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Tsunami risk perception, a state-of-the-art review with a focus in the NEAM region

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Large-scale coastal urban sprawl, development of tourist accommodations and industrial maritime poles have highly increased the tsunami risk to people living and/or traveling along the coasts of our planet. The disastrous tsunamis in the Indian Ocean (2004) and in the Pacific Ocean (2011), as well as a suite of other damaging events worldwide, have encouraged International Institutions, first of all UNESCO Intergovernmental Oceanographic Commission, National Governments and Local Communities to implement Tsunami Warning Systems (TWS), to raise awareness on tsunami risk, and to create a multilevel risk governance. In this framework, research on tsunami risk perception plays a key role. The results of these studies should be taken into account in designing risk mitigation programs and tools (such as drills, activities with local communities, emergency plans, *etc.*). This paper presents a review of such studies, carried out in several countries worldwide through many thousands of interviews performed with different techniques. Most tsunami risk perception studies were carried out in the regions where the Indian Ocean Tsunami Warning System and the Pacific Ocean one (PTWS) operate. In the NEAMTWS (North-East Atlantic, Mediterranean and connected seas Tsunami Warning Systems) region, only few specific studies were conducted, mostly within the EU-funded ASTARTE project (2013–2017) and more recently in a few extensive surveys on tsunami risk perception conducted in Italy between 2019 and 2021. Although the twenty-three studies analyzed in our review show a strong heterogeneity of methodological approaches and population samples, they allow us to outline some general considerations on tsunami risk as perceived by people in the different regions of the world. With the help of a table, we schematically summarized the emerging strengths, weaknesses and lessons learned in the twenty-three papers, noting an increase in the number of such studies in the last 5 years. The surveys were mostly concentrated in high-risk areas and focused on local residents. Some differences emerged depending on the memory of past tsunamis, education level, and local cultures. This provides useful hints for sound citizen-based tsunami risk reduction actions, including improved risk communication aimed at increasing the resilience of tsunami-prone populations. The need for increasing the assessment of tourists' tsunami risk perception, and for a more homogeneous survey strategy also emerge from our analysis.

KEYWORDS

tsunami risk, perception, communication, preparedness, awareness, Europe, neam, social science

1 Introduction

Tsunami risk is one of the most difficult risks to communicate and to deal with, for several reasons. The basic reason is that tsunamis are infrequent phenomena, and therefore citizens, local authorities, journalists, have a very limited knowledge of them. Even in the regions with the highest tsunami hazard worldwide, the recurrence of large, damaging tsunamis is low in comparison to other risks such as those related to extreme weather, forest fires, earthquakes. With a few exceptions, time intervals of damaging tsunamis in a specific coastal region of the world are of several decades, or even centuries. In the NEAM region (North East Atlantic, Mediterranean and connected seas), the occurrence of widely destructive tsunamis is very infrequent, and the latest of them date back to several decades.

Contrary to volcanic eruptions, landslides, earthquakes, storms, which affect mostly local communities, tsunamis can also spread their effects for hundreds to thousands of kilometers, also affecting people and countries very distant from the event origin point, and in areas where limited or no precursory signs of the incoming waves have been observed.

Another reason contributing to underrating the tsunami risk is the general belief that "small" tsunamis are not really dangerous. People often tend to identify the tsunami risk with the huge waves that occurred in Sumatra in 2004 or in Japan in 2011, while the occurrence of less relevant tsunamis (with one–2 m of runup) is neglected, even if these are by far more likely to occur than the abovementioned ones (Alam, 2016; Aytore et al., 2016; Constantin et al., 2017; Goeldner-Gianella et al., 2017; Cerase et al., 2019; Hall et al., 2019).

On the other hand, tsunami risk is also one such risk whose effects can be reduced more easily, at least those related to people's lives. Informed behaviors, like recognizing natural warning signs, knowing inundation areas and escape routes to reach high ground, recognizing official alert signs and sounds, *etc.*, are often sufficient to save lives. The same cannot be said for instance for seismic risk, that needs enforcing proper building codes, long times, and conspicuous funding to be reduced.

For the reasons above, it is extremely important to understand people's level of understanding and awareness of this risk, in order to define the best strategy for communication and prevention campaigns. With this goal, many studies on tsunami risk perception have been carried out in the past in several regions of the world. However, a comprehensive review that could allow a comparative analysis and define some common strategy for risk communication, is still missing.

The Centro Allerta Tsunami of the National Institute of Geophysics and Volcanology (CAT-INGV) operates as Tsunami National Warning Center (TNWC) for Italy, and as Tsunami Service Provider (TSP) within the ICG/NEAMTWS (Intergovernmental Coordination Group for North-Eastern Atlantic, Mediterranean and connected seas Tsunami Warning System), one of the four ICGs coordinated by UNESCO-IOC worldwide (UNESCO-IOC, 2015; UNESCO-IOC, 2017a; UNESCO-IOC, 2017b; Valbonesi et al., 2019; Amato, 2020; UNESCO-IOC, 2020; Amato et al., 2021; Basili et al., 2021). As such, its focus is on the NEAM region, which has similarities with, and differences from the other ICGs. Differently from the Pacific and the Indian oceans, where several countries facing the oceans have been hit by destructive tsunamis in the past few decades (like Japan, Indonesia, Thailand, Chile, United States, India, *etc.*), no large tsunamis have hit the Mediterranean or the Eastern Atlantic countries for more than half a century, and we have to go back to more than a century ago in the historical catalogs to find such a destructive event. In the XX and XXI centuries, the largest tsunami events in the Mediterranean occurred in Italy (Messina–Reggio Calabria, 1908) and in Greece (Amorgos, 1956). For the former event, it seems that its memory is still present among people living in the area, despite the long time elapsed, and this is important for defining a risk communication strategy. For many other regions in Italy, Greece, and other Mediterranean countries, the time distance from past tsunami events is so big that the risk perception is likely very low, and this poses a serious problem for risk communication.

