Tsunami hazard perception and knowledge of alert: early findings in Five Municipalities along the French Mediterranean coastlines

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Abstract

Along the French Mediterranean coastlines, most of the studies dealing with tsunamis have focused on hazards, evacuations, or effects of awareness-actions, more than on hazard perception and knowledge of alert, declared locally by the population. To bridge this gap, in this study, data collection yielded 750 responses coming from 150 people living and/or working in the tsunami evacuation zones of 5 municipalities (*e.g.,* Bandol, Bastia, Cannes, Six-Fours-Les-Plages, Sanary-sur-Mer). Early findings confirmed the tendency to underestimate tsunami hazard and misunderstanding of the alerting process. Interestingly, age or location of respondents explained differences between the 5 surveyed municipalities, more than gender and residency status. Discrepancies were also observed when we compare the rate of correct answers for similar questions addressed in other areas in the NEAMTWS (*North East Atlantic and the Mediterranean Tsunami Warning System*) region, thus confirming local effects. More surprisingly, the respondents who well perceive the tsunami hazard are not those who have a good knowledge of alerts, and the awareness actions do not really impact the tsunami knowledge we evaluated. Also, the results of this study could help local authorities to develop future tsunami awareness actions, and to determine more suitable strategies to be applied in the short term at local scales.

Key-Words: tsunami; perception; coastal population; Mediterranean basin; France.

1. Introduction

A tsunami is a series of long-period and powerful waves generated primarily by earthquakes, volcanic eruptions, landslides, or meteorite impacts (Geist and Parsons, 2006; Papadopoulos et al., 2014; Masina et al., 2017), that cause vertical changes in the seafloor, which in turn displace a large volume of water from its equilibrium position to a new position of rise or subsidence. The 2004 tsunami that occurred all around the Indian Ocean, which caused 230,000 casualties, including 90,000 in the Banda Aceh region of Indonesia, raised a global awareness of this risk (Leone et al., 2011; Mas et al., 2015; Péroche, 2016; Sun and Sun, 2019; Chen et al., 2022). Subsequently, many studies have focused on evacuation modelling (*e.g.*, Chen and Zhan., 2008; Cheff et al., 2019; Fathianpour et al., 2023), hazard mapping (*e.g.,* Tonini et al., 2021; Turchi et al., 2022; Basquin et al., 2023) or awareness raising actions (*e.g.*, Choi et al., 2016; Arimura et al., 2020; Ong et al., 2023). Good practice guides have also encouraged researchers to increase tsunami knowledge, to improve prevention for affected populations, and to contribute to evacuation planning and hazard mapping (Scheer et al., 2012; Sutton and Woods, 2016; UNESCO/IOC, 2017; Rafliana et al., 2022). Combined with effective alerts and education, the evacuation process can significantly minimize the number of fatalities. As a very relevant example, during the Tōhoku tsunami of 11 March 2011 in Japan, 582,000 people (*i.e.,* 96% of those at risk) evacuated in time, thanks to alerts disseminated in less than 5 minutes (Péroche, 2016).

1.1 Possible tsunami-generating events along the French Mediterranean coastlines

Compared to other basins, the areas adjacent to the French Mediterranean coastlines seem to be slightly exposed to tsunamis generated by earthquakes, mainly due to their low frequency (Terrier et al., 2013), low run-up heights (Filippini et al., 2020) and the low number of fatalities registered during past events (Courteau, 2019). Out of 225 events recorded in the global Mediterranean basin between -1660 and 2019 (Tinti et al., 2004; Maramai et al., 2014), only 13 tsunamis actually endangered the French territories. If the historical sources and the catalogue of tsunamis are not always reliable (Terrier et al., 2013), and can be incomplete (Sahal, 2011; Goff & Cain, 2016), the analysis of the seismic context and results of simulations (Filippini et al., 2020) therefore confirmed two scenarios along the French Mediterranean coasts, focused on two key areas in the western part of the Mediterranean basin.

On the one hand, the seismically active region of the northern Algeria has the potential to trigger large undersea earthquakes that could generate tsunamis. Such a regional tsunami could travel from the Algerian coast to French territory in 67 to 72 minutes (Filippini et al., 2020). The Boumerdès earthquake in Algeria on 21 May 2003, with a magnitude (Mw) of 6.9, illustrates this possibility. During this event, tsunami waves were registered along the Spanish and French coasts and were recorded by many tide gauges (Tinti et al., 2005). A field study confirmed that eight marinas along the Côte d'Azur department, in the eastern part of the French Mediterranean, experienced a significant drop in sea level (50 cm to 1.5 m), basin drainage, strong eddies and currents, damaged boats and displacement of bodies, all compatible with harbour resonance phenomena (Terrier et al., 2013). And the effects on the French Riviera were observed 76 minutes after the earthquake (Filippini et al., 2020).

On the other hand, the Ligurian Sea, located to the east of France, is another seismically active region. Although less frequent, the undersea earthquakes can produce local and sudden tsunamis. These tsunamis can be amplified by the complex undersea topography of the Ligurian Sea, increasing their potential impact on the French coast (Liotard et al., 2017; Boschetti et al., 2020). More specifically, a local tsunami could impact the French Riviera in a simulated time of between 2 (Nice) and 7 (Cannes) minutes (Filippini et al., 2020), reducing the time needed to alert and protect the population. Although of small amplitude, with simulated waves of less than one metre, such a local tsunami could cause human injury and material damage, particularly on crowded beaches, due to water velocity, current phenomena and floating debris. Crowd movements could also happen (Filippini et al., 2020). The Ligurian Sea earthquake of 23 February 1887, with a magnitude (Mw) of 6.5, which caused 685 casualties in Italy and 8 in France (Boschetti et al., 2020), illustrates this second seismic scenario. Different types of damage were recorded, with images showing the tide gauges of Nice and Genoa (Eva and Rabinovich, 1997; Tinti et al., 2005; Lorito et al., 2008). After the first quake, the sea level suddenly dropped by about one metre, leaving fishing boats and fish on the sand, and a two-metre wave covered some beaches. The sudden rupture of the submarine telegraph cable between Antibes and Corsica, at two different locations, led to the assumption that the amplitude of this tsunami was amplified by landslides mobilizing sedimentary deposits (Tinti et al., 2005).

1.2 Tsunami alerting process in France

To detect and forecast tsunamis in the north-eastern Atlantic Ocean and Mediterranean Sea, a dense monitoring network of seismometers and maregraph, and six *Tsunami Service Provider* (TSP), cover the region. Development of this network was supervised by IOC-UNESCO since 2005, so-called the *Intergovernmental Coordination Group for the Tsunami Early Warning and Mitigation System in the North-eastern Atlantic*, *the Mediterranean and connected seas* (ICG/NEAMTWS). Since 2012, France created and commissioned 1 of the 6 TSPs, so-called CENALT (*CEentre National d'Alerte aux Tsunamis* in French). In addition to its international monitoring missions, CENALT represents the National Tsunami Warning Centre (TWC) for France.

Respecting jurisdiction and police powers of authorities, the alerting process is organized in two phases in France: an '*upward alert'* (from CENALT to COGIC, *Centre Opérationnel de Gestion Interministérielle de Crise,* in French) and a '*downward alert*' (to the French Ministry of Interior and their local representatives, prefectures and mayors to the population). The '*upward alert'* must last a maximum of 15 minutes. During this first phase, the location of the epicenter, the *Tsunami Travel Time* (TTT) concerning the French coasts and the alert level are defined by the CENALT. Three levels are used in France: watch (red level), advisory (orange), or information (yellow) statement (Schindele et al., 2014). In case of watch, populations are intended to evacuate and to go high ground or inland, while for advisory, the population located in the tsunami evacuation zones must stay out of the water and away from beaches and waterways (Lindell et al., 2015). CENALT then writes the alert message and sent it to the COGIC, operating at the national scale. After that, the '*downward alert'* begins: the COGIC informs the departmental and local authorities, as soon as possible, and the latter should broadcast alerts to the population, using the tools they have at their disposal: sirens, SMS system, door-to-door, loudspeakers, radio, variable messages signs, etc. (Bopp and Douvinet, 2022). Since 2019, every first Tuesday of the month, trials are organized, to check the alert chain, to improve the understanding of the messages sent by the CENALT, and to shorten time required for transmitting information between authorities (Courteau, 2017). But the alerting tools do not exist everywhere, do not cover all territories, and they could be not used in appropriate time.

1.3 Research gaps and objectives

Although possible tsunamis generated by earthquakes are identified and a TSP has been created, many challenges remain. First, during the '*downward alert'*, little is known about how many people identify the alerting tools that really exist at local scales, and if they may apply safety instructions. Second, very few studies dealt with the hazard perception. The only previous sample in this area was carried out during the EU ASTARTE project (2013-2016), with 50 questions and face-to-face interviews carried out on beaches, boats, harbors and/or city centers, which allowed the collection of 1,159 questionnaires, but in six areas located in France, Greece, Norway, Portugal, Spain and Turkey (Goeldner-Gianella et al., 2017). However, the assessment of tsunami hazard perception is crucial for the protection of life and the definition of awareness actions (Hall et al., 2022; Rafliana et al., 2022). Knowing how people think react when receiving a tsunami alert is also important as of the direct consequences of not taking immediate protective actions, where a few seconds can be a matter of life and death (Wood et al., 2017). Furthermore, low hazard perception and lack of knowledge of alerts can lengthen time for decision-making process and timing for the evacuation (Dash and Gladwin, 2007; Lindell et al., 2015), and might be considered in designing risk mitigation programs and tools, such as drills, emergency plans, etc. (Cugliari et al., 2022).

In line with the ASTARTE project and literature considering same objectives, on tsunami hazard perception (Bird and Dominey-Howes, 2008; Liotard et al., 2017; Dohi et al., 2015; Lindell et al., 2015; Papageorgiou et al., 2015) and knowledge of alert (Bean et al., 2015; Bopp and Douvinet, 2022), we deployed a face-to-face questionnaire in tsunami-prone zones of 5 municipalities along the French Mediterranean coastlines. The data collection yielded 750 responses, with 150 responses collected in each municipality. Section 2 presents a summary of the literature review. Section 3 present the study sites, data procedure and methods we used. Section 4 identifies the main results and Section 5 enlarged the discussions, for research and practice.

