategy And Risk Reduction for Tsunamis in Europe*) endeavours to improve knowledge and management of this risk on a broad European scale[1]. This cross-cutting

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and multi-disciplinary project deals with every aspect of risk and brings together researchers in geosciences and humanities. The humanities researchers in particular conducted a comprehensive survey of the perception of tsunami risk in Europe, among 1,373 respondents. The results of the Norwegian case study are detailed here, as it contains a number of interesting specificities.

The ASTARTE programme examines ten test-sites where tsunamis occurred once or several times in the past: seven on the Mediterranean coast (Spain, France, Italy, Greece, Romania and two in Turkey), two on the Atlantic coast (Portugal and Morocco – the latter a non-European country but nevertheless included in the programme) and one in the Norwegian Sea. Apart from the Lyngen site (Norway), all these sites are exposed to earthquake-related tsunamis (Álvarez-Gómez et al. 2011) and several to eruptions of island volcanoes found in the Canaries and Greece. Tsunamis can also occur after underwater or subaerial landslides (Dawson et al. 2004). This was the case in Nice in 1979 (Sahal and Lemahieu 2011) and in the Norwegian fjords (Furseth 2006; Furseth 2012; Ramberg et al. 2008). Norway experienced three major "rockslide tsunamis" in the 20th century (1905, 1934, 1936) causing a total of 174 victims (Harbitz et al. 2014). Modelling recently showed that rockslides occurring in the fjords of western Norway are actually "the only high risk tsunamigenic sources in the North-eastern Atlantic" (Greenland excluded), whereas tsunamigenic earthquakes, volcanic events or landslides, from regional or far-field origins, are considered less critical (Harbitz et al. 2014). In fact, at least 25 fjords are vulnerable to rockslides and the ensuing flood waves (e.g. rockslide tsunamis) in southern and northern Norway (Ramberg et al. 2008, p. 565). Thus in the Norwegian county of Troms, the banks of the fjord Lyngen are highly exposed to a rockslide tsunami hazard (Figs. 1 and 2).

To respond to the questions raised by the ASTARTE programme, we conducted a survey among inhabitants and tourists on this test-site. However, unlike the objectives of the survey on the other ASTARTE programme sites, our aim in this case was not to measure whether the tsunami risk was locally known or not, but to start from the hypothesis – based on a discussion with the local authorities – that the population was already well aware of this risk. In fact, the municipal authorities, which are co-responsible for the warning system, consider that the population is ready to evacuate should a warning be issued: in their opinion, the people are well informed about the hazard and evacuation procedures, given the posters on the town hall, reports in the press and a recently conducted evacuation drill. The municipal authorities are therefore more concerned about whether the population would be willing to evacuate and whether the feelings that currently prevail are based on trust in the local authorities and their risk management capabilities or, on the contrary, fuelled by fear and uncertainty surrounding the risk (personal comments by the local authorities). The social survey we conducted at the Norwegian site was thus a matter of measuring not only knowledge of the potential tsunami risk and the crisis management system, but also confidence in the risk management procedures and risk managers (e.g. the municipal authorities). The survey was also designed to measure awareness and responsiveness among tourists

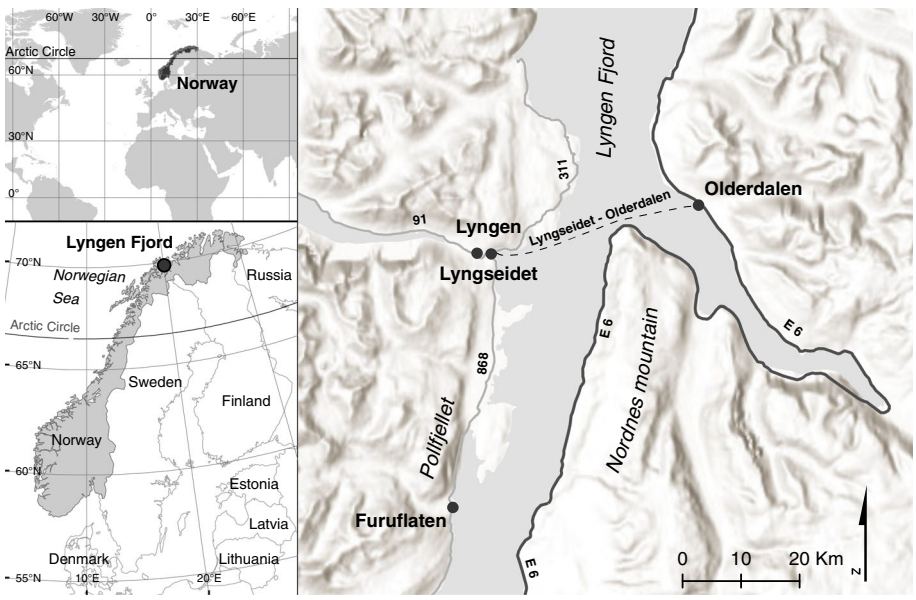

Fig. 1 Location of the fjord Lyngen

Fig. 2 View from the instrumented Nordnes Mountain of the fjord Lyngen and its threatened shores (L. Goeldner-Gianella, 27/05/14)

as in the other ASTARTE sites. In fact, researchers and risk managers are taking a growing interest in the risk perception of tourists and tourism suppliers (Rittichainuwat 2013), looking at the link between perceived risks and the choice of a tourist destination (Seabra et al. 2013). Around the fjord Lyngen, the population increases threefold in summer due to the influx of tourists.

Having presented the context and method applied for the survey, this paper will explore the main results of the survey and discuss three main questions: is the Lyngen population well-informed about the tsunami risk in general and about the potential evacuation time in particular? Is the local population as confident as the local municipality hope? Is there enough information on the tsunami risk for tourists, given their growing number?

Context and methods

Physical and social context of the survey

A tsunami in the fjord Lyngen could be the result of two factors: an underwater landslide, or the collapse or rockslide from a flank of Nordnes mountain which sits on the shore of the fjord (Figs. 1 and 2). A large rocky mass sliding into the fjord would be enough to trigger a tsunami, known locally as "flodbølge", and would have a major effect on the village of Lyngseidet, located 7 km away on the opposite bank (Figs. 1 and 2). On Nordnes mountain, there is a deformed area measuring 4 km long and 1.2 km wide, with an average slope gradient of 30° above a 300-400 m high, west-facing cliff (Braathen et al. 2004). With displacement occurring at a rate of 4 to 5 cm per year, a mass of 22 million m^3 could potentially slide into the fjord (NGI, 2010). Current modelling work by the Norwegian Geotechnical Institute (NGI) estimates the collapse as closer to 11 million m^3, with the resultant wave reaching up to 33 m high in Lyngseidet (NGI, 2013). The alert level has been heightened since October 2012 because displacement of the mountain mass gathered speed after significant rainfall (DSB 2013).