Furthermore, due to the low frequency, scarcity of data, and complexity of the phenomenon, tsunami hazard and risk assessment are affected by a strong component of uncertainty, that also influences people's perception and risk communication (see e.g., Behrens et al., 2021; Lorito et al., 2022; Rafliana et al., 2022).

2 Risk perception, theoretical reference

Risk perception research is based on a multidimensional approach aimed at investigating the way individual and social factors shape intuitive risk judgments on which the majority of citizens rely on (Slovic, 1987; Wildavsky and Dake, 1990; Slovic, 2000; Rippl, 2002; Botterill and Mazur, 2004). This premise makes it clear how difficult and variable a risk perception analysis is. Risk perception studies, dealing with either natural or anthropogenic risks, are based on two main approaches: psychological and socio-cultural.

The psychological approach aims at producing general models of explanation of manifest behavior, attitudes, emotions and beliefs of individuals facing risks, focusing on perceptual processes and how they influence decision-making, attributing a priority value to cognitive processes and individuals' psychological dispositions (Weinstein, 1989; Cerase, 2017; Chionis and Karanikas, 2022).

The sociocultural approach (see, e.g., Douglas and Wildavsky, 1982; Lupton, 1999; Lupton, 2006), highlights

the close connection between social structure in which individuals are embedded and their values, attitudes, and worldviews through which (whereby) people define and organize their knowledge of the world (Bradbury, 1989; Renn, 1992; Renn, 1998; Rosa, 1998; Lupton, 1999). Hence, social and institutional factors interacting with each other within a wide set of communication processes which take place through formal and informal channels (Renn, 1990; Renn, 2011). This means that individual risk perception, and hence, response to hazards, are affected by social influence exerted by the individual's surrounding context. The influence of sociocultural contexts on risk perception and disaster response has been stressed in countless anthropological and sociological studies within technological and natural hazard subfields (see, e.g., Krimsky and Golding, 1992; Tansey and O'Riordan, 1999; Boholm, 2003; Casimir, 2008; Tulloch, 2008; Zinn, 2009; Van Loon, 2013).

From here is defined that, risk perception is not a fully objective dimension; instead, risk is also a social construct: "what we measure, identify and manage as risks are always constituted *via* preexisting knowledges and discourses" that are strictly bound to the sociocultural contexts in which these understandings are generated (Lupton, 1999).

The term "risk," in the natural sciences, usually refers to an ontological–observer-independent–reality; a product of probability of an event and the resulting damage.

Therefore, risk perception patterns and the ways in which risks and disasters are managed are the results of social and cultural influences within different groups sharing common cultural values, moral principles and world views. Consequently, risks–and disasters–related notions may vary in time and space: what is considered a risk in a given era and place may no longer be seen so in a later period of time or in a different location (Tulloch, 2008; Field et al., 2012). Therefore, the mechanisms of individual risk elaboration strictly depend on reference social models and context; they are also moderated and filtered by the media that play an active role in the whole process.

As a consequence, while some risks with high probabilities and strong physical impact tend to be downplayed or neglected, some other risks with minor physical consequences may trigger strong public concerns and produce severe social impacts (Kasperson et al., 1998; Kasperson et al., 2003). Risk perception studies are deemed helpful to highlight and clarify what are the psychological conditions and sociocultural processes by which some of these risks are underrated whilst others are overestimated.

Susanna Hertrich's illustration (2008) graphically represents perceived risks as opposed to actual risks (Figure 1). Observing it, one can easily understand that risk perception is an extremely variable dimension influenced by both probability and severity of damages.

Risk perception is definitely a relevant issue for tsunami risk reduction. The way tsunami risk is perceived and understood may explain relevant differences in resilience and preparedness, both factors contributing to the different responsiveness of local communities (UNISDR, 2015).

This review is intended to trace back and analyze, in a simple way, several studies on tsunami risk perception that have been carried out in recent years. According to the very general definition

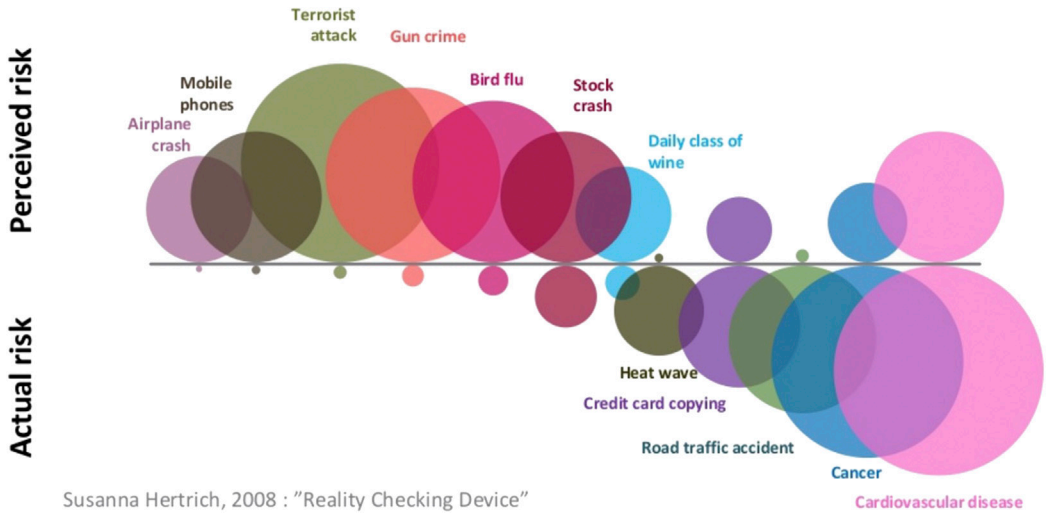

FIGURE 1
Comparison among different estimated vs. perceived risks. The circles' size below and above the horizontal axis are proportional to the "real" risk (estimated on a statistical basis) and the perceived one (estimated from perception studies), respectively. Modified from: *Risk perception and actual risk*. Image by Susanna Hertrich (2008) (based on the work of Dr Peter M. Sandman).