2. Literature review

2.1 Tsunami hazard perception

Research on hazard perception has taken a multidimensional approach, aiming to understand how individual and social factors shape the intuitive hazard judgments on which the majority of citizens rely (Loewenstein et al., 2001; Slovic et al., 2004). Two approaches are often distinguished: 1) a psychological approach, producing general models to explain the manifest behaviour, attitudes, emotions and beliefs of individuals facing a tsunami; 2) a sociocultural approach, which emphasises the link between the social structure in which individuals are embedded and their values, attitudes and beliefs (Cugliari et al., 2002). Without reviewing all the papers in this field, we can maintain, as Wachinger et al. (2013) argued, that perception is influenced by four groups of factors: 1) the type and severity of hazard, 2) the source and amount of information previously received, 3) personal (*e.g.,* age, knowledge of the hazard) and cultural characteristics, and 4) context, such as proximity to the hazard and community size. Kellens et al. (2013) added that situational factors (*e.g.,* personal experience with previous hazards, location of housing) can induce significant differences. Lechowska (2018) also pointed to the difficulty to explain the different levels of clarity and knowledge only studying socio-cultural backgrounds.

A significant body of literature has specifically examined tsunami hazard perception (*e.g.,* Kurita et al., 2007; Bird and Dominey-Howes, 2008; Arias et al., 2017; Sutton et al., 2018; Akbar et al., 2020; Hall et al., 2019; Rafliana et al., 2022). Most of these studies were carried out in the *Indian Ocean Tsunami Warning System* and the *Pacific Ocean* one (PTWS) operate. As example, the survey of communities affected by the Indian Ocean tsunami, conducted in different months in 2005 and involving around 1,000 interviews in 3 countries, showed that differences in hazard perception were mainly due to a lack of prior knowledge, a lack of adequate information during emergencies and a lack of tsunami drills, as well as socio-cultural backgrounds, leading to higher casualty rates in some areas (Kurita et al., 2007). Hall et al. (2019) showed that most respondents in Bali reported that they had not learned about tsunamis while travelling to and within Indonesia, and almost all participants said they would run to higher ground if a tsunami was approaching. In some countries (*e.g.,* Iran, Bangladesh, Pakistan or Australia), most respondents said that the area where they were interviewed could be affected by a tsunami, but few remembered the exact date and area affected by the last tsunami (Cugliari et al., 2022).

Less studies were conducted in the NEAMTWS, *North-East Atlantic, Mediterranean and connected seas Tsunami Warning Systems* (Courteau, 2019). Recently, a meta-review founded on 23 papers (Cugliari et al., 2022) therefore outlined important considerations in this region. The tsunami hazard is generally not considered to be major by respondents, for example along the Black Sea (Romania), or in Sinès (Portugal), compared to earthquakes, storms, pollution or explosions (Cugliari et al., 2022). In Southern Italy, respondents showed a widespread consciousness that a tsunami may occur, but they also said that in case of tsunamis they would not know how to behave due to lack of preparedness (Gravina et al., 2019). Moreover, in this same study area, tsunamis were generally perceived as low, despite their high severity (Cerase et al., 2019), and the areas affected by tsunamis in the (relatively) recent past (such as the Tyrrhenian and Ionian coasts) still preserve a historical memory, handed down orally and revitalized by both the local and social media (Cugliari et al., 2022). Rafliana et al. (2022) recently added that media exposure, collective memories, knowledge, experiences from past events, scientific lectures, related social processes and images cumulatively influence tsunami risk perception. Cugliari et al. (2022) finally showed that all the surveys previously carried worldwide consisted of diverse questions, were performed with different techniques, and pointed out: 1) the widespread lack of appropriate policies for dealing with the tsunami risk; 2) the low level of trust in official institutions; 3) the presence of a fatalistic attitude, probably due to religious beliefs, and 4) the low interest of authorities in dealing with tsunami risk, considered unlikely, unimportant or too difficult/expensive to deal with.

Although researchers have gained significant insights into the tsunami perception and identified singular between areas overwide, there is limited understanding regarding the hazard perception declared by the population along the French Mediterranean coastlines. Specifically, little is known about how many people would declare running to higher ground if a tsunami was approaching, and how many think a tsunami would arrive suddenly or with a delay of more than half and one hour. Also, it still remains unclear how images relayed by the media disrupt or lead to errors in tsunami perception. In our view, an in-depth examination of this perception is therefore essential to measure the effectiveness of information campaigns and reactions face to real alerts. Given these critical gaps, first objectives of this study were **(RQ1)** to evaluate and compare the hazard perception in tsunami prone areas, especially in five municipalities along the French Mediterranean basin, and **(RQ2)** to determine whether the age, gender, residence status, information source or awareness raising actions impact levels of perception. Questions related to experience, preparedness, proximity to the hazard or cognitive aspects (*e.g.,* self-efficacy or community ownership) were excluded because they required time and important resources to be understood (Akbar et al., 2020; Buylova et al., 2020; Hall et al., 2022). We hypothesised that each of the parameters we examined (*e.g.,* age, gender, residency status…) may produce slight differences at local scales **(H1)**, but also that cumulating these differences may generate high discrepancies between the 5 municipalities (**H2)**.

2.2 Knowledge of alert

Studies carried out to measure the knowledge of alerts become more and more numerous, especially thanks to the developments in technology which enabled the release of information through mobile phones (e.g., Bean et al., 2015; Yoo et al., 2021; Smith et al., 2022; Chen et al., 2023; Sutton et al., 2023). Five aspects are often analysed:

1) the *content* of alerts (what, where, when, why, for what to do, etc.), 2) the *format* of alerts (*i.e.,* text, sound, graphics, maps, etc.), 3) the *channels* (*i.e.,* siren, radio, website, SMS, Cell-Broadcast); 4) the *actors* delivering the alerts (*i.e.,* the prefects, mayors or French Ministry of Interior in France); 5) the *time* between the alerts and the impacts of the hazards. Study of the spatial (in)accuracy (Bopp et al., 2023), interactions between recipients and content of messages (Chen et al., 2023), or trust in the alert sender (Smith et al., 2022) can also be studied.

A crucial aspect is the way in which alerts are disseminated to the population and the time it takes to reach them. If alerts can be broadcasted through different disseminators, they strongly differ according to the countries and authorities (Bopp et al., 2021). In the US context, the FEMA (*Federal Emergency Management Agency*) and the Department of Homeland Security can use the WEA (*Wireless Emergency Alerts*) since 2012, to push messages to mobile devices in the probable affected geographical areas (Chen et al., 2023). In Japan, immediately after an earthquake occurs, the JMA (*Japan Meteorological Agency*) estimates the possibility of tsunami generation-event from seismic observation data and if needed, inform on the disastrous waves expected in the coastal regions (Yoo et al., 2021). In Samoa Islands, a specific signal has been defined and may be broadcasted through bells (Atwater et al., 1999). In Indonesia, each region may use sirens, loudspeakers, or relay the alert to community leaders (*e.g.*, through the *Komunitas Siaga Tsunami*), if time is sufficient for this (Bopp et Douvinet, 2022).

Another crucial aspect is then the interactions between signals and recipients. Two models are currently used to understand factors that influence people's perceptions and actions after receiving alerts (Chen et al., 2023): the Warning Response Model (Mileti and Sorensen, 1990) and the Protective Action Decision Model (Lindell et al., 2012). Both these models emphasize the need to consider the current relationships between the message design and environmental, social, psychological, physiological or characteristics of the public audience, as they impact perceptions (Sutton et al., 2023).

However, if alerts have the common intention of motivating protective actions, populations do not automatically apply them. Various studies have proven this. 39% of the population declared they decided to evacuate hearing sirens during the 2011 Japan event, while 18% evacuated without waiting alarms (Murakami et al., 2012). During the 1960 event in Hawaii, sirens rang three hours before the tsunami arrived, but meaning of signal was unclear for most of the inhabitants (Atwater et al., 1999), and if 95% of the population heard sirens, only 32% evacuated (Lachman et al., 1961). During the 2009 tsunami on Samoa Islands, bells were also used, so the population were aware that a danger was arriving, but the specific tsunami signal was not used, so many people was waiting before evacuating (Lindell et al., 2015). Some people also waste valuable minutes in gathering information, calling family or neighbours, or listening to radio, television or other channels, before applying instructions (*e.g.,* Grothman and Reusswig, 2006; Lindell et al., 2015; Sun and Sun, 2019; Fakhruddin et al., 2020; Sutton et al., 2023).

Thus, the assessment of the knowledge of alert is a crucial gap, as it can influence the ability of the population to evacuate in case of a tsunami (Chen et al., 2023). However, to the best of our knowledge, no studies have been carried out in this field along the French Mediterranean coastlines. Also, it is difficult to confirm whether residents or workers are actually aware of the alerting signals that can be broadcasted at local level, how they should react in the event of a tsunami alert, and whether they trust the signals. It also remains unclear how alerting tools can be efficient and how hazard perception can interfere with signal interpretation, although this has already been suggested in several studies (Courteau, 2017). In this context, related to the previous questions, we also aimed to determine (**RQ3**) whether local residents are aware of alerting tools, the time of their activation, and the actors responsible for tsunami alerts, and (**RQ4**) whether age, gender, residence status, information source, or impact of awareness-raising activities influence this knowledge. We hypothesised that the potential of alerting tools is underestimated (**H3**), and that actors remain unknown, especially among youngest and workers, despite efforts in communication and information carried out by several municipalities (**H4**).

3. Methods and data

3.1 Study area

In a previous study, we mapped the tsunami evacuation zones at a fine scale for the 187 municipalities likely to be hit by a tsunami along the French Mediterranean coastlines (Carles et al., 2023). These zones correspond to all areas with an altitude of less than 5 meters and a distance from the sea of less than 200 meters along the river mouths. This distance is extended to 500 meters from the mouth of the coastal rivers (Carles et al., 2023). Such deterministic mapping was chosen more than a probabilistic model, because of the different resolutions used in the previous models, the uncertainties of the sources and the limitations of the catalogues. This choice, which is different in Italy or Spain, for example, has several advantages: 1) to have a common regional coverage with a precise resolution; 2) to take into account low-frequency scenarios (Mw > 8 earthquake in Algeria, for example); 3) to integrate the maximum sea level rise feared with global warming (Alhamid et al., 2022). The maximum height (5 m) remained consistent with the results of the probabilistic model (PTHA), tested and applied in Italy within the European project TSUMAPS-NEAM (2018). Two main results were obtained along the French Mediterranean coastlines: 1) the evacuation zones cover 20,700 hectares (ha), and 2) according to national data, a tsunami may accommodate 163,000 inhabitants and 830,000 beach users during the peak summer period (Carles et al., 2013).