This type of hazard, whose origins may lie in the combined effects of the tectonic fragmentation of the mountain and post-glacial rebound, has already occurred in this fjord. On 30 June 1810, a 2-km wide segment of a slope on the western bank of the fjord, approximately 20 km south of Lyngseidet, collapsed, leaving a large scar that is still visible in the landscape today (Furseth 2012; Fig. 3). There were apparently three tsunami waves after this landslide, with run-up heights ranging from 2 m to the south of the fjord and reaching 10 m or more to the north (Furseth 2012). This tsunami resulted in 14 deaths and extensive damage in the agricultural and maritime sectors (Furseth 2012; Ramberg et al. 2008).

Concerning the Nordnes mountain, NGI has established a very detailed modelling of the rockslide and subsequent tsunami inundation of the fjord banks (NGI, 2008; NGI, 2010; NGI, 2013). Two scenarios, based on the collapse of 7 to 11 million m^3, have been established, using models built on various scales and then nested. They give wave heights ranging from 6 to 33 m at Lyngseidet on the fjord's western bank; these waves would arrive on the shores 2 to 3 minutes respectively after the rocky mass hits the sea. However, the effects of this wave would be locally contained and have little impact outside the fjord Lyngen like other rockslide tsunamis in the country (Ramberg et al. 2008). At the time of the survey, the mountain was being monitored by the NNFO (Northern Norwegian Mountain Surveillance), which used 70 instruments to take 300,000 measurements a day. Nowadays, it is monitored by NVE (Norges Vassdrags- og Energidirektorat). Surveillance levels are just as high as in other Norwegian fjords concerned by

Fig. 3 Pollfjellet mountain (Furuflaten/Lyngen) and its scarp formed by the 1810 rockslide (B. Anselme, 02/06/14)

rockslides: today's technology makes it possible to detect movements of no more than a few millimetres with great precision (Ramberg et al. 2008). On Nordnes mountain, this permanent, high-precision surveillance enables the site to be placed on a "red level" whenever the rate of displacement exceeds 15 mm per day. The time interval between this acceleration and the real rockslide is thus relatively long, measured in "days" and not in hours or minutes. The warning system is managed by the municipality in cooperation with NVE. Based on this threat, a crisis management drill was performed under the umbrella of the Norwegian Directorate for Civil Protection in 2013, as part of the joint rescue exercises implemented since 2008 by a number of countries lying on the Barents Sea (http://www.dsb.no). The drill simulated a red alert and included the evacuation of a number of elderly and sick residents (DSB 2013). It is important to highlight that there are, north of the Arctic circle, specific problems related to tsunami impact and evacuation in the winter time, such as low temperatures, cold water, slippery roads, darkness almost 24/7, and snow storms. In this context, evacuation drills are of particular importance. Since this 2013 drill, the town council has been locally promoting the fact that the population and the municipal services will be moved several weeks before a rockslide, as soon as the likelihood of its release is considered certain. The population will receive a final alert at least 72 hours before the rockslide and subsequent tsunami. This timing is related to the Norwegian Planning and Building Act, requiring that such an event should be forecast at least 72 hours in advance, otherwise, the region must be abandoned or not developed further (Harbitz et al. 2014). People will therefore not be forced to leave the site rapidly – i.e. in a matter of minutes – because they will be alerted several days before the rockslide and subsequent tsunami. Generally speaking, the population is alerted using standard methods in case of natural risks, e.g. through websites or national media, when storms, avalanches or road closures are announced. However, in certain fjords, and in particular in Lyngen, the population will also be alerted by SMS in the case of a rockslide tsunami (personal comments by the municipal authorities). In such a scenario, human casualties should be avoided, although material destruction is inevitable, on condition that the population closely follows the planned evacuation procedures. The issues of warning and evacuation differ completely in this case from what those, for example, on a densely occupied Mediterranean beach exposed to an earthquake-related tsunami.

Despite the low population density (under 4 inhabitants/km^2), Lyngen's population is relatively exposed to the tsunami risk because of the number of dwellings on the coast. In 1801, Lyngen Municipality comprised 965 inhabitants. There were 2,687 in 1910 and 2,861 in 2016 (www.ssb.no/en/). The municipality includes twenty scattered villages and settlements such as Lyngseidet and Furuflaten on the western side of the fjord Lyngen, or Olderdalen on its eastern side (Fig. 1). In these Norwegian maritime regions, the risk of tsunami is relatively higher today than in the past, given the increase in human exposure brought about by the greater numbers of inhabitants on the coast and of tourists visiting the fjords. The municipality numbers 1,300 dwellings, 90% of which were built after 1945 and a quarter of which are holiday homes (www.ssb.no/en/). The villages are connected to one another and to the emergency services by ferry or via the only coastal road, which itself is subject to tsunami and other hazards such as avalanches. Among the most vulnerable population groups, the over-80s account for almost 7% of the population and the under-15s for almost 16% (01.01.2016, www.ssb.no/en/). Aside from agriculture, which occupies 20% of the land along the fjord in 2015 (www.ssb.no/en/), other economic activities include fishing and fish processing, tourism and light industry, mainly in Furuflaten (personal comments by the local municipality).

Methods used for the ASTARTE survey

A comprehensive survey was conducted among the 1,373 people on the ten sites of the ASTARTE programme, including the test-site at Lyngen. The humanities and social science researchers designed and standardised the questionnaire, which was conducted in several countries, in such a way that as many points of inter-site comparison as possible could be listed, despite the significant socio-economic and cultural differences. "Comparing the incomparable" is no longer taboo, in the view of Belgian historian M. Detienne (2008), who positively advocates comparing societies at different times and in different places, allowing what was previously unnoticed, unusual, or hidden to emerge and give rise to new theories. This method of comparison can be applied to all sort of distant, theoretically incomparable objects, such as countries, sites, contexts, themes, populations and policies, as exemplified by J. Diamond's comparison of societies which had experienced some sort of "collapse" (Diamond 2005). Several humanities and social science disciplines, including geography, have adopted Detienne's prescription for themselves, bringing greater depth and openness to their methods of comparison, whose objectives embrace two well-known goals: "informing generality" and "explaining uniqueness" (Bradshaw and Wallace 1991). RW Schrauf (2016) explains how quantitative cross-cultural research can be used for similar between-group comparisons, for questions of society or behaviour. In 1978, Burton et al. already evoked such a method by proposing a wide cross-cultural comparison of responses

and choices to 8 natural hazards, concerning 40 places in 17 different countries, 120 people being generally interviewed in each place. Because of *"severe methodological and communication obstacles"*, *"it was necessary [for the searchers] to ask what few findings seem to be generally applicable, and what combinations of local conditions account for differences in findings from place to place"* (Burton et al. 1978). This explains the decision of the social science researchers of the ASTARTE programme to undertake a vast survey in nine different (mostly European) countries, and not only to analyse each site independently – as in the example given here – but to compare the various sites with each other, (Goeldner-Gianella et al. 2015), thus transcending national socio-cultural differences.