provided by the Royal Society, risk perception "involves people's beliefs, attitudes, judgements and feelings, as well as the wider social or cultural values and dispositions that people adopt, towards hazards and their benefits' where hazards were regarded as "threats to people and the things they value" (Pidgeon et al., 1992). The way risk is perceived by individuals and communities is held to be a relevant explanatory factor to forecast effectiveness of risk mitigation behaviors and possible impacts on a given socio-natural context (Lupton and Tulloch, 2003). "The understanding of risk perception is relevant to hazard prevention, risk management and safety enhancement in several ways" (Renn and Rohrmann, 2000; Rohrmann, 2000). However, risk is a multidimensional concept that cannot be synthesized into a single analysis model and theory (Tulloch, 2008). Hence, different disciplines studying the interaction between people and their context such as psychology, sociology, cultural anthropology and ethics are directly involved in studies on risk perception (Fischhoff et al., 1993).

3 Studies on tsunami risk perception

Tsunamis can cause casualties, along with property, infrastructure, agriculture and the environment destruction at a local, regional or global level. These phenomena are utmost elusive and highly challenging for risk perception scholars due their special characteristic such as low frequency, high uncertainty, non-linearity, extreme variability of impacts and the multiplicity of physical cause that might trigger one or more tsunamis (namely earthquakes, submarine landslide, volcanic eruption and even meteorological phenomena). These variables make it particularly difficult to address the way these phenomena are perceived and understood both at individual and societal level. These characteristics discouraged risk perception studies until the 2004 Sumatra Tsunami, where the unbearable burden of the 250.000 victims sparked a new interest in tsunami risk perception studies, aimed at improving both risk communication and the effectiveness of mitigation measures to reduce tsunami risk.

However, tsunamis' low frequency of occurrence does not reduce their destructive potential. Moreover, how important it is to study people's perceptions of natural hazards (Bonaiuto et al., 2016; Wachinger et al., 2013; Paton et al., 2009; Lindell et al., 2011), particularly tsunami risk perceptions, emerges in various studies conducted in at-risk countries that were affected by tsunamis, such as for example, the 2004 Indian Ocean tsunami or the 2011 Japan tsunami (Kurita et al., 2007; Sugimoto et al., 2010; Alam, 2016; Arias, et al., 2017; Akbar et al., 2020).

The primary goal of multidisciplinary paradigms underpinning risk perception research is to get a comprehensive understanding of the phenomena, also tackling fragmentary explanations and poor assessment of complex interactions between psychological, sociological, cultural and political dimensions of tsunami risk perception.

In this regard, this literature review compares research carried out in different geographical areas (from Oregon to Japan, through New Zealand and from Bangladesh to Australia and Europe) focusing on the population at tsunami risk.

Therefore, although the articles described in this study analyze people's perception of tsunami risk from various perspectives and methodologies, our review does not have an evaluative purpose, rather it aims to possibly provide an overview of the present literature to propose new study insights and data gaps.

Besides the suite of papers focused on the assessment of risk perception that we describe in this review, several other studies were carried out in the last 15 years, that deal with tsunami risk from the perspectives of preparedness, knowledge, awareness, evacuation, local culture traits, attitudes and practices in use in different regions (e.g., Paton et al., 2008; Achuthan, 2009; Paton et al., 2009; Bird et al., 2011; Goto et al., 2012; Esteban et al., 2013; Kanhai et al., 2016; Nakasu et al., 2018; Makinoshima et al., 2020; Martinez and Toulkeridis, 2020; Sutton et al., 2020; Tanner and Reynolds, 2020; Bailey and Mahutonga, 2021; Hawthorn et al., 2021; Lindell et al., 2022). However, we do not include these papers in our analysis as they are out of our review focus.

We have analyzed a total of twenty-three papers published on peer-reviewed scientific journals: seven in the Indian Ocean area, ten in the Pacific Ocean area and six in the Mediterranean area.

All the twenty-three papers analyzed here were published after the 2004 Sumatra tsunami, but mostly appeared in the last 5 years (see Figure 2).

The emerging highlights in the reviewed papers are addressed using a table of analysis which examines *strengths, weaknesses and lessons learned* from past events.

4 A meta-review of tsunami risk perception surveys and studies

As explained in the introduction, this meta-review aims to provide access to recent surveys on tsunami risk perception in several geographical areas that present significant differences (geomorphological, demographic, cultural, political, economic, and consequently have different levels of vulnerability) and to provide some insights on current directions in tsunami risk perception studies and their possible contributions to improve our understanding of social response to tsunami, thus improving risk governance. This required a great synthesis of the surveyed texts and, to facilitate the reading and the purpose of the work, just the core of each survey was extrapolated.

This paper examines twenty-three studies that we describe below, following the IOC-UNESCO worldwide organization of Tsunami Warning System ICGs,:

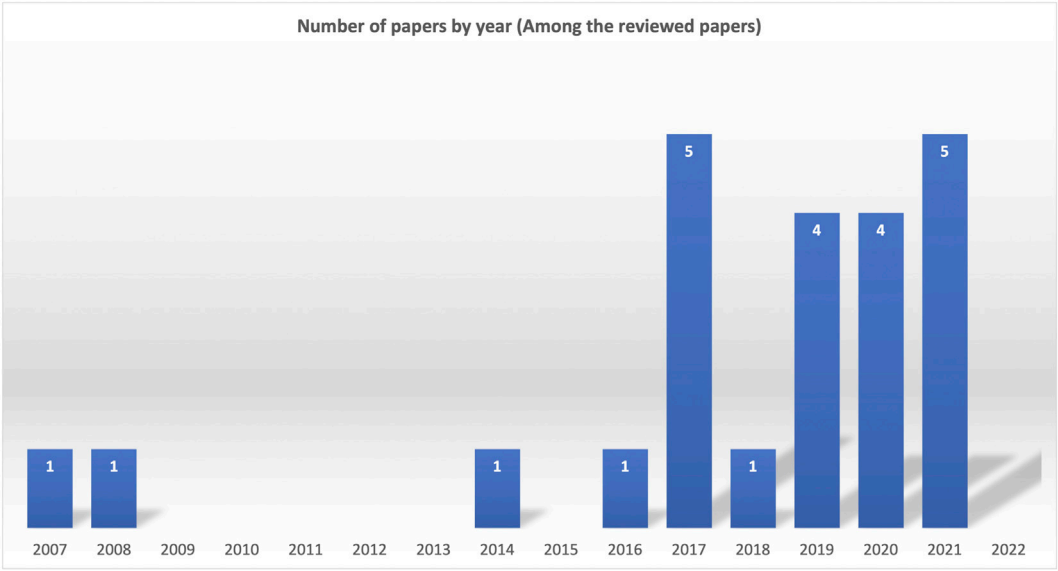

FIGURE 2
Number of reviewed papers by publication year.

- Seven surveys with focus on the Indian Ocean (IOTWS)
- Ten surveys with focus on the Pacific Ocean (PTWS)
- Six surveys with focus on the Mediterranean Sea (NEAMTWS)

The papers were selected by web search keywords by entering: Tsunami Risk Perception + the ICG competence area. The strictness of the search criteria did not allow the introduction of papers addressing perception from a multi-risk perspective or similar. In the following section, for each study we describe the basic elements and the main results, trying to retrieve the most relevant features and to identify common elements and differences.

4.1 Surveys conducted in the Indian Ocean–IOTWS

4.1.1 Regional characteristics of tsunami risk perception among the tsunami affected countries in the Indian Ocean

Study location: This study by Kurita et al. (2007) was conducted in Indonesia, Sri Lanka and the Maldives (Indian Ocean) which in 2004 were catastrophically damaged by the Indian Ocean tsunami (Kurita et al., 2007, Journal of Natural Disaster Science).

Tsunami local history: In Indonesia since 2000 to date (2022), there have been nine disastrous tsunamis that caused more than 173,000 casualties. The major tsunamis that affected Sri Lanka are 4 (1883, 1907, 2004 and 2005) with more than 35,300 casualties. The Maldives was recently affected by the 2004 tsunami that caused 82 fatalities and 24 missing (NCEI/WDS, 2022).

Sample and methods: The survey aims to study the tsunami risk perception among residents, students, teachers and government officials using a structured questionnaire trying to fill the gap in comparative studies among different areas affected by the 2004 tsunami.

The survey was conducted in different months of 2005 and collected around 1,000 interviews in each of the three countries above. The participants were selected by dividing the coastal zones and the questionnaire was randomly administered using an interview-style method. The local surveyors visited people at home, questioned them, and then recorded their answers on questionnaire forms.

Main results:

- A lack of prior knowledge concerning tsunamis among residents was a common trait in all three countries.
- Many residents in Indonesia indicated that the damage would not have been reduced, even had they been equipped with such knowledge in advance due to the extreme proximity to the tsunami source giving residents little time to evacuate.
- Respondents in Indonesia and Maldives answered that they would prefer to receive alerts through TV while in Sri Lanka respondents would like to be directly informed by their families and neighbors.

The paper includes some results from data collected in Simeulue Island where factors such as historical memory and conscious behaviors dramatically helped to reduce tsunami deaths. Reliance on oral transmission among Simeulue Islanders produced a contrasting result: most respondents said there was no need to introduce disaster education in schools. Conversely, in Nias Island, where the loss of life was much greater than in Simeulue, residents preferred that disaster education be introduced in schools.

Brief conclusion: The survey results show that both Indonesia, Sri Lanka residents and the government officials confirm how important it is to improve tsunami knowledge, receive adequate information about tsunamis, and to carry out evacuation activities supported by early warning systems.

4.1.2 Tsunami knowledge, information sources, and evacuation intentions among tourists in Bali, Indonesia

Study location: The survey assesses, through a multidisciplinary approach, the tsunami risk perception, knowledge, and evacuation intentions among tourists in Bali, Indonesia (Hall et al., 2019, Journal of Coastal Conservation).

Tsunami local history: Since 1900, the island of Bali experienced 5 moderate-sized earthquake induced tsunamis (in 1917, 1985, and three in 2018) and two volcanic eruption induced tsunamis (NCEI/WDS, 2022).

Sample and methods: The first part of the paper comprehensively reviews the existing literature on tourism managers' perceptions of natural hazards and tourists' expectations of tour operators. The survey on tourists' assessment of tsunami risk perception, perception of tsunami causes, tsunami knowledge sources, and evacuation intentions was developed with a pen/paper questionnaire.

Main results: Among the survey results, it is worth noting that:

- Most of the respondents reported that they had not learned about tsunamis while traveling to and within Indonesia.
- More than half of the respondents know about tsunamis through the media.
- Three-quarters of the respondents correctly believe earthquakes can cause tsunamis.
- Almost all participants said they would run to higher ground if a tsunami were approaching.

The results also show a higher time expectancy for evacuation. The model considered in the paper (Titov et al., 2011) shows that the time frame for an evacuation would be much shorter than tourists imagine.

Brief conclusion: The authors, concluding their analysis, note the lack of tsunami knowledge on about 3/4 of respondents traveling to Indonesia. Few of them claim to have learned information from the appropriate signs and even less from tour operators, reading material provided in travel, hotels or airports. Results suggest a need for education through channels more used by tourists in which simple explanations on correct behaviors in case of earthquakes should be provided.

4.1.3 Disaster Risk perception and household disaster preparedness: Lessons learned from tsunami in Banten

Study location: The survey has been carried out in the Pandeglang Banten coastal areas, Indonesia, which directly experienced the catastrophic Banten tsunami (Akbar et al., 2020, IOP Conference Series: Earth and Environmental Science).