These zones were aggregated at the municipal level. Thus, we used these data to identify a set of municipalities presenting high densities of evacuation zones, and to conduct appropriate face-to-face questionnaires. Our final selection (**Table 1**) allows us to select 5 municipalities with different demographic features. Cannes, with an area of approximately 1,962 ha and a population of 72,435 inhabitants, is the most densely populated. Sanary-sur-Mer and Bastia are similar in size but less densely populated (*i.e.,* 48,296 and 17,173 inhabitants.km^{-2}). Six-Fours-Les-Plages has the largest area (2,658 ha) but a lower density than Bastia (**Figure 1**). The choice of these communes was also motivated by the scientific knowledge accumulated over many years. Every year since 2016, Cannes has organized awareness raising actions in which we participated, in particular during the World Tsunami Awareness Day (WTAD). Since 2021, Cannes has also been working with UNESCO to obtain the Tsunami Ready community recognition, which is expected at the end of 2023. In Bastia, a tsunami communication strategy is in place since 2019, particularly following the real-life tsunami evacuation on 25 April 2015, when 20 terraces in seaside restaurants were evacuated by the authorities, who banned traffic on the seafront for almost an hour, even though it turned out to be a false alarm. Evacuations were planned and mapped out in Sanary-sur-Mer and Cannes, but not in Bastia and Bandol. Choosing these 5 different municipalities, we aimed at observing differences in the tsunami hazard perception. This survey may also provide interesting results on the knowledge of alert. In Cannes, 7 sirens have been in place since 2019, covering about 78% of the population in the 2km audible range (Douvinet et al., 2021), and 2 sirens are located not far from the tsunami evacuation zone (**Figure 1**). In addition, a SMS alert system can potentially inform more than 33,000 people (data from 2018). In contrast, there is only 1 siren in other municipalities. A SMS alert system also exists in Bandol. However, we do not have precise data on the number of registrations. Finally, the face-to-face areas were selected combining the tsunami evacuation zones and the most densely areas, to obtain a maximum number of questionnaires during the days of investigation.

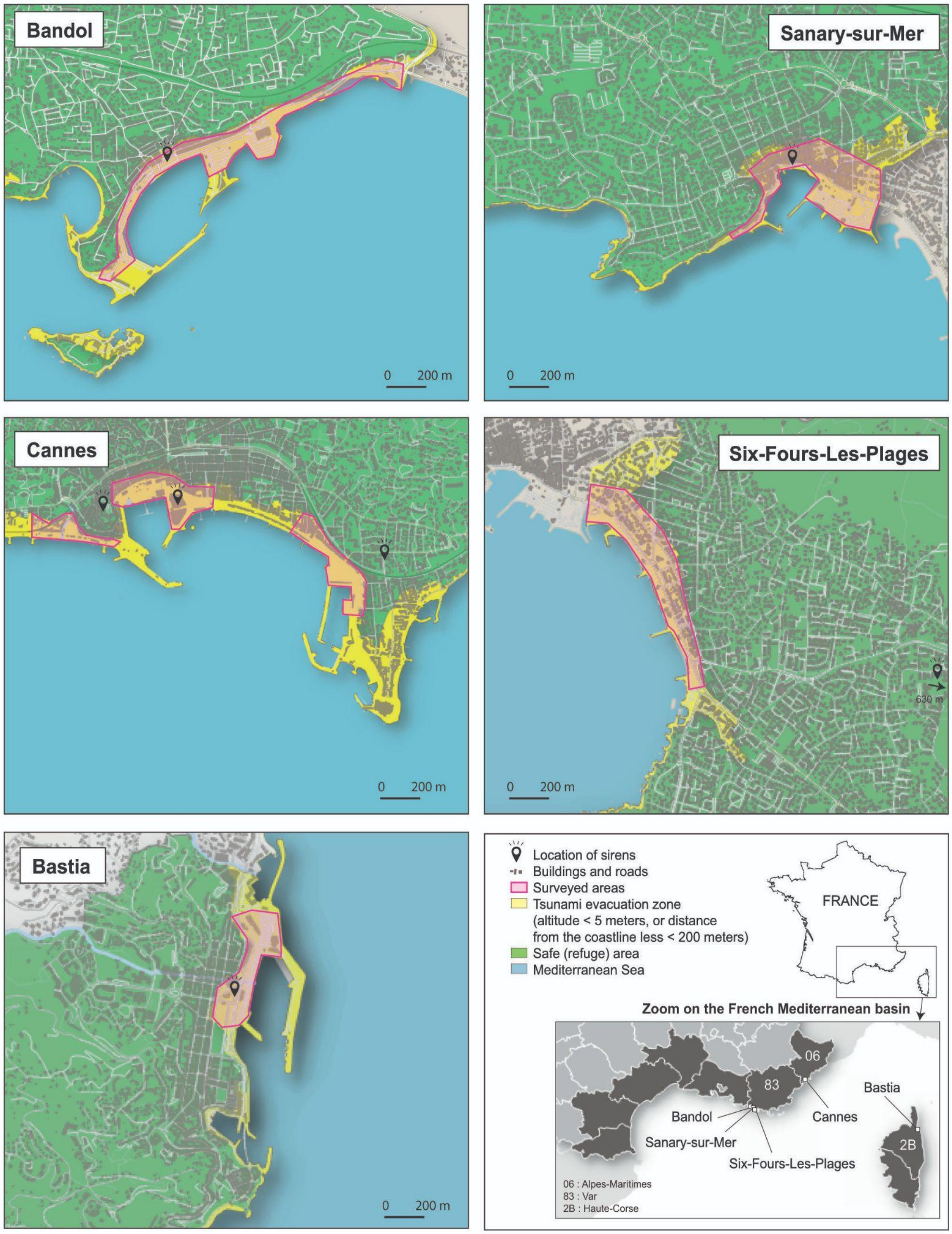

Figure 1: Location of the surveyed areas, with sirens and the evacuation zones mapped at fine scale. Copyright: the authors

Studied municipalities (abbreviation)	Municipality size (in hectares, ha)	Census Population (inhabitants, i.e., hab)	Tsunami evacuation zone (ha)	Number of residents in evacuation zones (hab.)	Density in the tsunami zones (inhabitant per km^2)	Period of the survey (year, month, day)	Number of daily collected questionnaires	Final sample (n)
Bandol (BAN)	858.2	8,359	35.1	939	2682	2019/12/09	122	150
						2020/01/20	28	
Bastia (BAS)	193.8	48,296	80.2	1,191	1489	2019/10/24	71	150
						2019/10/25	79	
Cannes (CAN)	195.4	72,435	73.8	4,961	1810	2019/11/29	124	150
						2020/01/23	26	
Sanary-sur-Mer (SAN)	192.4	17,173	43.9	1,882	4277	2020/09/14	97	150
						2021/06/26	53	
Six-Four-Les-Plages (SIX)	265.8	35,339	20.1	1,902	1585	2020/09/15	100	150
						2022/09/24	50	

Table 1: Geographic and demographic characteristics of the 5 surveyed municipalities located along the French Mediterranean coastlines.

3.2 Data collection

3.2.1 Questionnaire

The questionnaire used in this study, dispensed in French (**Appendix 1**), was adapted from related literature with similar objectives, in particular from the ASTARTE project (Liotard et al., 2017). The sample consisted of 5 sections and 17 questions, including 6 closed questions with yes/no options, 5 multiple choice questions and 6 open questions (**Figure 2**). In section 1, the questions were designed to get to know the respondents. In section 2, we addressed the perception of hazards existing in the municipality, and how they think they could be alerted for each one, using the classification of tools listed by Bopp and Douvinet (2022), who distinguished the traditional tools (siren, TV, radio, door-to-door, loudspeaker) to modern tools (SMS, social media, internet). In section 3, we defined 5 questions on tsunami hazard, in particular on the maximum levels that could withstand inundations during a tsunami (Q7). In section 4, questions focused on the knowledge of tsunami alert, more especially on the intentions declared by the respondents if they may receive a SMS watch message, with the protective measures recommended by UNESCO and defined as follows: "*Tsunami alert! Leave the coast and seek higher ground*" (Q14, **Figure 2**). This can be also explained by the fact that several municipalities deployed SMS calling centers since a few years. Finally, section 5 aimed to assess some socio-demographic variables. The questionnaire was designed with the help of two psychologists, who was invited to participate in March 2019. In addition, five students were asked to comment on any aspect of the questionnaire, before the field administration. Based on their feedback, mobile phones were added to question Q15 and Q4, Q6 and Q7 were slightly reformulated.

3.2.2 Survey procedure

We invited residents or workers we met in the tsunami evacuation zones to participate in the survey. Once half of the expected number of responses had been collected (75 out of 150), a preliminary assessment was made between the interviewers to see if the expected aging groups needed to be rebalanced. Due to the containment measures imposed by the COVID-19 pandemic in France, and in particular during three periods (17 March-11 May 2020; 20 October-15 December 2020; 3 April-3 May 2021), when movements were strictly prohibited, the survey was conducted on different days (**Table 1**) and took longer. We therefore decided to keep the face-to-face process to avoid disruptions in the survey, to ensure the presence of the same interviewers to administer the questions, and to guarantee that we had all the answers to the questions at the end of the questionnaire. 86 people started to complete the questionnaire, but stopped when we were dealing with the tsunamis. So, their answers were not kept. All respondents were also asked to give their consent to participate in this research, respecting the GDPR (General Data Protection Regulation) protocol that has been in place in France since 2015 (**Figure 2**).