But the research undertaken in the ASTARTE programme is also applied research, aimed primarily at local actors involved in tsunami risk management. The results of the survey of perceptions of this risk must for example help them measure the degree of risk-awareness among populations, improve the information where necessary and identify which groups are better or less well informed. As a result, following the survey, the programme also produced information leaflets on the local tsunami risk to be used by local actors. The ASTARTE survey was thus not created in order to prove or disprove conceptual research hypotheses, as other researchers in rockslide tsunami risk have done in Norway (Rød et al. 2011; Rød et al. 2012); it was created with researchers in each country in response to the demands and questions of every test-site. The objectives of this study in the case of the Norwegian site of Lyngen are therefore largely the result of local demand.

Finally, most questionnaire surveys are preceded by interviews, which inform both the style and substance of the questionnaire. Given the impossibility of conducting such interviews in all nine countries of the programme, prior to the questionnaire campaign, the researchers designed the questionnaire based on their own experience in the fields of social perception of natural risks and in survey techniques. Their position, in terms of risk perception, was one of geographers and psychologists of natural risk, based on a classic distinction between hazard and risk (a combination of hazard and vulnerability). They were interested in perception and "social representations" of the risk and in resultant behaviours (De Rosa 2013; Goeldner-Gianella et al. 2015; Mei et al. 2013; Rüstemli and Karanci 1999; etc.). The techniques in question were well-known and widely used (Berthier 2002; Goeldner-Gianella and Humain-Lamoure 2010).

Methods used for the ASTARTE survey in Lyngen

This paper sets out the data collected from inhabitants and tourists in the municipality of Lyngen. As recommended by Bird concerning natural hazards (Bird 2009), a questionnaire was designed to acquire information on the public perception of the potential rockslide tsunami. A single questionnaire was used in all the European countries covered by the ASTARTE project, although it also included a few specific questions for each test site. Its content was partly based on the model put forward by Bird and Dominey-Howes 2007. Almost 1,400 people were surveyed between spring 2014 and autumn 2015, including 99 people on the banks of fjord Lyngen in June 2014. The number of people surveyed in Norway may seem relatively low (approximately 3% of the local population), but this is due to the low population density, the fact that only one person per family was questioned and the low acceptance of participation, in English or even in Norwegian. This low participation may be due to a certain lack of interest in the survey's theme or to the lower level of education in the municipality: 41.7% of the Lyngen population (16 years and over) has a level of education "below upper secondary education" compared with only 27.3% in Norway (www.ssb.no/en/. The questionnaire took between 15 and 30 minutes in most cases, and comprised around 50 questions, most of which were closed questions although there were a few open questions. They covered the respondents' relationship with the site, their knowledge of the tsunami hazard, their conduct in the event of a tsunami, their awareness and opinion of the alert, and finally, some personal data. Because the questionnaire had not been tested on the Norwegian site, it was revised and completed with subject-specialist Norwegian researchers shortly before its implementation. They added five questions relevant to the site, based on the feeling of threat and the levels of information, surveillance and emergency procedures put in place locally. After the field works, a statistical analysis was carried out for frequency distribution and cross-tabulation, backed up by chi-squared testing.

During the survey, the 99 people interviewed face-to-face were approached at random in different places: 62.5% within Lyngseidet (Fig. 4), 21% on the ferry crossing the fjord between Lyngseidet and Olderdalen (Fig. 1), and around 17% in the neighbouring villages. 73% of the people questioned live or work at the site of the survey (39% inhabitants and 33% local workers respectively) – often having done so for more than ten years (57%) - while the other 27% were tourists (Table 1). People of Norwegian origin clearly formed the majority of the sample (87%; Table 1). As the respondents were randomly selected, the sampling base is not strictly representative of the local population. Indeed, in terms of the inhabitants exclusively, we questioned a larger proportion of women than in the municipality (52.6% in the survey compared to 48.4% for the Lyngen municipality in 2014 (www.ssb.no/en/), more adults aged 23-66 (84.6%

Fig. 4 The Lyngseidet municipality, located on the banks of the fjord and surrounded by mountains (B. Anselme, 27/05/14)

in the survey compared to 52.5% for the Lyngen municipality in 2016 (http://www.ssb.no/en/) and fewer people aged over 67 (7.7% in the survey compared to 22.9% for the Lyngen municipality in 2016 (www.ssb.no/en/)). Meanwhile, the respondents were mostly familiar with the region: two-thirds of them come to Lyngen once or several times a year, and one-fifth of them have been coming for more than ten years. 78% of the tourists are Norwegian; the others come generally from neighbouring Scandinavian countries.

Table 1 Profile of the surveyed people in the Lyngen survey (inhabitants, local workers and tourists; *n*=99, in %)

Why are you here?	I work here (but don't live here)	33,3
	I'm on holiday/I'm visiting	27,3
	I live here	39,4
Ages distribution (according to Norwegian statistics)	0 to 15 years old	0
	16 to 22 years old	6,1
	23 to 66 years old	85,9
	67 years old and more	8,1
Sex	Man	47
	Woman	53
How long have you lived or been here?	a few hours or days	28,3
	less than 1 year	3
	1 to 5 years	8,1
	5 to 10 years	3
	more than 10 years	57,6
Nationality	From Norway	86,9
	From another country (concerned by the ASTARTE survey)	0
	From another country (not concerned by the ASTARTE survey)	13,1

Results

A well-known hazard in the Norwegian study site in comparison with other European sites

A classification of the vocabulary used shows that the three "main [natural and human] hazards which could affect Lyngen", spontaneously cited by the people interviewed in an open question, are tsunamis - or "flodbølge" in Norwegian - (41.6%), then avalanches (34.7%) and thirdly rockslides (11.9%). Only 8% of the respondents did not mention any hazard in Lyngen. If we refer to the results obtained across the whole ASTARTE survey, we notice that Norway is the country where tsunamis are the first spontaneously mentioned hazard, whereas it only appears in 4th position in France, 5th in Portugal, 7th in Turkey, 9th in Spain and 11th in Italy, after other cited [natural or human] hazards. Moreover, it is also in Lyngen that the surveyed people are the most aware of a past local tsunami event in comparison with the other study sites (Fig. 5). Lyngen belongs also, with Italy, France and Portugal, to those sites where people are more aware of the possibility of a future tsunami event (Fig. 6).