Tsunami local history: The study area has been affected by many tsunamis throughout history. Most of them, especially recent tsunamis, were generated by volcanic eruptions or landslides (aerial or submarines) as the 2018 tsunami caused by the Anak Krakatau volcano eruption (NCEI/WDS, 2022).

Sample and methods: To develop the questionnaire items, the authors started with the dimensions used in two survey instruments: the Risk Perception Belief for disaster measurement (NSHRP) developed in 2012 by Yong (published in 2017), and disaster preparedness through a survey instrument used by the Indonesian Institute of Sciences (LIPI) and shared by UNESCO.

A structured Likert scale-based questionnaire with six response grades was administered for the survey. The questionnaire was administered to a non-probabilistic sample of 174 people living on the coast of Sumur district.

Main results: Survey results show a positive correlation between disaster risk perception and disaster preparedness. Data analysis also indicates that about three-quarters of households have good disaster preparedness, and the entire sample has a very good perception of risk.

Brief conclusion: The authors conclude their analysis noting that Pandeglang's families have a high perception of natural hazards in their area. This impacts their responsibilities, behavioral control, acceptance of living in an area prone to natural hazards and encourages communities to increase their preparedness and resilience.

4.1.4 Tsunami awareness and evacuation behaviour during the 2018 Sulawesi earthquake tsunami

Study location: The survey was conducted on the coastline of Palu City and Donggala Regency in the Sulawesi district of Indonesia after the 28 September 2018 Sulawesi earthquake and tsunami (Harnantyari et al., 2020, International Journal of Disaster Risk Reduction).

Tsunami local history: Sulawesi district has a long historical background of tsunamis. Since 1900 there have been 10 such events, eight of which were caused by strong earthquakes and two by volcanic eruptions (which occurred in 1918 and 1919). Of

these, the 2018 tsunami caused the largest number of casualties and extensive damage (NCEI/WDS, 2022).

Sample and methods: The paper-based questionnaire was administered in the Palu and Donggala Regency residential area about 1 month after the event, between October 27th and 31st, 2018, concentrating interviews on the coastline of Palu City and Donggala Regency. 200 paper/pen questionnaires have been collected, following the same format of Chile and Indonesia research (Esteban et al., 2013).

Main results: All respondents (100%) are aware that they live in a tsunami risk area, this can be associated with recent tsunami experience, particularly the one of the 2004 Indian Ocean tsunami.

- Most respondents know that a strong earthquake could anticipate a tsunami.
- Most respondents answered that during the 2018 tsunami they evacuated because they saw someone else was evacuating.
- A lower percentage say they evacuated after they felt the strong earthquake.

Brief conclusion: The authors conclude their analysis noting that younger people have a lower tsunami risk perception, so education for action during an emergency needs to be increased. They also highlight the key role of social media in accelerating emergency communication. To some extent, this compensated for the lack of rapid official alerting. They also highlight the lack of effective evacuation plans and clear evacuation routes, that created congestion during evacuation.

4.1.5 Earthquake and tsunami knowledge, Risk perception and preparedness in SE Bangladesh

Study location: The study conducted by Alam (2016) explored the perception and preparedness for earthquake and tsunami risk in SE Bangladesh, including Chittagong city, the second largest city in Bangladesh with more than 6 million people.

Tsunami local history: Bangladesh has been affected by two major tsunamis: the 1762 tsunami, due to a strong earthquake in the northern Bay of Bengal, and the 2004 tsunami that caused two fatalities (NCEI/WDS, 2022) (Alam, 2016, Journal of Geography & Natural Disasters).

Sample and methods: The survey was carried out using different tools within a mixed methods approach: questionnaire; Focus Group Discussion (FGDs); informal interview for deeper understanding about general hazard perception and knowledge.

The survey consisted of two phases: the first cognitive phase, in which the lead author informally interviewed residents to structure the second survey phase.

The second survey phase included: twenty-five in-depth household interviews (15 male and 10 female) as they play the main role in economic activities and disaster response processes. Twenty informal interviews were conducted involving people indicated by local people as educated and influential respondents who better know about earthquakes and tsunamis. Five Focus Groups, two in each location with equal numbers of males and females in each group and with age over twenty-five were randomly selected.

Main results: Among the most interesting results are to be noted:

- Respondents show a widespread lack of knowledge about tsunamis. They also do not remember any damage or casualties caused by tsunamis or earthquakes.
- Low perception of risk and subsequent lack of preparedness to deal with these types of events.
- Lack of direct experience with earthquakes and tsunamis and more attitude to face more frequent hazards like tropical cyclones emerges both in focus groups and in the interviews.
- Lack of government and NGOs disaster risk reduction strategies for earthquakes and tsunamis.

Brief conclusion: The survey results show that people are aware of the low frequency of occurrence of earthquakes and tsunamis in their area and they have no recent experience with them. Therefore, they do not consider themselves personally at risk. Their faith in Allah increases fatalism, which leads them to not adopt proactive behaviors.

4.1.6 People's risk perception of tsunami hazard in a developing district of Balochistan, Pakistan: The case of Gwadar

Study location: The survey was conducted in Gwadar, a district of Balochistan in Pakistan (Mengal et al., 2020, Pakistan Geographical Review).

Tsunami local history: Pakistan was affected by strong earthquakes generated along the Makran Subduction Zone, off the southern coasts of Iran and Pakistan. Since 1900, the area has been affected by two strong earthquakes that have generated tsunamis. The largest being the 1945 event that caused about 4,000 casualties by both earthquake and tsunami (NCEI/WDS, 2022).

Sample and methods: The questionnaire used by Mengal is based on approaches adopted in similar studies conducted by Bird and Dominey-Howes (2008). In addition to the socio-demographic section, the questionnaire contains a section to study aspects of tsunami disaster management and to survey the emotional responses of the indigenous population living in Gwadar district. The survey collected 264 questionnaires administered by telephone and e-mail.