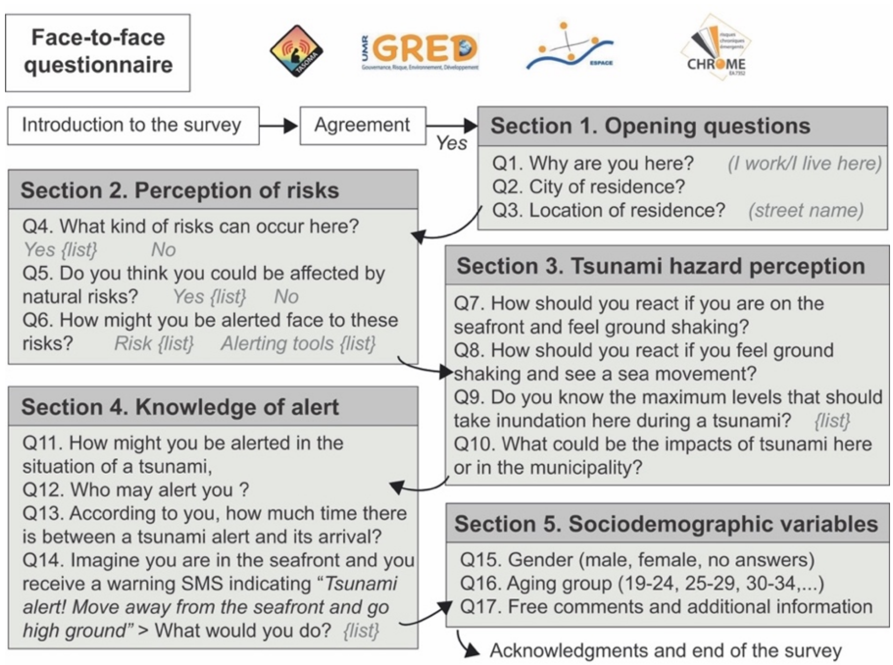

Figure 2: The list of questions and handsets addressed to collect tsunami perception and knowledge of alerts. Copyright: the authors

3.2.3 Profile's respondents

Table 2 shows the descriptive statistics for the profile sample. The 750 respondents were 53.6% female and 46.4% male, aged between 60 and 74 years (29.1%), 45-59 years (25.7%), 30-34 years (18.3%), 15-29 years (16.9%) and the rest (10.0%) were 75 years and over. 68.1% of respondents lived and 31.9% worked in the areas surveyed. The global age group shows that 15-74 was over-represented, while 75 was under-represented. Specifically, the 45-59 age group was over-represented in Bandol and Cannes and the 60-74 age group was over-represented in Six-Fours-Les-Plages. These disparities are due to the fact that the 0-15 age group was not surveyed in accordance with French regulations, as well as the challenge of finding older people and persuading them to participate in a face-to-face questionnaire (Sun and Sun, 2019). 34 of the 86 respondents who terminated the survey prematurely were over 75 years of age. These questionnaires were then deleted. While these biases are consistent with other questionnaires (Cerase et al., 2019; Cugliari et al., 2022; Ong et al., 2023), their impact is limited unless they are so severe as to attenuate the variances of the variables (Lindell and Perry, 2000).

	Studied areas (abbreviations)	Bandol (BAN)	Bastia (BAS)	Cannes (CAN)	Sanary-sur-Mer (SAN)	Six-Four-Les-Plages (SIX)	Average in % (* on global sample)
Location of respondents	Only for working	52	34	99	26	28	31.9 *
	Living here	98	116	51	124	122	68.1 *
Gender	Female (and %)	68	81	84	85	84	53.6 *
	Men (and %)	82	69	66	65	66	46.4 *
S - Age groups of respondents in our sample (in %)	15-29	16.7	21.3	14.0	12.0	20.7	16.9
	30-44	12.0	27.3	24.0	16.7	11.3	18.3
	45-59	30.7	25.3	29.3	21.3	22.0	25.7
	60-74	31.3	22.7	24.0	33.3	34.0	29.1
	> 75	9.3	3.3	8.7	16.7	12.0	10.0
C - Age groups (%) in the census population (INSEE, 2020)	15-29	10.2	16.4	16.4	10.4	11.4	12.9
	30-44	12.2	21.5	17.1	11.8	15.2	15.6
	45-59	19.6	18.7	18.6	18.4	20.5	19.1
	60-74	27.3	15.7	18.7	27.4	23.3	22.5
	> 75	19.9	10.0	17.1	22.1	16.7	17.1
Differences between sample (S) and census (C)	15-29	6.5	4.9	-2.4	1.6	9.3	3.9
	30-44	-0,2	5.8	6.9	4.9	-3.9	2.8
	45-59	11.1	6.6	10.7	2.9	1.5	6.6
	60-74	4.0	7.0	5.3	5.9	10.7	6.7
	> 75	-10.6	-6.7	-8.4	-5.4	-4.7	-7.1

Table 2: Census demographics of the respondents who answered to the face-to-face questionnaire

3.3 Data analysis

The 750 questionnaires were analyzed using *Sphinx online* and *RStudio*, to allow filtering and statistical analysis. Three approaches were carried out. First, a qualitative analysis was carried out to compare the average values obtained in each site. Figures summarizes results by opposing accepted (with a variation of green color ranges) to negative (with variation in the red color ranges) answers. Second, for each question, the chi-square method χ^2 was used to statistically confirm trends in the collected data we detected. The age, gender and the residency status (residents or workers) were used as explanatory variables. When the null hypothesis (H0) was rejected (with $p<0.001$), the Cramer index (Ci) was calculated for measuring the strength of the independence relationship. Third, two Multiple Correspondence Analysis (MCA), one referring to the tsunami hazard perception (Section 3), another to the knowledge of alerts (Section 4) were carried out. In addition, two HAC (*i.e.,* Hierarchical Ascendant Classification) were conducted on the coordinates of the two previous MCA, to group the respondents in function on the occurrence of declared answers. Once classifications were analyzed, we looked at the distribution of the respondents in each of the HAC, and studied if the municipalities joined or not the same "profiles". If yes, a strong relationship between tsunami hazard perception and knowledge of alerts is proven. If not, then, we analyzed why there is any difference, and followed the discussion in the last section.

4. Main results

Data collected for tsunami hazard perception (Section 3) and knowledge of alert (Section 4) were analyzed for the global sample and by comparing each municipality. We also statistically evaluated the relationship with socio-demographic variables (*e.g.,* age, gender, residence status...) in order to answer the four research hypotheses.

4.1 Tsunami hazard perception

First, when the 750 respondents imagined being on the seafront and feeling the ground shake (Q7), 13.4% said they would move to higher ground, 11.7% would move away from the seafront, and 22.1% would leave. Added together, these responses give a global rate of 47.2% (**Figure 3**). Then, only 47.2% of respondents claim to be able to take appropriate protective actions. 19.3% of respondents in Sanary-sur-Mer said they would move, compared with only 4.2% in Bastia. On the other hand, 13.2% said they would take shelter in buildings, with high figures in Six-Fours-Les-Plages (25.5%) and Sanary-sur-Mer (20.1%). 18.9% said they would not leave, 13.8% did not know what they would do and the remaining 6.6% combined other answers (*i.e.,* call for help, call friends, call the school, go to the beach, or go on a boat...). The number of respondents who say they could take protective measures is not correlated with the number of respondents who do not know what to do and do not go. The chi-square test with age ($\chi^2 = 53.22$; $p < 0.001$; Ci = 0.13) shows that people aged 30-44 are more likely to take shelter, while those aged 45-59 are less likely to do so. People aged 75 and over are more likely to express the intention to stay in place, although they also show a tendency to be more numerous to move away from the sea.

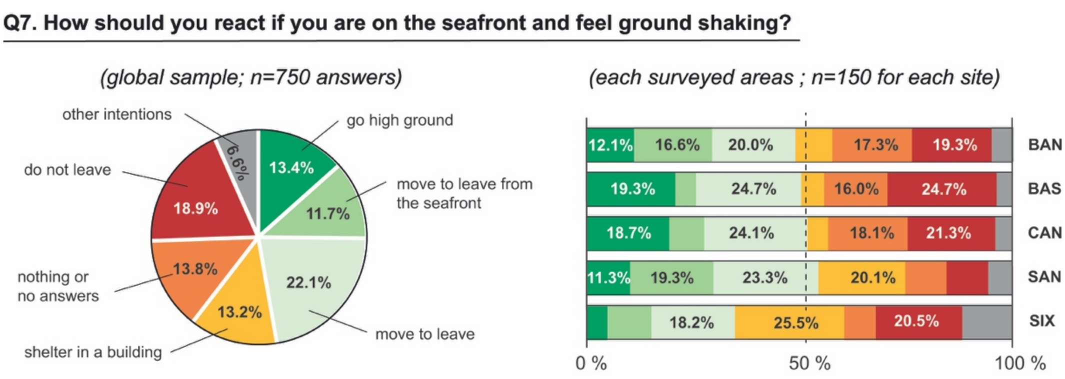

Figure 3: Results obtained for Q7. Copyright: the authors

Related to the previous question, when respondents imagined that they felt the ground shaking and saw the sea moving along the seafront (Q8), 29.1% said they would move to higher ground, 10.5% would move away and 25.7% would leave. Also, these intentions give a global rate of correct answers of 65.3% (compared to 47.2% for Q9). The main difference is explained by the number of respondents who reported going to higher ground (**Figure 4**). In contrast, only 1.1% reported taking shelter in buildings. 17.1% said they did not know what to do, and this rate was 25.3% in Bastia, 20.1% in Sanary-sur-Mer and 20.7% in Cannes, compared to only 12% in Sanary-sur-

Mer. It is interesting to note that 46.5% associate a tsunami with ground tremors and sea movements, while 14.5% refer to a meteorological event, an earthquake and others (38.9%) do not know what is happening. The chi-square test on location ($\chi^2 = 79.91$; $p < 0.001$; Ci = 0.16) confirms the high number of respondents who do not leave in Bastia and the higher values for respondents who move away from the seafront in Sanary-sur-Mer. The chi-square test with age ($\chi^2 = 49.5$; $p < 0.001$; Ci = 0.12) confirms that those aged 60-74 are the most likely to say that they move away from the seafront, while those aged 75 and over are the most likely to not move away, but are also the most likely to say that they take shelter. But no relationship exists with gender or residence status.