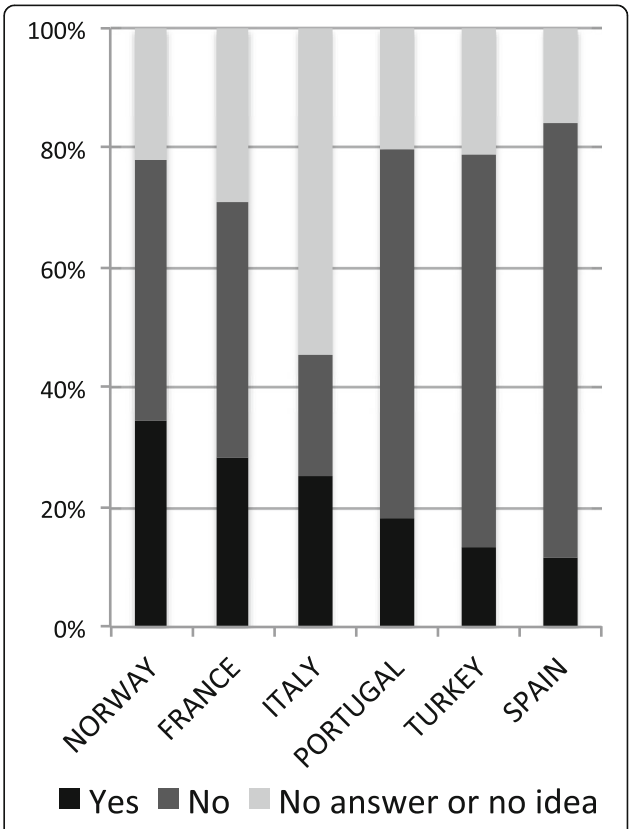

Fig. 5 Answers to the question *"Do you think this site (that is the study site) has already been affected by a tsunami in the past?"*. Legend: *n* = 1373, p: 0,05, degree of freedom: 10, chi2: 169,25, ASTARTE survey

	ITALY	NORWAY	FRANCE	PORTUGAL	TURKEY	SPAIN
Yes	116	77	304	95	195	80
No	9	18	78	27	157	73
No answer or	23	6	18	11	64	22

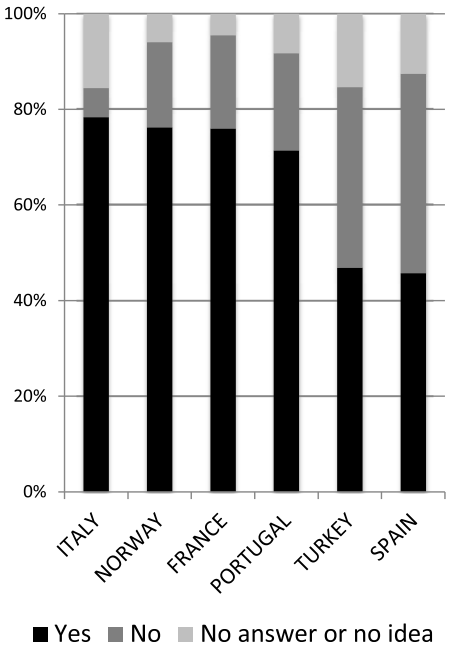

Fig. 6 Answers to the question *"Do you think this site (that is the study site) could be affected by a tsunami in the future?"*. Legend: *n* = 1373, *p*: 0,05, degree of freedom: 10, chi2: 147,03, ASTARTE survey.

Several questions therefore clearly highlight the fact that this hazard is especially well-known at the Norwegian site. Moreover at that site, a classification of the used vocabulary reveals that many of the respondents are familiar with the term tsunami, which they associate with something "big" (40%) and a "wave" (50%) when answering the open question "What is a tsunami?" (Fig. 7). In addition, many of them (30%) also define the term tsunami using the Norwegian word "flodbølge" – whose literal meaning suggests that a tsunami is "a wave causing a flood". Another question on the causes of a tsunami illustrates how far they understand the term: 55% refer to rockslides and 25% to earthquakes. Few of them (8%) give imprecise or irrelevant replies (such as

Fig. 7 Word cloud showing the answers to the open question *"What, in your opinion, is a tsunami?"*. Legend: *n*=99, ASTARTE survey. The size of the words is proportional to the percentage of answers

"mountain" and "sea bottom", or "arctic", "avalanche", "yes", "it will happen or not"…). These answers closely match the causes of a tsunami suggested by respondents "in the event that Lyngen is affected in the future": here again, subaerial landslide-type movements are referred to (70%), and especially those recorded on the Nordnes mountain (56%). In general, this high awareness of tsunami risk is linked to the fact that the country has experienced two to three catastrophic events per century, leading to 250 deaths in the last four centuries (Harbitz et al. 2014).

However, it is worth noting that 30% did not respond or did not know how to respond to the question on the general causes of a tsunami and that a quarter did not respond or did not know how to respond to this question specifically in relation to Lyngen. Knowledge of tsunamis is, for 70%, acquired from television[2] (especially by tourists), 13% from school and 10% from intense media coverage after the tragedies of 2004 and 2011 in the Indian Ocean and Japan. Only 2% of surveyed people said they had acquired such a knowledge through "public information", which exists in Lyngen, as we know.

Tsunami remains an unfamiliar hazard for tourists

However, these answers differ slightly according to the profile of the people interviewed. While inhabitants and local workers mentioned the tsunami hazard first (54% and 48.5% respectively in the open question "Which hazard could affect Lyngen?"), and then avalanches (23% and 33%), tourists (mostly Norwegians) were more likely to mention avalanches before tsunamis (52% compared to 18.5%). However, they placed rockslides second (29.6%), perhaps implicitly thinking of the Nordnes Mountain case. While more inhabitants and local workers mention the tsunami risk first, they are also more numerous in thinking that a tsunami could affect Lyngen in the future whereas tourists are more likely to think the contrary or admit their ignorance (Fig. 8). In addition, tourists are also less aware that tsunamis have affected Lyngen in the past (Fig. 9)[3].

To the question "What could the maximum tsunami wave height be in this area?", many local workers (79%) and inhabitants (72%) estimate that wave height may exceed 10 m - which is actually the case in this very specific context – while tourists are just as likely to opt for this wave height (37%) as they are to admit that they do not know (37%). There is accordingly a clear gap between tourists and non-tourists, illustrating in several respects the lack of knowledge among tourists concerning the local tsunami hazard. This lack of knowledge among tourists was clearly highlighted in the whole ASTARTE survey, in particular for tourists at the Spanish study resort (Goeldner-Gianella et al. 2015).

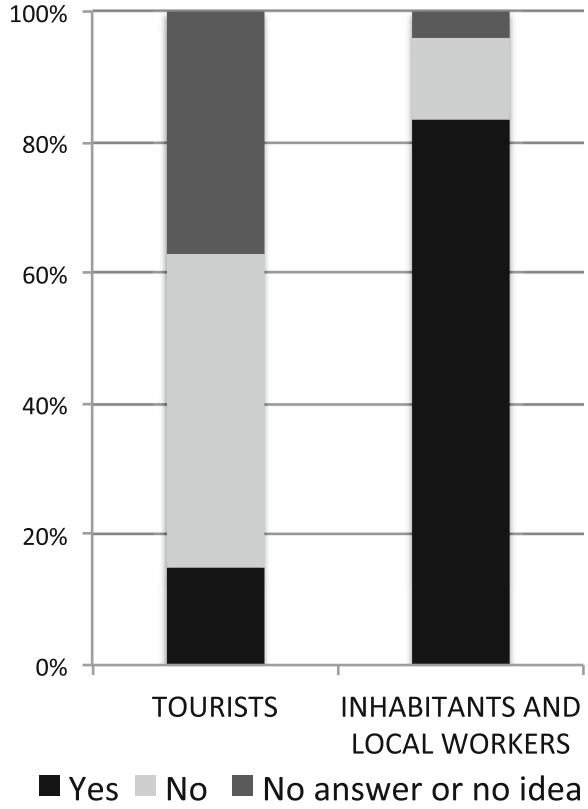

Fig. 8 Answers to the question *"Do you think Lyngen could be affected by a tsunami in the future?"*. Legend: *n* = 99, *p*: 0,05, degree of freedom: 2, chi2: 41.65, ASTARTE survey