Main results:

- The interviewees, on average, show a high tsunami risk perception and are aware of the possibility that Gwadar district may be affected by a tsunami.
- Most of the respondents access disaster information preferably on their mobile phones, secondarily by TV, newspapers, internet, and lastly radio.
- A high percentage of respondents say that an earthquake may be the major cause of a tsunami. Few of them say a tsunami can be generated by landslides or volcanic eruptions.
- Most respondents cite mortality and human injury as among the major effects of a tsunami and imagine that their shores could be hit by tsunami with run-ups greater than 2 m and mostly between 5 and 10 m.

Brief conclusion: Since this is the first study on the topic done in the area, the survey aims to give a broad overview of tsunami risk perception in Gwadar due to the exposure of the area to tsunami hazard. The survey also aims to facilitate the creation of risk mitigation policies and management plans that can be implemented and easily used by the population.

4.1.7 Knowledge, awareness, and attitudes toward tsunamis: A local survey in the southern coast of Iran

Study location: The study carried out by the authors surveys respondents' knowledge, awareness, and attitudes toward a tsunami in four cities located in the Gulf of Oman in southern Iran: Chabahar, Konarak, Tis and Ramin (Salah and Sasaki, 2021, Sustainability).

Tsunami local history: Historically Iran has been affected by tsunamis generated in the Makran subduction zone but in the last 75 years no major events were recorded. Since 1945 there have been four minor events (1945, 1990, 2004 and 2017) the last of which was a meteo-tsunami. For the previous events, no casualties were recorded and damage was contained (NCEI/WDS, 2022).

Sample and methods: The survey uses a mixed method approach consisting of questionnaires, interviews among residents and beach users, and focus groups based on questionnaire results. In Chabahar city, 153 questionnaires were collected using random methodology (in densely populated areas). In Konarak city, 45 questionnaires were collected by locating inhabitants living in the tsunami-prone area by GPS method. In Ramin and Tis cities, 24 face-to-face interviews were surveyed. The 3 focus groups were conducted in fishing ports involving fishermen and beach-users.

Main results: The survey shows widespread low tsunami risk awareness among those who have basic knowledge of tsunamis. Lack of awareness and risk perception are associated by the authors with:

- Lack of information and absence of evacuation maps.
- Citizens did not receive or hear information about tsunamis from local government and other territorial agencies (NGOs, emergency department, local disaster management authority)
- Absence of community education programs.

Brief conclusion: In conclusion, the work shows a lack of trust in institutions, civil protection and warning systems increasing the vulnerability of the areas. According to the authors, such a lack of trust is associated with religious differences.

4.2 Surveys conducted in the Pacific Ocean (PTWS)

4.2.1 Testing the use of a "questionnaire survey instrument" to investigate public perceptions of tsunami hazard and risk in Sydney, Australia

Study location: The questionnaire administration was conducted in Sydney, Australia (Bird and Dominey-Howes, 2008, Natural Hazards).

Tsunami local history: Sydney city and Australia more generally are affected by many seismic sources surrounding it, capable of generating strong earthquakes and tsunamis. From 1900 to the present, Sydney tide gauges detected sea level changes for the 1960 Chile tsunami (for which historical sources report: Slight to moderate damage to boats in harbours at Evans Head, Newcastle, Sydney and Eden) and the 2011 Japan tsunami (for which, unusual currents have been observed in Sydney Harbor and Kembla) (NCEI/WDS, 2022; http://www.bom.gov.au/, last accessed on October 2022).

Sample and methods: The questionnaire was administered face-to-face to 30 participants and was also administered to a "captive group" consisting of environmental experts, engineers and insurers who deal with the risks, in order to have an experienced counterpart. The snowball sampling technique is used to obtain participants through the recommendation of other participants (Atkinson and Flint, 2001), which guarantees that all respondents are interested in the topic. The authors note that the survey tool developed is a baseline that must be implemented as needed, and in the article they suggest useful insights for the proper achievement of survey objectives.

Main results:

- Most respondents have heard about tsunamis before the Indian Ocean event (2004) even if they do not show scientifically in-depth knowledge of the phenomenon.
- All the respondents claim that earthquakes are the major cause of tsunamis followed by underwater volcanic eruptions.
- Most respondents say Sydney could be hit by a tsunami but few remember the last tsunami that affected the city.

Brief conclusion: The questionnaire implemented by the authors to study the tsunami risk perception shows to be an effective survey tool for those who want to deepen their knowledge and perception of tsunami risk perception in a study area. It is also an effective tool for collecting population data before implementing communication strategies and policies for tsunami risk mitigation. Moreover, this survey tool could be adapted to different contexts. They also recommend that the questionnaire should be integrated with in-depth interviews for better information and qualitative opinions from the population.

4.2.2 Tsunami risk perception and preparedness on the east coast of New Zealand during the 2009 Samoan tsunami warning

Study location: The survey was conducted in Tairua and Pauanui, on the east coast of New Zealand (Couling, 2014, Natural Hazards).

Tsunami local history: New Zealand is susceptible to being hit by tsunamis generated in different regions. Since 1900, 15 tsunamis have impacted New Zealand's coastlines. None of these have resulted in casualties but several damages have been recorded (NCEI/WDS, 2022).

Sample and methods: Qualitative data were collected using face-to-face interviews to produce the fullest possible description of evacuated residents. Participants were fifteen, selected using the snowball technique: nine females and six males, with an age ranging from early thirties to the eldest participants who were 95 years old.

Main results:

- Tsunami risk perception is generally very low or nonexistent ("the risk does not exist").
- Lack of knowledge of the natural signs of a tsunami and a lack of communication between the Ministry of Civil Defense and Emergency Management (2010) in New Zealand and citizens are evident.
- The respondents know that they must move to a high place if they receive a tsunami warning, but they do not know the phenomenon.
- Interviews also show that the population would not adopt a rapid evacuation for the reasons written above and because of low tsunami risk perception. Moreover, during the 2009 tsunami alert, there was a lot of traffic on Pauanui's main street, suggesting that residents wrongly thought they would run away with their vehicles.