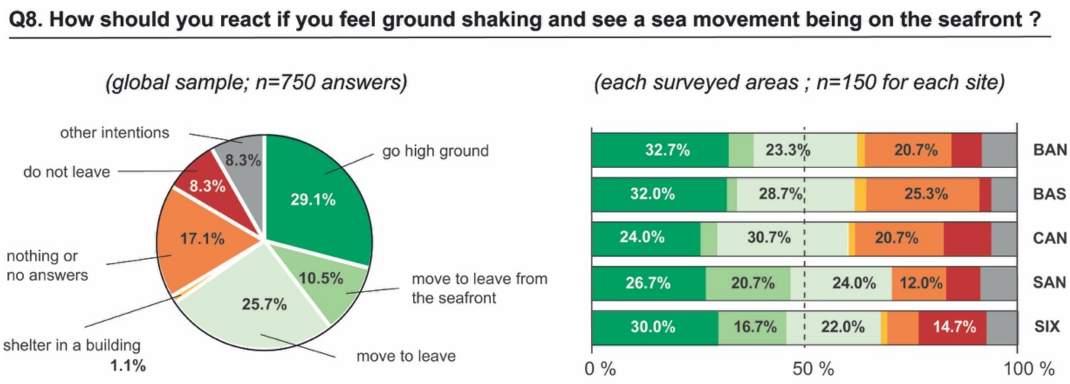

Figure 4: Results obtained for Q8. Copyright: the authors

On the other hand, we analyzed the inundation heights declared by the respondents (Q9). The analysis reveals a strong misperception of possible run-up heights (**Figure 5**). 25.1% of the respondents stated that a tsunami could generate heights between 2 and 5 meters, with the highest rates of positive responses in Bandol (28%) or Cannes (27.3%), and the lowest in Sanary-sur-Mer (20.7%). The number of correct responses, indicating values between 0 and 5 meters, is 30.4%, with variations between Bastia (26%) and Six-Fours-Les-Plages (35.3%). On the other hand, the number of respondents who indicated heights of between 5 and 10 meters (25.5%) or more than 10 meters (22.9%) is significant. These two responses add up to an overall percentage of 48.4%. When completing the questionnaire, many respondents recall the 2004 event and the media or photos they saw on TV and Internet. The number of respondents who did not mention altitude was high (21.2%), particularly in Bandol (30%). The chi-square test with location ($\chi^2 = 49.5$; $p < 0.001$; Ci = 0.13) shows that the number of respondents who indicated a maximum height of 1-2m in Six-Fours-Les-Plages is high, as is the number of 'no answers' in Bandol. Relationships with gender, age group or residence status were therefore not statistically proven.

Respondents were also asked to imagine impacts of a tsunami in the area where they work or live (Q10). 4 groups emerge when we classify terms reported for this open question. In one group, some respondents indicated that tsunamis might cause no damage or only minor flooding or damage. These responses totalized 24.1%, with slight variations between the five surveyed municipalities (**Figure 6**). Material and serious damage are declared by the second group, with cumulative percentages ranging from 22% in Bandol to 38% in Bastia. Destruction of the seafront or the town formed the third group. The percentage varies greatly, ranging from 10% in Cannes to 34% in Bandol. The last group declared that tsunamis may cause deaths, and not systematically material damage. The number of respondents reporting this impact is higher in Sanary (18.8%), Six-Four-Les-Plages (20.0%) and Cannes (17.1%), where 14% said that tsunamis can cause deaths without serious material damage. The chi-squared test with age ($\chi^2 = 56.58$; $p < 0.001$; Ci = 0.17) confirms that the youngest (15-44 years) expected at least material damage, compared to the oldest who expected little or no impact on coastlines. The post-hoc analysis of the standardized results also shows that the observed frequencies for those aged 75 and over who expected no impact were significantly lower than expected.

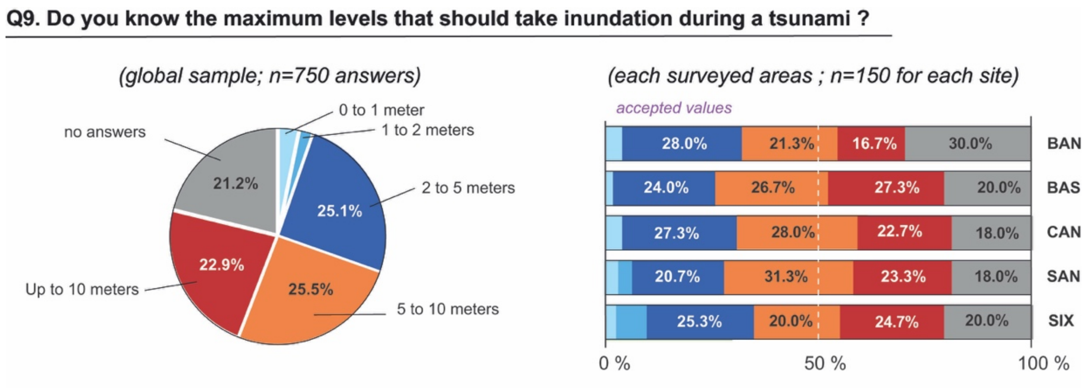

Figure 5: Results obtained for Q9. Copyright: the authors

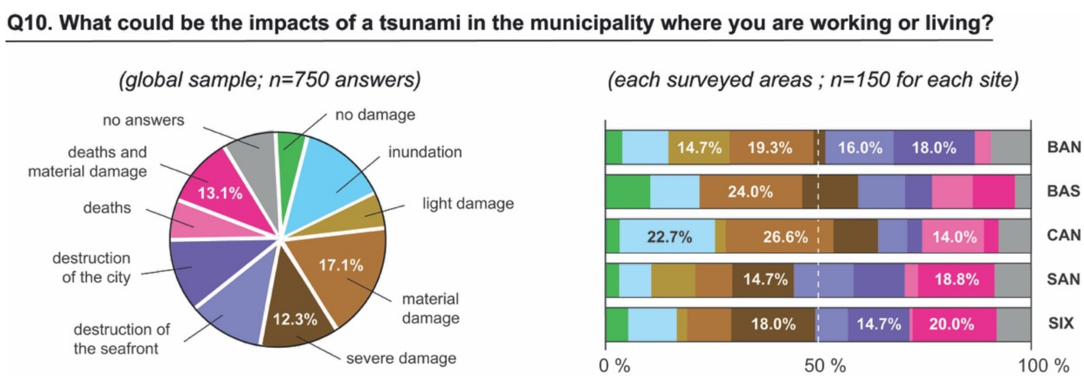

Figure 6: Results obtained for Q10. Copyright: the authors

4.2 Knowledge of alert

When we asked respondents how they would be alerted in the event of a tsunami (Q11), sirens emerged as the most alerting disseminators (**Figure 7**). On average, 42.3% of the respondents we interviewed in Cannes, Bastia, Sanary-sur-Mer and Bandol answered correctly. Local differences appear, as only 38% of respondents identified the sirens in Cannes (while there are 7 sirens). In Six-Fours-Les-Plages, 48.7% thought they could be alerted by sirens, although the siren is far from the tsunami evacuation zones. The second tool mentioned was SMS alert systems. The number of respondents in Cannes (10%) and Sanary-sur-Mer (14.7%) is higher than in Bandol, where it is only 2.7%. In the other areas, people wrongly believe that they can be alerted by SMS. Loudspeakers received the highest number of responses in Sanary-sur-Mer (14.7%) and Cannes (9.1%), where these tools really exist, while the low rates in the other areas can be explained by their absence. TV (5.3%), social media (4.5%) and radio (2.7%) all recorded low response rates. On the other hand, 25.3% said they did not know how to be alerted. Interestingly, the chi-squared test with location ($\chi^2 = 130.5$; $p < 0.001$; Ci = 0.28) statistically shows a high number of no answers, and social medias in Bastia, but no relation with gender nor residency status.

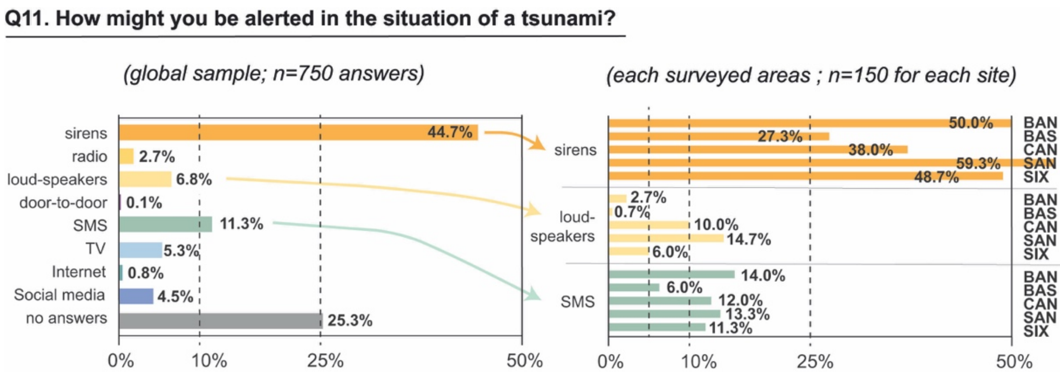

Figure 7: Results obtained for Q11. Copyright: the authors

In relation to the previous question (**Figure 8**), when respondents were asked who should alert them in the event of a tsunami (Q12), 45.5% did not know who should alert them, and only 29.4% correctly named mayors (25.1%) and prefectures (4.3%). The number of positive answers in Sanary-sur-Mer (40%) is higher than in other areas. In contrast, 63.3% of respondents did not know who could alert them in Bandol. On the other hand, 9.9% wrongly believe that they will be alerted by the emergency services, 7.2% by TV, 1.6% directly by the Tsunami Alert Centre, and 5.9% think that the alert may never be sent. These differences are statistically confirmed by the chi-square test with the location ($\chi^2 = 98.1$; $p < 0.001$; Ci = 0.25). However, there are no additional relationships with age ($\chi^2 = 4.54$; $p > 0.27$), gender ($\chi^2 = 1.45$; $p > 0.36$) or residence status ($\chi^2 = 3.52$; $p > 0.31$).