A certain lack of knowledge concerning the warning system

Despite the fairly accurate perception of the tsunami hazard among the local population, the warning and evacuation system is less well-known and local people are not especially well prepared for an evacuation. Figure 10 provides information on awareness of the time available for evacuation. Here again, there is a marked contrast between inhabitants and local workers, who are the only categories to mention a possible evacuation time exceeding 24 hours, and tourists who are more likely to say they do not know the answer or to indicate a shorter time. However, this split in opinion is actually more complex and demonstrates that knowledge is less widespread among people living by the fjord than we might have assumed. In fact very few people, even among inhabitants and local workers, are aware that evacuation time exceeds 24 hours (36% and 18% respectively). What is more, among these populations who should be more informed, the number of people who did not answer the question and were unaware of the evacuation time is relatively high (39% of the inhabitants and 33% of the local workers). Very short times (less

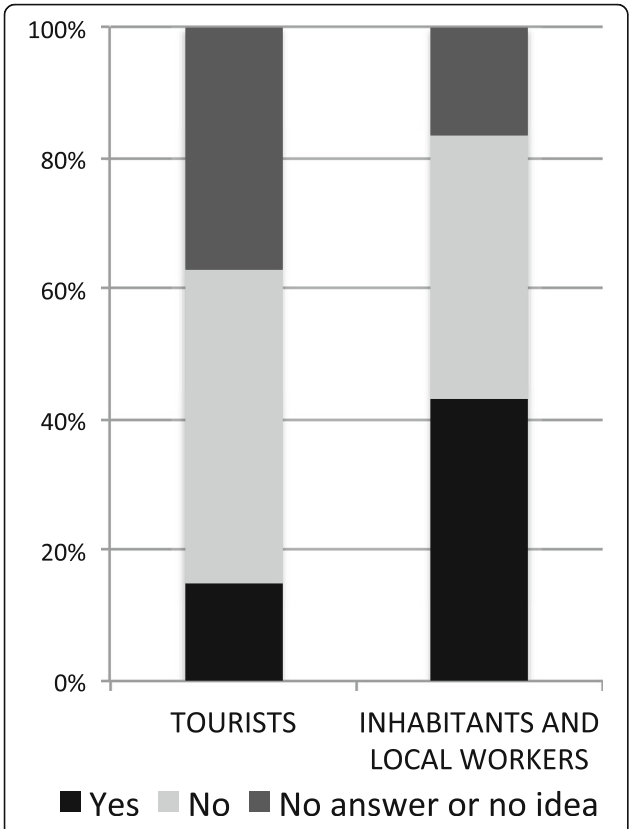

Fig. 9 Answers to the question *"Do you think Lyngen has already been affected by a tsunami?"*. Legend: *n* = 99, *p*: 0,05, degree of freedom: 2, chi2: 34.60, ASTARTE survey

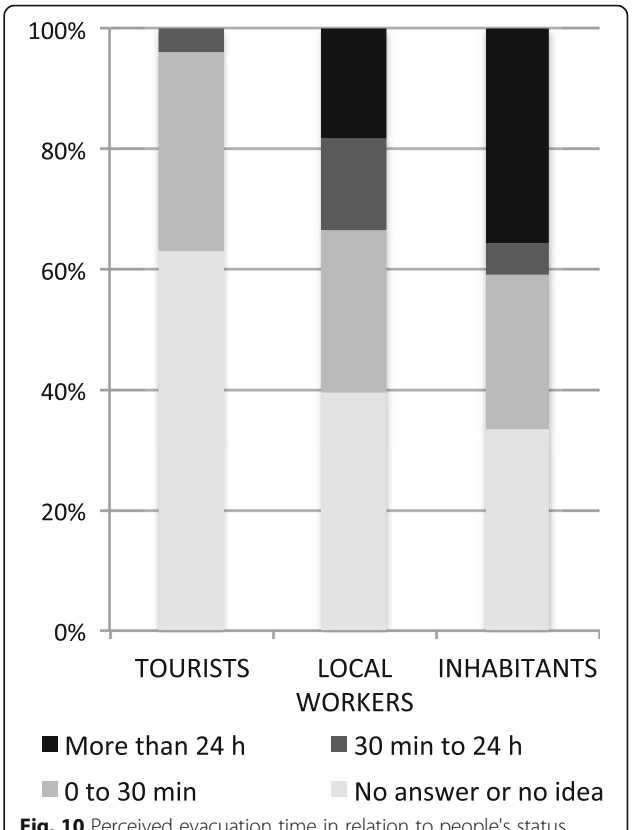

Fig. 10 Perceived evacuation time in relation to people's status. Legend: *n*=99, *p*: 0,05, degree of freedom: 6, chi2: 17,14, ASTARTE survey

than 10 minutes or 10 to 30 minutes) are often mentioned (13% and 15% respectively of interviewed people), which might suggest that some people did not really understand the question: they may have been thinking about the time required for the wave to reach the Lyngen coast once the rocky mass hits the water[4], whereas the question asked actually referred to the time available for evacuation: "*How much time is there between a tsunami* ***alert*** *and the first tsunami wave*?". In this specific case, because of the intense monitoring of the Nordnes mountain, this time available for evacuation will be longer than just some minutes. Besides, if the respondents were to receive a tsunami warning message, only 15% would follow the given instructions, while 64% would leave immediately, even if such urgency is not necessary in this specific case.

Despite a certain lack of awareness of the warning system, this is higher among the local population than among tourists: in fact, 76% of local workers and 74% of inhabitants are aware that there is a tsunami warning system at Lyngen, compared to 56% of tourists. However, it should be noted that 5% of inhabitants also replied that there was no tsunami warning system, and that around 20% of local workers or of inhabitants did not know the answer. Among those able to provide more details on the system (half of the people questioned), 50% of them mentioned the text message warning, while responses from the remaining interviewees were more varied (siren, phone call, etc.). People want this tsunami warning system to provide information firstly on the time available for evacuation and on where to go (Table 2). Such information would be useful, especially for tourists but also for some local workers and inhabitants.

With respect to the question asking "which route people would follow after receiving an alert", 60% of them answered they would go west using the main road, 22% of them would "go up into the mountains" surrounding the municipality (Fig. 4, Fig. 11) - even if there was enough time to evacuate - and 14% would go to the south using the coastal road. We notice that only 4% in total would go to the north to reach their home or to the east in the fjord Lyngen. But 18% did not know what to do or did not answer this question.