Brief conclusion: The authors report that good communication between the institutions and the community is needed; in addition, the government must consider the official use of redundant communication methods that reach the population directly.

4.2.3 The low-likelihood challenge: Risk perception and the use of risk modelling for destructive tsunami policy development in New Zealand local government

Study location: The survey was conducted in three New Zealand locations: Gisborne, Hawke's Bay and Wellington (Crawford et al., 2019, Australasian Journal of Disaster and Trauma Studies).

Tsunami local history: The historical local tsunamis have been previously described (see Section 4.2.2).

Sample and methods: Survey methods included analysis of 58 official documents addressing risk management policies with the aim of identifying specific tsunami risk management policies. Twenty-three in-depth interviews, involving people with expertise in this type of risk, were then conducted in the 3 locations surveyed. The interviewees were also asked whether RiskScape risk modeling platform through proper communication was successful in increasing risk perception and stimulating the creation of effective tsunami risk management policies.

Main results: Text analysis reveals a paucity of risk-based policies for tsunami risk management. Out of fifty-eight documents analyzed, only three deal with tsunami risk. In-depth analyses highlight some important aspects including:

- A complex natural hazard management legislative environment.
- The scarcity of available natural hazard data and information and disconnection between science and policy.

Brief conclusion: Interviews also show that respondents trust RiskScape as a useful tool for communicating risk because it facilitates risk communication to a wide public. However, the authors remain uncertain about its usability and how much decision makers accept it among their management choices.

4.2.4 Assessment of households' responses to the tsunami threat: A comparative study of Japan and New Zealand

Study location: This is a comparative analysis between the towns of Christchurch in New Zealand and Hitachi in Japan (Wei et al., 2017 International Journal of Disaster Risk Reduction).

Tsunami local history: One of the countries most affected by tsunamis in its history is Japan. From 2000 to the present (2022), the catalog reports 36 events, of various magnitudes, for which sea level changes were recorded. Among them it is necessary to mention the 2003 tsunami (which caused two casualties) and the 2011 tsunami (which caused 18,428 casualties). Kamakura city was also affected by several historical tsunamis (NCEI/WDS, 2022).

Section 4.2.2 provides historical tsunamis that occurred in New Zealand.

Sample and methods: A total of 589 interviews (257 from Christchurch and 332 from Hitachi) were collected using a random sample. This survey was carried out based on the Protective Action Decision Model (PADM) (Lindell and Perry, 2012).

Main results:

- Several socio-demographic differences are present in the two surveyed communities (Higher average age in Hitachi than in Christchurch; larger families in Hitachi; longer average community tenure in Hitachi; and greater proximity to the coast for the Japanese community).
- Hitachi residents on average show a generally higher tsunami risk perception (tsunami expectation, city damage, city casualties) than Christchurch's ones.
- Significant difference in the arrival times expected by citizens of the two communities for a tsunami. Very short for Hitachi residents and longer for Christchurch.
- A positive correlation emerges between risk perception and evacuation attitude.

Brief conclusion: Risk perception is the best predictor of evacuation. This is positively correlated with hazard awareness, information sources, household size, and home ownership but is negatively correlated with proximity from the coast, income, and education.

4.2.5 Tsunami awareness and preparedness in Aotearoa New Zealand: The evolution of community understanding

Study location: The survey was conducted in Wellington, Wairarapa, Hawke's Bay and Gisborne in New Zealand (Dhellemmes et al., 2021, International Journal of Disaster Risk Reduction).

Tsunami local history**:** see Section 4.2.2.

Sample and methods: This is an evaluative study of tsunami risk mitigation initiatives carried out by various local agencies between 2003 and 2015. A similar questionnaire was administered, in the same area, before and after the initiatives. The questionnaire consists of 68 mostly closed-ended questions that explore: knowledge of tsunami hazard, risk perception, knowledge of mitigation actions and self-responsibility, preparedness to deal with a tsunami emergency and evacuation intentions. A total of 874 questionnaires, in paper-format, directly sent to households' mailboxes were considered valid.

Main results:

- In the ten Aotearoa communities, between both questionnaire administration phases, the general awareness and tsunami risk perception from 2003 to 2015 has increased.
- Respondents identify among the main risks that could affect the local community in 2015: earthquakes and tsunamis. In a 2003 survey, "coastal erosion" and "storms or cyclones" had a high percentage response rate.
- The three proposed scenarios (local, distant, and regional) show differences in preferred evacuation behaviors. In the local and regional scenarios would be by foot and in the distant tsunami scenario would be by car.
- The population's preferred warning methods include TV, Radio and sirens. "Earthquake" as a natural warning sign also received high response rates, indicating a good knowledge of the natural hazard that can trigger a tsunami.
- The education campaign to acknowledge the natural signs that can anticipate a tsunami's arrival (long strong shaking) positively increases the awareness that it is not necessary to wait for the official warning before starting the evacuation.

Brief conclusion: The survey showed an increase in respondents' risk perception and awareness of people living in a tsunami risk area. The authors encourage the creation of an official warning communication system that would reduce confusion around tsunami warnings.

4.2.6 A low-cost toolbox for high-resolution vulnerability and hazard-perception mapping in view of tsunami risk mitigation: Application to New Caledonia

Study location: The survey was conducted in New Caledonia, an archipelago of islands located in the South Pacific Ocean (Thomas et al., 2021, International Journal of Disaster Risk Reduction).

Tsunami local history: The population living in these islands is exposed to tsunamis threat generated by strong earthquakes, frequently higher than magnitude 7, like the events of 5 December 2018 (Maré, magnitude 7.5) and 10 February 2021 (Matthew Island, magnitude 7.7). From 1900 to date, 17 tsunamis induced by strong earthquakes are mentioned in the catalog. None of them have caused casualties.