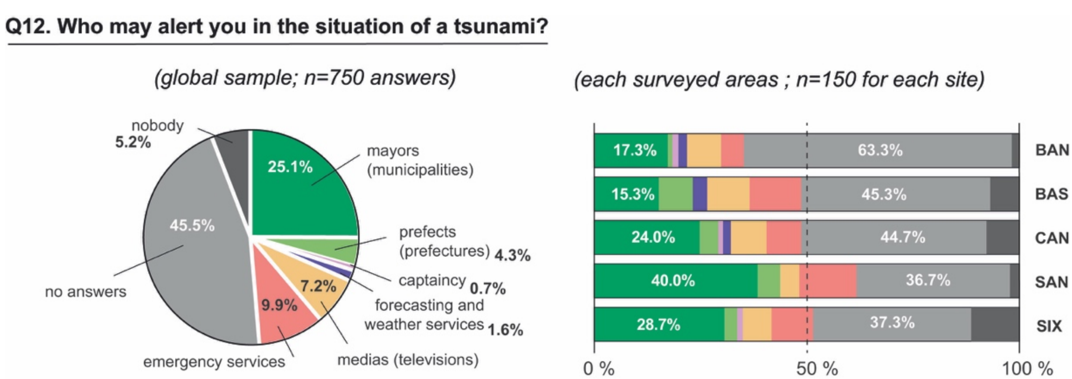

Figure 8: Results obtained for Q12. Copyright: the authors

On the other hand, 55.9% of respondents estimated the time between a tsunami alert and its arrival locally (Q13) to be less than 1 hour (**Figure 9**). 21.6% also estimated it to be less than 10 minutes and 18.3% estimated it to be between 10 and 30 minutes. Interestingly, 2.9% said they could not give an exact time, stating that this depended on the location of the earthquake or the speed of the tsunami waves. This can be considered satisfactory in view of the current state of art. In Sanary-sur-Mer, the final rate of exact answers equals 63.4%. On the other hand, 25.7% of respondents were unable to answer this question, 7.4% gave a time of more than 5 hours and in Bandol, and 9.3% of respondents gave a time of between 5 and 24 hours. The chi-square test on location ($\chi^2 = 70.9$; $p < 0.001$; Ci = 0.15) confirms the large differences described above. The chi-square test with age ($\chi^2 = 74.81$; $p < 0.001$; Ci = 0.16) shows that the 15-29 are more likely to say 1 to 5 hours and 45-59 less than 10 minutes. Those aged 15-44 are also the least likely to say they do not know, in contrast to those aged 75 and over.

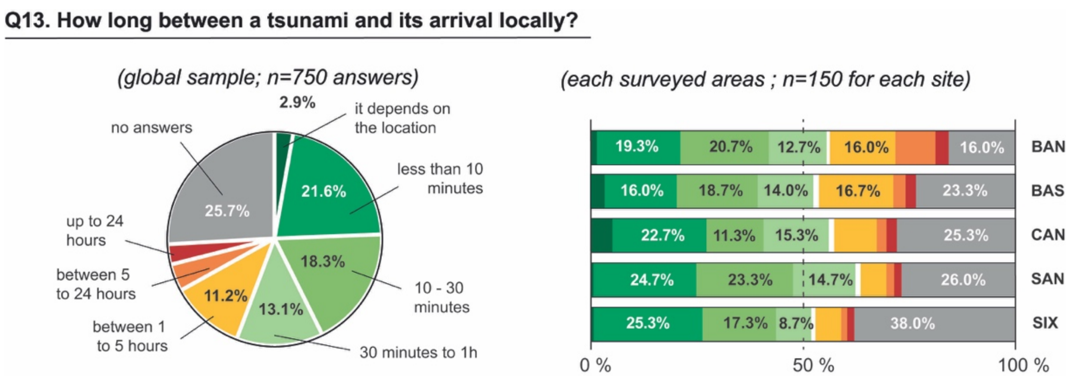

Figure 9: Results obtained for Q13. Copyright: the authors

We finally asked respondents (Q14) how they thought they react if they received a SMS warning message saying "*Tsunami alert! Move away from the coast and get to high ground*". 55.7% said they would immediately think of going to higher ground, with values ranging from 49.3% in Bastia to 68.7% in Bandol (**Figure 10**). However, before leaving, 10.1% said they would take time to inform their family members, 7.5% to inform people nearby, 7.5% to get information to check the credibility of the SMS, 4.7% to collect their belongings, 4.7% to look for their car and 3.1% to collect their children's. These responses represent a cumulative rate of 37.5%. In addition, 4% of the 750 respondents said they would stay where they were (8.7% in Bastia), 1.7% did not know what to do (4.7% in Six-Fours-Les-Plages) and 1.7% would take shelter in a building (3.3% in Cannes). This SMS message is therefore not sufficient to generate protective intentions in the event of a tsunami, and is in line with previous studies (Cain et al., 2021; Smith et al., 2022). Surprisingly, the recommendation '*to go to high ground*' was not fully understood by some respondents, the latter reported going upstairs (4.7%) or using their car (1.3%). The chi-squared test with residence status ($\chi^2 = 13.89$; $p < 0.001$; Ci = 0.17) shows that respondents who work in the surveyed municipalities are less likely to evacuate immediately, compared to those who live there. However, the chi-square test cannot be used for variables such as gender, age group and residential status.

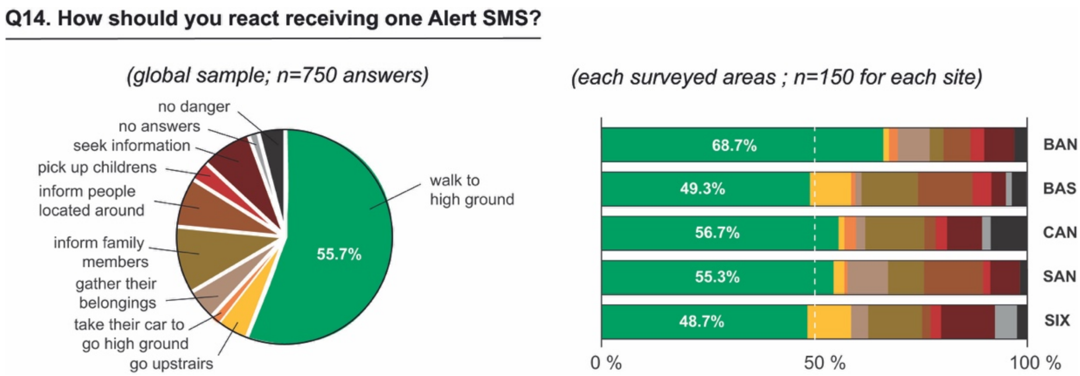

Figure 10: Results obtained for Q14. Copyright: the authors

4.3 Relation between tsunami hazard perception and knowledge of alert

This study continued by examining the possible relationships between tsunami hazard perception and knowledge of alert. To achieve this, a first MCA was realized using the rates of correct answers obtained for each question in the Section 3. Of the total inertia of 1, 29.3% is accounted for by F1 (*i.e.,* the first axis), 20.4% by F2, 19.1% by F3, 16.9% by F4 and 14.3% by F5. Cumulatively, the first two axes account for 49.7% of the total inertia. The rates of negative answers of respondents (Q8) when they felt the ground shaking and saw the abnormal sea movement (Contr. = 0.19) and when (Q9) they estimated the water heights of a possible tsunami (Contr. = 0.11) contribute most to F1. The rate of negative answers (Q9) contributes most to F2, with a clear association with the lack of identification of the tsunami (Contr.= 0.08) in Q4. Respondents who gave a positive answer to Q8 (Contr.= 0.18) but a negative answer to Q9 (Contr.= 0.17) are grouped in F3. F4 includes the respondents who mentioned tsunamis as a risk in Q4 (Contr.= 0.25) and gave positive answers to Q7, Q8 and Q9.

The Hierarchical Ascendant Classification (HAC) carried out on the basis of the MCA coordinates and the analysis of the dendrogram allows us to identify 4 classes (**Figure 11**). Group 1 includes most of the respondents who gave incorrect answers to Q8 (140 people out of a global sample of 255) and Q9 (141 out of 517) and who did not mention the term "tsunami" (143 out of 630). Group 2 consists of respondents who gave a good answer to Q9 (with 86% of the total number of respondents who answered this question correctly), but who also did not mention the tsunami as a risk (196 people out of 630). 44% of this group also gave no correct answer to Q8. Group 3 consists of a large proportion of respondents who gave a correct answer to Q8 (291 out of 489), but who gave an incorrect answer to Q9 (291 out of 522). Finally, the Group 4 consists exclusively of respondents who correctly perceived tsunami hazard (119 out of 119). 75% of the respondents showed proficiency in answering Q8, while 56% showed proficiency in answering Q7. As a result, in Group 4, the respondents had a greater tendency to recognize the arrival of a tsunami and to take the appropriate protective actions.

The total inertia of the second MCA (**Figure 11**) gives the following results: F1 accounts for 30.9%, F2 for 25.5%, F3 for 22.5% and F4 for 21%. The cumulative contribution of the first two axes is 56.4% of the total inertia. The incorrect answers for alerting tools (Q11) as well as the time between alert and the arrival of the tsunami (Q13) contribute most to F1 (Contr.= 0.2 and 0.17 respectively). The respondents who did not follow the instructions after receiving the SMS (Q14, Contr.= 0.36) and who did not identify actors involved in the tsunami alert process (Q11, Contr.= 0.29) contribute most to F2. F3 is derived from the contribution of Q13 (positive answers: Contr.= 0.23; negative answers: Contr.= 0.27), while Q14 mainly contributes to F4 (for positive answers: Contr.= 0.29 and negative answers: Contr.= 0.31).

The classification carried out with this second HAC also allows the identification of 4 classes (**Figure 11**). Group 1 consists of respondents who answered Q14 incorrectly (198 people out of the total sample size of 287) and Q12 incorrectly (198 out of 526). In addition, a significant proportion of 59% did not answer Q11 correctly (116 out of 366), while 56% answered Q13 incorrectly (109 out of 353). This group includes respondents who have a slight understanding of the warnings. Group 2 includes only respondents who gave incorrect answers to Q13 (167 out of 397) and Q12 (149 out of 526), while they should apply the instructions when receiving the SMS (149 out of 463). Group 3 includes most of the respondents who successfully answered Q13 (179 out of 397) and Q14 (179 out of 463), but also who did not answer Q12 correctly (179 out of 526). Finally, Group 4 includes 100% of those who answered Q12 correctly (224 out of 224) and 59% of those who answered Q11 correctly (133 out of 383). However, while most of the respondents in Group 4 showed accurate knowledge by answering both Q11 and Q12 correctly, it is worth noting that a significant proportion, 40.6%, also gave an incorrect answer to Q13 (91 out of 367). While the first MCA allows the identification of a group in which all respondents have positive intentions (Group 4), this second MCA highlights a class (Group 1) that has, in contrast, a very poor understanding of alert, both in terms of actors, procedures, timeframes and tools.