In conjunction with these uncertainties, the local population is not really prepared for the risk. To the question "*Have you made arrangements or prepared*

Table 2 Classification of the answers to the question "*What kind of information do you expect from a tsunami warning system?*"

Time available for evacuation	Where to go (mountain, ferry and beyond, refuge areas)	Explanations on the event	Behavior to be adopted	Other informations (on alert, contacts, controls)	Which roads ?
37.9%	37.9%	27.6%	19%	10.3%	6.9%

Legend: *n* = 58, ASTARTE survey. The total is higher than 100% as respondents were able to give several answers

equipment to protect yourself (at home or at work) from a tsunami?", only 5% of inhabitants say that they have, while nearly 80% of them and 30% of local workers have not. What is more, a third of the local workers and 70% of inhabitants do not know "how they could better prepare" for this risk[5]. This general lack of preparation could be linked with the fact that evacuation will not be immediate, in the case of a rockslide tsunami, but also with a certain "risk denial". Indeed, 64% of the people interviewed "don't feel threatened by the Nordnes Mountain": 74% of them "rarely" or even "never think about this threat". Since the 1970s, the scientific literature has been full of examples showing that the denial of risk or threat, or "unrealistic optimism" in the face of risk (Sattler et al. 2000), is extremely widespread (Burton et al. 1978). This denial is considered, like fatalism, as a form of "non-protective response" to the threat, enabling us, like protective responses, to reduce the degree of threat appraisal (Grothmann and Reusswig 2006). For example, people living in regions exposed to seismic threat will deny or minimise this to calm their anxiety or because they feel unable to do anything to deal with it (Heller et al. 2005). The responses obtained in Lyngen are also doubtless consistent with this theory.

An average level of confidence in risk management and local risk managers

Regarding their confidence in local authorities, the responses are varied. Many local workers and inhabitants think that "in general, the preparation measures for tsunamis are satisfactory in Lyngen" (Fig. 12; 57.5% and 43.5% respectively). In fact, local inhabitants and workers feel very positively about the government's surveillance of Nordnes mountain (69% positive opinions for the two groups put together; Table 3). But it is also true that far fewer people feel positive about "the information given by the local government on the rockslide stability" (35% positive opinions

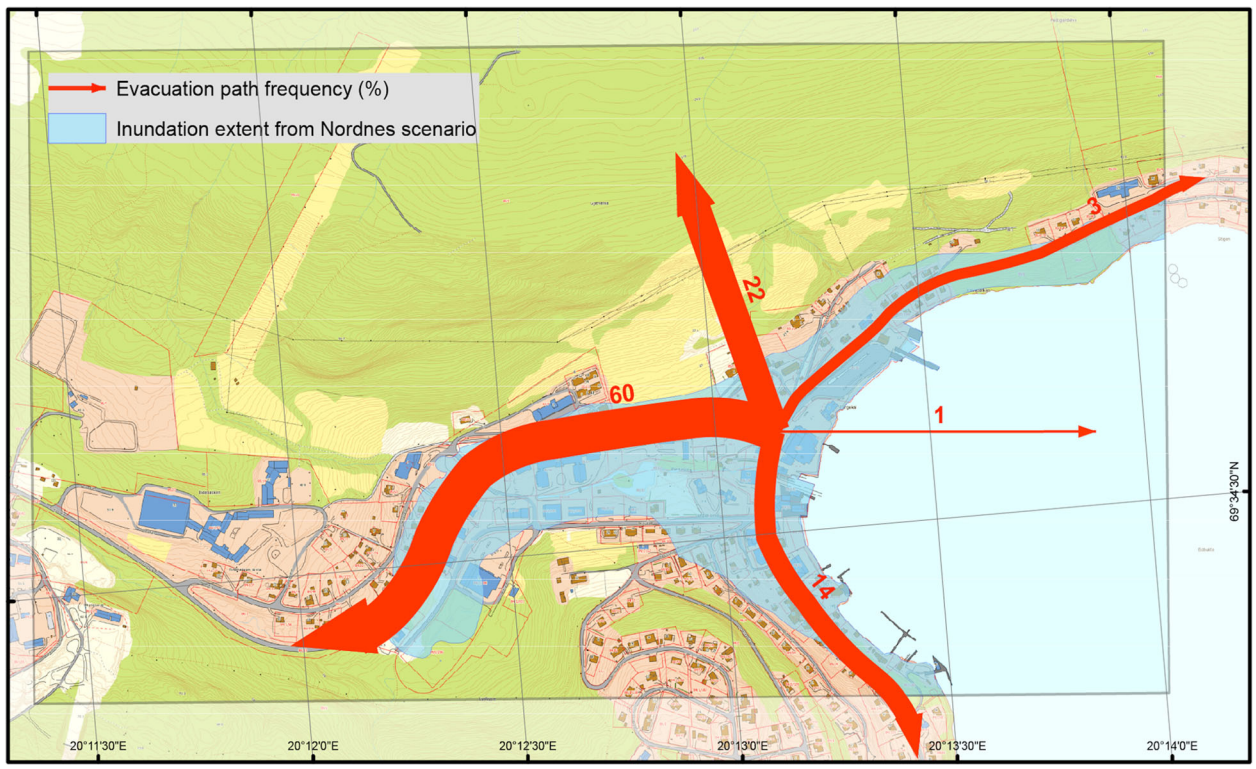

Fig. 11 Answers to the question *"Which route would you follow (from Lyngseidet) after receiving an alert?"*. Legend: n=81, in %, ASTARTE survey. Background data from Kartverkert-FKB2 web map service (wms.geonorge.no), Nordnes scenario: ASTARTE Deliverable D8.8 http://astarte-project.eu/index.php/deliverables.html

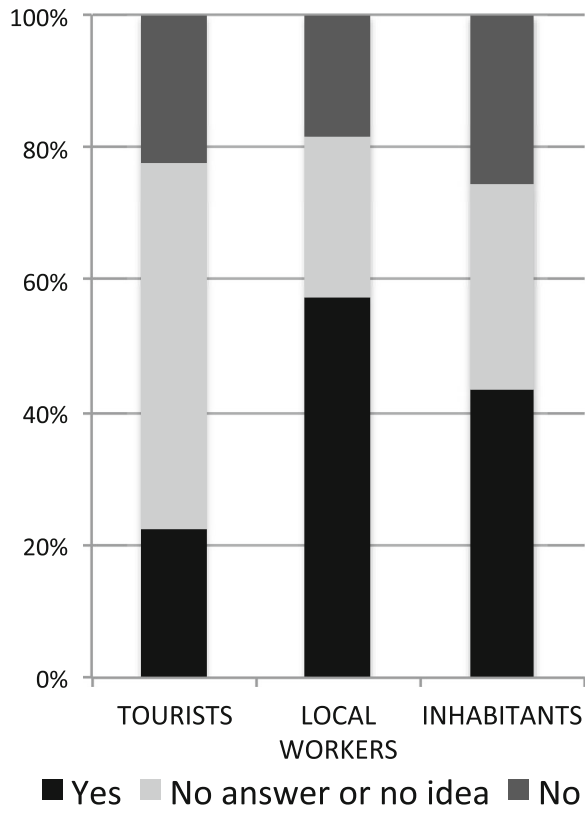

Fig. 12 Answers to the question: *"In general, are the preparation measures for tsunamis satisfactory in Lyngen?"*. Legend: *n*=99, *p*: 0,05, degree of freedom: 4, chi2: 9.34 non-significant, ASTARTE survey

for the two groups put together; Table 3). However, those who know "who is responsible for giving the alert" refer to actors on a local level (25%) – generally speaking, the municipality – before actors on a national level (8%), (Table 4). But there are many inhabitants and local workers who in fact do not know "who is responsible for giving the alert" (56% for the two groups put together)… Ultimately, confidence in this local level seems to us to be imperfect, because confidence concerning hazard surveillance is higher than confidence in the information provided on risk and management.

Table 3 Evaluation by the inhabitants and the local workers of the government's surveillance of the mountain and of the local government's given information

"How do you evaluate the governement's surveillance of the Nordnes mountain?" (in %)		*"The local governement is adequately informing us about the rockslide stability?"* (in %)	
Good to very good	69,4	Agree and completely agree	34,7
Neither bad, neither good	6,9	Neither agree, neither disagree	23,6
Bad to very bad	2,8	Disagree and completely disagree	20,8
No answer	20,8	No answer	20,8

Legend: *n*= 72, in %, ASTARTE survey

Table 4 Classification of the inhabitants' and local workers' answers to the question *"If yes (if there is a tsunami warning system), who is responsible for giving the alert?"*

No answer	Local governement/ scale	National governement/ scale	Civil defense	Other (dispersed) answers	NFFO/NVI
55,6	25	8,3	4,2	4,2	2,8

Legend: *n*= 72, in %, ASTARTE survey

Discussion

Is the local population as well informed and confident as the municipal authorities believe?

Despite the efforts made by the local and national authorities (e.g. information provided in town halls, press articles, the evacuation drill in 2013, etc.), the information has not reached the whole local population: a number of local inhabitants do not know how much time is available for evacuation, and are unaware that a warning system exists or how they would evacuate. What is more, a very large majority of inhabitants (80%) have neither made arrangements nor prepared any equipment for the tsunami risk.

We might first question the role of education in disseminating information, as it is known that school or hazard education play a key role in case of a tsunami (Dengler 2005; Keating 2006; Morin et al. 2011; Priest et al. 1996). If we refer to the results obtained across the whole ASTARTE programme (Table 5), we can see that Norway is the country where school was least often mentioned by respondents as a source of information on tsunamis. Only 13% of the whole people questioned in Lyngen mentioned school – and only 7% of inhabitants – while it is mentioned much more frequently at sites in Portugal (51%) and around the Mediterranean (around 20% in Turkey, Italy and Spain). It is true that Portugal experienced an earthquake and devastating tsunami in 1755, which is still widely known, in this country and in Europe. But school in Lyngen could give more focus to tsunamis associated with rockslides, such as the one that occurred in the fjord Lyngen in 1810 (Fig. 3). The scar of this rockslide, just a few miles outside Lyngseidet, could be seen by schools directly in the field, because indirect experience with a past tsunami increases the awareness of people in as yet unaffected areas (Rachmalia et al. 2011). A survey conducted in Norway into rockslide tsunami risk also showed that those people who were willing to follow evacuation instructions lived in places where identical disasters had already occurred (Rød et al. 2012). It would therefore be of benefit provide more information about the nearby Pollfjellet mountain's scarp (Fig. 3) in

Table 5 Answers to the question *"How did you hear or learn the word tsunami?"*

Country	Norway (*n*=101)	France (*n*=400)	Italy (*n*=148)	Portugal (*n*=133)	Spain (*n*=175)	Turkey (*n*=416)	Total (*n*=1373)
Information sources	% Obs.	% Obs.	% Obs.	% Obs.	% Obs.	% Obs.	% Obs.
Television	70.3	76.8	64.9	52.6	62.9	59.9	65.8
Media coverage after a tsunami	9.9	33	39.2	14.3	61.7	55.8	40.7
School	12.9	15	20.3	51.1	19.4	22.6	21.8
Internet	1	3.8	11.5	6.8	7.4	13	7.9
Radio	3	10	4.7	5.3	10.3	4.6	6.8
Books	0	3	4.1	8.3	2.9	7	4.6
Personal studies	1	8.2	2	1.5	1.1	4.3	4.3
Films	0	1.8	2	1.5	4.6	9.1	4.2
Other sources	5.9	3.5	1.4	0	2.3	2.9	2.8
Family	1	1	5.4	3	4.6	2.2	2.5
Public information	2	1.8	1.4	3.8	0	3.1	2.1
Travels	1	3.5	0	1.5	0	0.7	1.5
No answer	4	0	0	0	0	0.5	0.4
Word "tsunami" never heard	0	0	0	1.5	0	0.7	0.4

Source: ASTARTE survey

order to raise awareness of the risk of rockslide tsunami on a local level. Moreover, it was also demonstrated that parents whose children lived in a rockslide risk area tended to believe that all forms of information about the risk were useful (Rød et al. 2011). Local schools could therefore devote more energy to the subject. Secondly, the results of the ASTARTE survey also show that sources of a more cultural nature (e.g. books, personal studies, internet, films and travel) are not often mentioned in Lyngen. However, television is mentioned more often than at most other survey sites, so reporting on the tsunami hazard specific to the mountain fjords in regional TV programmes on a regular basis would appear to be a worthwhile development.

A Europe-wide comparison shows that the people questioned in Norway have great confidence in the text message warning, even if people are not yet used to receiving SMS-warnings about natural risks in Norway. However, as the ASTARTE survey shows, it is in Norway that the highest number of people would evacuate rapidly if a message saying *"Warning tsunami! Leave the shoreline"* was received (61% for Lyngen inhabitants compared to an average 52% in Europe) and, above all, they would not question the warning received by seeking other sources of information (0% for Lyngen inhabitants compared to an average 29% in Europe). Therefore, despite the few shortcomings in awareness of the warning and the level of preparedness, we can consider that the local population remains confident in the level of warnings received. Other questions in the cross-European comparison highlight a high degree of trust in local authorities among the people interviewed in Norway. In fact, the population interviewed in Lyngen is by far the most satisfied with the measures taken to address the tsunami hazard (Table 6) - especially among inhabitants and local workers – and, alongside Portugal, the most aware of these measures. Part of the goal has therefore been achieved; the local authorities now just need to increase and improve the dissemination of information already out there. This is all the more important given that information about risk is seen, in many European countries, as an

Table 6 Answers to the question *"Are preparation measures against a tsunami satisfactory in (each study site)?"*

Country	Norway (*n*=101)	France (*n*=400)	Italy (*n*=148)	Portugal (*n*=133)	Spain (*n*=175)	Turkey (*n*=416)	Total (*n*=1373)
Answer	% Obs.	% Obs.	% Obs.	% Obs.	% Obs.	% Obs.	% Obs.
No answer	10.9	0	0	0	0.6	2.4	1.6
Yes	41.6	5.8	0	17.3	0.6	1.7	7
No	21.8	48.8	46.6	58.6	35.4	68.3	51.7
Don't know	25.7	45.5	53.4	24.1	63.4	27.6	39.7

Source: ASTARTE survey

essential effectiveness factor of an emergency plan, as highlighted, for example by Lumbroso et al. (2011) in their analysis of flood emergency plans. And on the same subject, maps that demonstrate the local context are particularly appreciated by stakeholders as means of improving communication around risk (maps showing water levels, the speed of outflows, flood risk scenarios). We might advocate the greater public dissemination of maps showing the risk of rockslide tsunamis – maps which already exist (NGI 2008, 2010, 2013) but would need to be adapted for use by the general public.