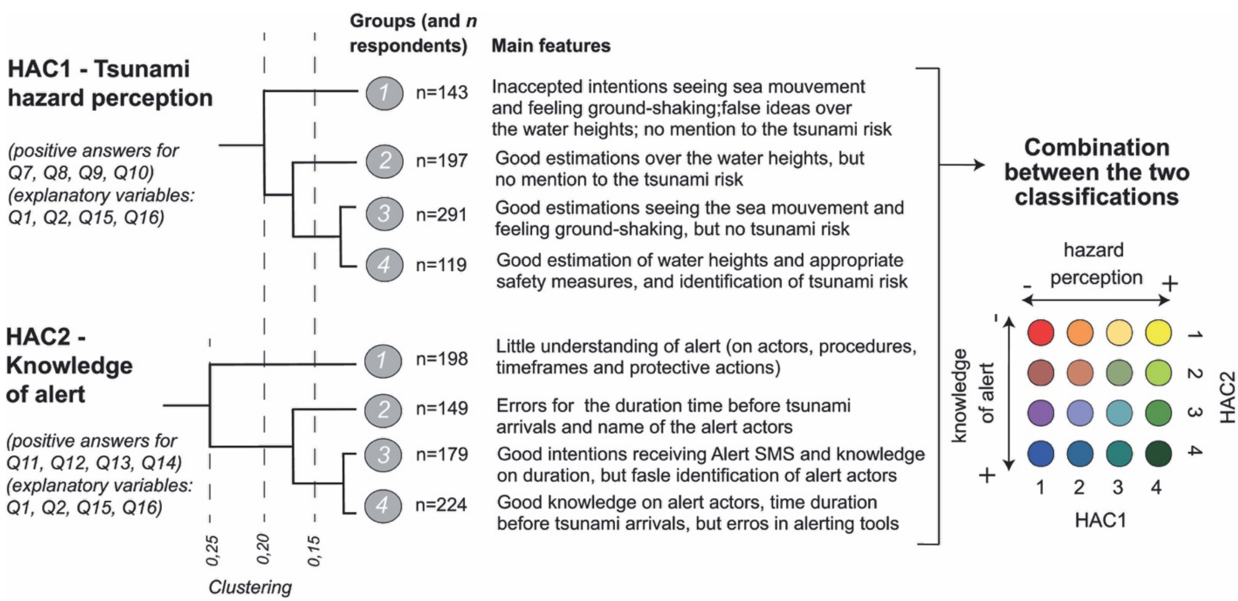

Figure 11: Association between the MCA-HAC and profiles' respondents, Copyright: the authors

Combining the distribution of the 150 respondents in each classification finally allows to have a synthetic overview for each of the municipalities, that we can then compare (**Figure 12**). In Bandol, a great majority of respondents present an average level for tsunami hazard perception and knowledge of alerts. In Cannes, there is a difference in the number of respondents possessing a more accurate knowledge of alerts, which is approximately twice as much than in Bandol. In Bastia, the number of respondents with low hazard perception is the lowest among the surveyed areas. In Six-Fours-Les-Plages and Sanary-sur-Mer, a scarce presence of moderate perspectives profiles, while notable differences set them apart from each other. Six-Fours-Les-Plages counts an equal number with low and high tsunami hazard perception profile, while in Sanary-sur-Mer, the balance shifts markedly in favor of the respondents endowed with a further knowledge of alert (50% of the respondents are in the Group 4). Last but not least, 75 and above are often joined in groups characterized by low perception and knowledge. It could be a problem, due to their low capacity (Arimura et al., 2020; Hall et al., 2022), and because most of them lived alone, and are less likely to be associated with disaster preparedness (Sun and Sun, 2019).

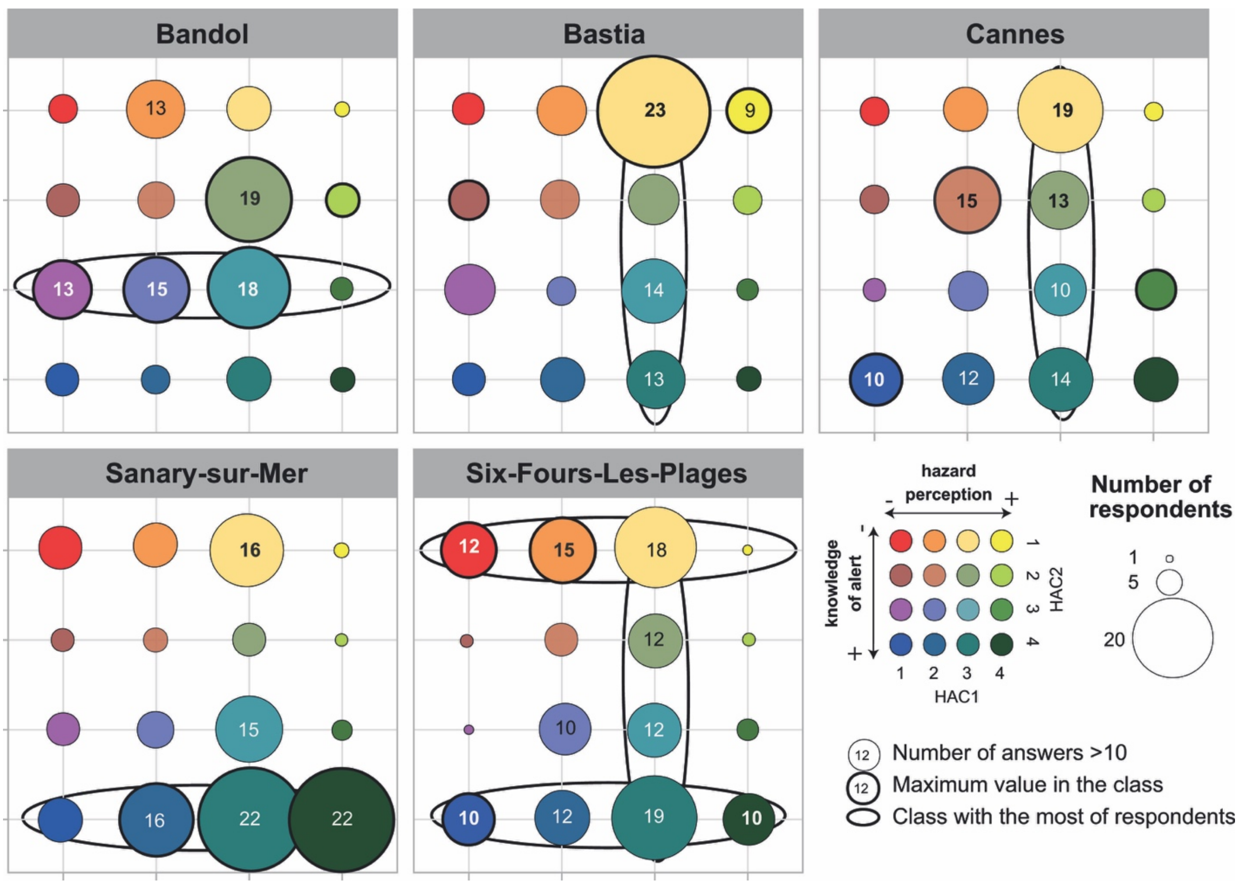

Figure 12: Results obtained in the five surveyed municipalities, Copyright: the authors

5. Discussion

5.1 Limitations

Methodologically, the face-to-face questionnaire is likely to introduce biases. This non-probabilistic approach is based on the availability, geographical proximity and willingness of participants to take part in a survey, rather than on well-defined statistical criteria (Cerase et al., 2019). Unfortunately, it does not guarantee the significance of the results (Etikan et al., 2016). The wording and order of questions can also play a role in the way respondents answer (Venkatesh and Davis, 1996). There is often a gap between declaration of intentions (*i.e.,* what individuals say they know how and what to do) and the actual behaviours they should take during real tsunamis or real alerts, as demonstrated in previous studies (*e.g.,* Weiss et al., 2011; Cugliairi et al., 2022; Ong et al., 2023). The period over which we collected the 750 questionnaires is also debatable. In Cannes, a storm caused significant flooding on 23 September 2019 (*i.e.,* 6 days before the first survey in this area), and sirens were activated, which may have affected the results. In Bastia where data were collected in October 2019, a false alarm for a tsunami occurred a few years ago in 2015, which can probably have changed the local people's awareness about this risk. However, data collected in this study allow us to answer the four initial hypothesis and open up discussions, especially when we compare the rate of correct answers with those calculated in other areas of the NEAMWTS region (Goeldner et al., 2017; Lavigne et al., 2017; Cerase et al., 2019; Cugliari et al., 2022).

5.2 Implications for research

This study first confirms that, as elsewhere and in similar proportion, the perception of the tsunami hazard is low. As relevant example, 23% of respondents in our sample incorrectly stated that possible run-up heights could be more than 10 metres, and this belief was closest to that reported in Heraklion, Greece (21%) or Tangiers, Morocco (19%). Videos, images or newspaper articles of catastrophic events such as the 2004 and 2011 events may explain this overestimation, rather than a realistic understanding of the tsunami processes (Rafliana et al., 2022, Cugliari et al., 2022). On the other hand, 22% of the respondents in our survey incorrectly stated that the time between a tsunami alert and its arrival could be less than 10 minutes, with a high proportion of the youngest, as proven in Heraklion (20%).