Recommendations to raise awareness of the tsunami risk among tourists

This fjord region draws many tourists, especially from Scandinavia and Russia, who come here for various sports activities (fishing, hiking, running, cycling, Nordic skiing, etc.). In the ASTARTE survey, the Norwegian tourists however form the majority, with only six tourists from other origins. It is important to raise awareness of the flodbølge hazard among the tourist group in general, so as not to raise fears unnecessarily or reduce the area's appeal. Tourists are a specific population group, a significant portion of which may not be sensitive to risks of any kind (Seabra et al. 2013). For instance, in the case of tsunami risk, Johnston et al. have clearly shown how a large part of visitors to coastal Washington had not seen the tsunami hazard maps and was unaware of the tsunami warning system (Johnston et al. 2002), and that levels of staff training and preparedness for tsunami hazards were generally low, in particular in small hotels and guest houses (Johnston et al. 2007). In Lyngen, we have seen that the interviewed tourists had a very different awareness and perception of the tsunami risk compared to the people living or working there: tourists are more concerned about the risk of avalanche because Lyngen is a popular Nordic skiing destination and avalanches are a major and well-known risk for Norway. But they are not aware that Lyngen could be affected by a tsunami in the future and they are unfamiliar with the tsunami warning system and the time available for evacuation. Finally, they would not know how to evacuate, since the only information available to them is in town halls and other public service sites.

It would therefore seem necessary to raise awareness of the tsunami risk among this population group as a matter of urgency, because 52% of them come to Lyngen several times a year. One simple means of communication, suitable for these non-residents, would be issuing information on the ferry that connects Lyngseidet to the villages on the eastern banks of the fjord, giving people thirty to sixty minutes to read an information leaflet or a poster on the local potential tsunami risk, and what to do in case of an alert. It would also certainly be useful to raise awareness among tourism suppliers, as highly recommended on other touristic coasts (Johnston et al. 2007; Rittichainuwat 2013; Virapart 2011), and, if necessary, allay any anxieties they may themselves have because "crisis management [often] creates unwanted safety concerns" (Rittichainuwat 2013).

Conclusion

With respect to the question of knowing whether "the Lyngen population is as well-informed about the tsunami risk in general and about the potential evacuation time in particular", the survey conducted in Lyngen demonstrates that the local population has a fairly clear perception of the tsunami hazard, associated with the potential rockslide from a flank of the mountain into the fjord. However, a number of local inhabitants do not know how much time is available for evacuation, and are unaware that a warning system exists or how they would evacuate. What is more, a very large majority of inhabitants (80%) have neither made arrangements nor prepared any equipment for the tsunami risk. The warning and evacuation system introduced over the past few years thus do not appear to be sufficiently well-known and the population is not sufficiently prepared for evacuation, despite the communication work already done by the local and national authorities. Hence, the municipal authorities have still to improve and increase the dissemination of the information, even if it does already exist.

Regarding the question of whether "the Lyngen population is as confident as the local municipality hopes", the survey shows an average degree of trust in local authorities among the people interviewed in Norway. This confidence is higher in respect of hazard surveillance than in the information delivered on risk or its management. However, the population interviewed in Lyngen compared to the population interviewed in other European countries is by far the most satisfied with the measures taken to address the tsunami hazard – especially among inhabitants and local workers – and, alongside Portugal, the most aware of these specific measures. This greater confidence in local authorities, if examined on a European scale, can only motivate the municipal authorities to improve the quality of information delivered locally, which is still inadequate in some regards.

And in respect of whether "there is enough information on the tsunami risk for tourists", the survey shows for national or international tourists that they are, as is the case elsewhere, less informed about local natural hazards and evacuation conditions. In fact, the tourists interviewed in Lyngen had a very different awareness and perception of the tsunami risk compared to the people living or working there: tourists more concerned about the risk of avalanche are not aware that Lyngen could be affected by a tsunami in the future and are unfamiliar with the tsunami warning system and the time

available for evacuation. Finally, they would not know how to evacuate. Thus, it would appear necessary to improve the information available to them, without however harming the tourist sector that forms one of the region's few economic activities. The challenge here is not so much to inform them of the necessity to evacuate urgently, as on the Mediterranean beaches, but to inform them of a possible evacuation during their stay. It is especially important to spread the information on tsunamis in Norway because residents or tourists – on land and on cruise boats – are currently increasing in numbers in the fjords. Furthermore, the rockslide tsunami hazard should itself increase in the future due to the specific consequences of climate change.

In addition, nowadays in Lyngen, natural risks do not originate solely from the sea, but also from the land: there are other risks inland, related to climate change and with potentially serious coastal human impacts, namely the melting of the permafrost and glaciers (Jackson and Ragulina 2014). As such, future communication on hazards in Lyngen should not focus only on rockslide tsunamis and their impact on the coast; it should also encompass, besides the recurring and well-known risks of avalanches and snowstorms, the more recent hazards associated with climate change.

Endnotes

[1]http://www.astarte-project.eu.

[2]Examples of this include the TV miniseries "Tsunami: the Aftermath" by B. Nalluri, released in 2006, the Japanese documentary "The Tsunami and the Cherry Blossom", directed by L. Walker in 2011 and nominated for the documentary category at the 2012 Oscars, and the film "The Impossible" by J.A. Bayona, released in 2012.

[3]Nonetheless, inhabitants and local workers appear to be less "well-informed" about past events than the future situation.

[4]The tsunami wave should arrive in approximatively 2 mn in Lyngseidet and 3 mn in Olderdalen (NGI).

[5]In the case of a predictable rockslide tsunami, such a preparation consists in setting aside important documents, having at home a kit of rescue or eventually a boat.

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Availability of data and materials
The dataset supporting the conclusions of this article is included within the article.

Authors' contributions
LG-G: survey's conception, survey in the field in English, survey's analysis, manuscript's redaction and corrections. DG: survey's conception, statistical treatment, survey's analysis. ØR: survey's conception, survey in the field in Norwegian, manuscript's corrections. BA: survey in the field in Norwegian. DB: Fig. 11. FL: survey's conception, survey in the field in English. All authors read and approved the final manuscript.

Competing interests
The authors declare that they have no competing interests.

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