However, this study also shown significant differences, particularly when we look at the rate of correct answers estimated to certain questions. The proportion of respondents who indicated that possible run-up heights may exceed 10 meters is lower than in Italy (ranging from 31 to 41% in Cugliari et al., 2022), in Siracusa (34,5%), or in Sinès, Portugal (46% in Liotard et al., 2017). This result could be explained by the highest probability of violent earthquakes in Italy or Portugal (Cugliari et al., 2022), but also by the fact that no major and mediatised tsunami has happened before our data collection. On the other hand, the proportion of respondents who think that alerts may arrive between 10 to 30 minutes is lower in our study (18%) than in Heraklion (45%) or in Sinès (38%). We also postulate that the alert is considered to be short or too long, with no intermediate duration (Courteau, 2017), but this idea needs to be certified in future surveys. Moreover, the part of the respondents who do not know this time (21% in our study) is nearest in Tangiers or in Siracusa (23%), but higher than in Nice, Saint-Laurent-du-Var or Villefranche-sur-Mer (14%). No significant difference exists with the residency status and age, then we think here that the lack of recurrent campaign of information could explains this higher rate of wrong answers. The proportion of respondents who react seeing an anormal sea movement and feeling the ground shaking in the seafront is also lower in our survey (48% if we sum up the different protection actions) than in Sinès (91%, Liotard et al., 2017). This may be explained by the fact that the interviewers never mentioned the term "*tsunami*" starting the questionnaire. We also proposed various answers, that induces multiple choices and a cooling-off reflection for the respondents, or by the fact that we address questionnaires face-to-face and not using the internet.

Knowledge of alert is also not satisfying. In this study, authorities responsible of the '*upward alert*' are identified by only 29.2% of the respondents. Content of the SMS watch alert does not guarantee the appropriate reactions, as only 55.4% of the respondents declare going high ground, while it was clearly mentioned in the SMS message. Such SMS can even push people into a more dangerous situation, as 9% of the respondents declared they stay in place. Results obtained in the ASTARTE project were quite different, as 11% know who may alert the population, and 52% declare they may evacuate or go high ground if they receive a SMS watch alert. Lack of alert campaigns, both on national and local level, and the limited local initiatives about sensibilisation on tsunami may explain this weak knowledge. At the opposite, thanks to numerous campaigns on tsunami carried out since 2016 in Norway, half of the respondents correctly mentioned the text message warning on their phones as a way to receive an alert without questioning it or searching other sources of information (Goeldner-Gianella et al., 2017). Also, these results depend on the meaning of alert currently used locally and need to be replaced in the context when the study has been made. Thus, since we carried out our study, a new alerting tool name FR-Alert had been deployed in June 2022 in France using cell-broadcast technology (Bopp and Douvinet, 2021).

Another relevant finding in our survey is that most of the differences between respondents are explained by age, more than the residency status or gender (**RQ2**). As people get older, they seem more likely to react passively to the risk of a tsunami (Arimura et al, 2020). In addition, higher aging groups often tend to recognize subjective norms more than younger (Terumoto et al., 2022). In this study, we confirmed that the 75 years and above underestimate risk and alerts, confirming their vulnerability. The youngest seem to have better perceptions, and it is encouraging as they represent the future generations (Hall et al., 2022). However, this differs with a recent study in Cascadia that found that age was not significantly associated with earthquake and tsunami perception (Chen et al., 2021). On the other hand, gender or residency status do not play a key role, while females seem to be more likely to believe that they are susceptible to a tsunami in other studies (Hall et al., 2022).

5.3 Implications for practice

According to our results and the previous studies, there is a consistent effort to raise public awareness on tsunami hazard in NEAMWTS region. By evaluating the tsunami hazard perception and knowledge of alert, we suggest the municipalities may further communicate and inform on tsunamis. On the one hand, this study is struggling to be sustained (Rafliana et al., 2022), and additional efforts are required. On the other hand, developments could be thought so as to question new scientific fields on hazard perception (*e.g.,* the role and effects of social medias, the influence of social groups) and alert (*e.g.,* siren sound propagation, people receptivity to CB alerts). Such local knowledge can be shared to local authorities which can also find international support with UNESCO to organize events about tsunamis. The *International Oceanographic Commission* (ICG)/NEAMTWS has organized 4 regional tsunami exercises since 2012 and the NEAMWave23 is yet planned. These exercises are opportunities to maintain a high operational readiness, practice response protocols, and guarantee that crucial communication lines function smoothly (UNESCO, 2023). Communities can also apply to the "Tsunami Ready" program to prepare to face a tsunami. Several communities are on their way to obtain this recognition soon in the NEAMTWS region (*i.e.,* Cyprus, Egypt, Greece, Italy, Malta, Morocco, Portugal, Turkey, Israël and France). In Cannes, evacuation itineraries are physically marked along several places (beach exits, promenades, harbor area, roads) and equipped by many loud-speakers. Trials or current exercises may improve the perception, but actions should be combined and repeated to increase both the tsunami and alert perceptions. In Cannes, the tsunami risk perception is slightly higher than in other areas, but reciprocity with knowledge of alert is missing.

This sample also questions the evacuation from the tsunami zone (Wei et al., 2017; Hall et al., 2022), defined as the single effective response that can lead to safety (Goto et al., 2012). In this survey, 7.8% and 18.9% of the respondents respectively declare they shelter in a building or they do not leave if they feel ground shaking on the seafront, and 9.8% do not leave even if they see an anormal sea movement. In this case, if people go upstairs and follow signposts into the buildings, these actions seem coherent, and the vertical evacuation could then be included in plans (Rafiana et al., 2022). However, respecting the current legislation in France, we have not considered these answers as positive because such vertical safe zones in buildings needs to be 24h-7j accessible and to obey specific construction rules (*i.e.,* earthquake resistance or the venue capacity). By this way, as planning vertical evacuation is essential for low-lying areas subject to the risk of local tsunamis, we need to involve designating buildings and to clearly communicate on which buildings can be used for this (Hall et al., 2022). And a systematic evacuation could be not needed in these areas, as water heights are evaluated from 2 to 3 meters, and with a maximum of 5 meters.

6. Concluding remarks

This study offered the opportunity to question both tsunami hazard perception and knowledge of alert along the French Mediterranean coastlines. Results confirmed the tendency to underestimate tsunami hazard perception, as only 30.4% of the respondent correctly identified possible run-up heights, and 46.5% claimed to be able to take appropriate protective actions if they feel ground-shaking being on the seafront. Knowledge of alerting process is also unsatisfying, as only 38.1% of respondents correctly identified sirens as existing disseminators, and 29.4% correctly named mayors or prefectures as the alert senders. However, 65% declared they think going high ground or evacuate if they also see an anormal sea movement, and 55.7% said they would immediately think of going to higher ground when receiving a warning SMS. Age or location of respondents explain differences between the 5 municipalities, more than gender or residency status. This differs from previous surveys carried out in other areas located in the *North East Atlantic and the Mediterranean Tsunami Warning System* (NEAMTWS) region, and this confirms the existence of local effects. More surprisingly, the respondents who well perceive the tsunami hazard are not those who have a good knowledge of alerts, and the awareness actions do not really impact the tsunami knowledge we evaluated. Also, the results of this study could help local authorities to develop future tsunami awareness actions, and to determine more suitable strategies to be applied in the short term at local scales.

Interpreting reasons for explaining the local and site differences therefore remains challenging. Recent awareness initiatives and preparedness exercises in which authorities and, to some extent, the citizens of Sanary-sur-Mer participated could explain high rate of correct responses for alerts. Nevertheless, it is peculiar that they stand out so much from the neighbouring municipalities of Bandol and Six-Fours-les-Plages. Conversely, it is surprising that Cannes does not significantly distinguish itself from others, due to the involvement of the municipality in raising awareness of tsunami risk since 2019. One could argue that conducting the surveys in 2019 was not sufficient to have an observable effect on the population's perceptions. On the other hand, the recent deployment of Cell Broadcast (CB) alerts, since June 2022, offer a good opportunity to shorten time for alert diffusion, and increase the time for evacuation in the situation of a regional tsunamis in the French Mediterranean coastlines.

Data availability. The dataset generated for the present study is not publicly available because the questionnaire has not yet been administered in all French coastal areas, and the data are being further analyzed by the research team. However, data are available from the corresponding author on reasonable request.

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Appendixes

Appendix 1: Questionnaire (traduced in English for the paper; answers in grey colour)

Get to know the interviewee

Q1. Why are you here *(name of the municipality)*? *a) I work here* *b) I live there*

Q2. City of residence? *Free comments*

Q3. Location of residence (street name)? *Free comments*

Perception of risk existing in your municipality

Q4. What kind of risks can occur here? *a) Yes {list}* *b) No*

Q5. Do you think you could be affected here by natural risks? *a) Yes (risk?) {list}* *b) No*

Q6. How might you be alerted face these risks? *a) Risk {list}* *b) Way to receive alert: {list}*

Tsunami hazard perception

Q7. How should you react if you are on the seafront and feel ground shaking? *Free comments*

Q8. How should you react if you feel ground shaking and see a sea movement? *Free comments*

Q9. Do you know the maximum levels that should take inundation here during a tsunami? *{list}*

a) 0-1m *b) 1-2m* *c) 2-5m* *d)5-10m* *e)10m* *f) I don't know*

Q10. What could be the impact of a tsunami here or the municipality? *Free comments*

Knowledge of alert

Q11. How might you be alerted in the situation of a tsunami? *Free comments*

Q12. Who may alert you? *Free comments*

Q13. According to you, how much time there is between a tsunami alert and its local arrival? *{list}*

a) <10min *b) 10-20min* *c) 30min-1hr* *d) 1-5hr* *e) 5-24ha.* *f) >24ha* *g) I don't know*

Q14. Imagine you are in the seafront and receive the following SMS "*Tsunami alert! Move away from the seafront and go high ground*" What would you think to do first? *{list}*

a) *"I don't feel in danger, I am continuing my activities"* *b) "I immediately go to high ground"*

c) "I verify the information" *d) "I inform people around me"*

e) "I inform my family and my friends" *f) "I gather my important belongings and evacuate my home/work/seaside"*

g) "I collect my kids at school first" *h) "I try to go upstairs in the first building around me to shelter"*

Socio-demographic variables

Q15. What is your gender? *{list}* *a) Male* *b) Female* *c) Other* *d) I don't want to answer*

Q16. How old are you*?* *{list}* *a) 0-14y* *b) 15-29y* *c) 30-44y* *d)45-59y* *e)60-74y* *f) >75y*

Q17. Do you have any questions or remarks, or do you need information on tsunamis? *Free comments*