Sample and methods: The research follows mixed methodology analysis with the aim of developing a set of quick-use tools named by the authors "low-cost toolbox." The toolbox contains several tsunami hazard assessment methodologies in a bundle, useful for two purposes: first, to facilitate decision makers to identify and quantify the population most exposed to tsunami risk due to living in vulnerable areas (using as few personal data as possible, for privacy reasons), and second, to survey the general public's tsunami risk perception. For this, a structured questionnaire was administered to a sample of 402 respondents. The authors aim to give the toolbox a local reproducibility in similar contexts.

Main results:

- The majority of New Caledonia's population lives between 0 m and 50 m above sea level.
- Mapping population distribution and building use patterns proves essential to develop ad hoc local tsunami risk mitigation policies.
- Many natives believe that tsunamis pose a real hazard to the islands indeed, revealing a higher tsunami risk perception than non-natives.
- Respondents widely believe that coral reefs and mangroves can mitigate the effects of a tsunami.

Brief conclusion: The study shows how important it is to integrate different methodologies into a single "low-cost toolbox" to obtain population mapping in relation to territorial characteristics and, together with population data, activate effective tsunami risk mitigation policies. The data on tsunami risk perception also show how important the historical transmission of past tsunamis is between native and non-native islanders. This has an important influence on tsunami risk perception.

4.2.7 Risk awareness and intended tsunami evacuation behavior of international tourists in Kamakura city, Japan

Study location: The survey was conducted in Kamakura city, Japan (San Carlos Arce et al., 2017; Safety Science).

Tsunami local history: see Section 4.2.4.

Sample and methods: The authors, before interviewing tourists, decided to provide background on the communication strategies implemented by the authorities. The survey design and the non-probability sample did not allow the data to be treated statistically, and consequently the survey results are not generalizable to the general population. The survey is based on a mixed method approach. Key informant interviews, on-site surveys and questionnaire surveys have been used to understand the risk awareness of this target. 163 structured questionnaire surveys were considered valid.

Main results:

- Most respondents know the natural signs that may precede a tsunami and that tsunamis constitute, together with earthquakes, one of the major natural hazards that could affect Kamakura.
- On average, respondents would not evacuate quickly.
- Most respondents said they had not seen or heard any information regarding natural hazards in Kamakura.
- Most respondents, following an earthquake, would evacuate.
- The issue of evacuation means also emerges. Many respondents would evacuate using public transportation, cars, or other means of transportation.

Brief conclusion: The authors report that good communication between the Disaster Prevention Offices and the Tourism organizations, both at the city and prefectural levels is needed. They also highlight the need to place evacuation signs in more visible places and unify the language and format.

4.2.8 Household risk perceptions and evacuation intentions in earthquake and tsunami in a Cascadia Subduction Zone

Study location: The survey was conducted in Seaside, a small town located on the coast of central Oregon (United States) (Buylova et al., 2020, International Journal of Disaster Risk Reduction).

Tsunami local history: North America is exposed to tsunamis generated from nearshore sources such as the Cascadia Subduction Zone (CSZ), as well as to tsunamis generated from very distant sources. The NOAA catalog reports 16 earthquake-induced tsunamis that affected the coastline since 1900 (NCEI/WDS, 2022).

Sample and methods: The research follows the PADM model stages starting from the socio-environmental variables to reach the behavioral intentions, through the psycho-cognitive aspects and the socio-demographic variables. A structured online questionnaire was administered to an initial sample of 944 households, out of which 211 were completed. As a result of factor analysis, two behavioral indexes were created: evacuation behavioral intentions and pre-evacuation behavioral intentions.

Main results:

- People who have participated in tsunami risk mitigation exercises, evacuation simulations or risk planning processes have higher intention to evacuate immediately in case of emergency and low intention to be engaged in pre-evacuation actions.
- Those who have been involved in or have had recent experiences of extreme events show greater risk perception and greater intent to engage in pre-evacuation behaviors and during evacuation.
- The study shows that the evacuation behaviors adopted are directly correlated with the risk perception and self-efficacy.
- The tsunami risk perception is influenced by: a) where respondents live (more or less close to the coast) b) physical preparedness that correlates with better self-efficacy attitudes c) confidence in basic tsunami knowledge.

Brief conclusion: The study shows that the application of the PADM model can provide a framework on pre-evacuation behaviors. The study also shows that there is no linear relationship between hazard knowledge and adopting conscious behaviors especially in an emergency. The study therefore suggests increasing the level of preparedness and self-efficacy as they contribute to increased tsunami response intentions and immediate evacuation.

4.2.9 Tsunami preparedness and resilience in the Cascadia Subduction Zone: A multistage model of expected evacuation decisions and mode choice

Study location: The survey was conducted in Coos Bay, Oregon and Crescent City, California (Chen et al., 2021, International Journal of Disaster Risk Reduction).

Tsunami local history: The historical local tsunamis have been previously described (see Section 4.2.8).

Sample and methods: This survey uses the PADM model to study tsunami hazard perception, tsunami hazard knowledge, effectiveness of evacuation methods and evacuation intentions of the coastal population surveyed. The sample consists of 483 respondents randomly selected: 258 from Coos Bay and 225 from Crescent City.

Main results:

- Almost half of the respondents report a moderate likelihood that a major earthquake (M9) will occur in the next 10 years and that it will cause fatalities and infrastructure damage.
- Respondents are confident in their perceived tsunami hazard knowledge, which is positively influenced by the evacuation drills previously conducted.
- Risk perception, perceived hazard knowledge, and perceived self-efficacy are directly related to some demographic variables and experiences (field experiences, drills).
- Evacuation intention is positively correlated with psychological variables such as: risk perception, self-efficacy, and knowledge of perceived danger; not related to socio-demographic variables and past experiences. This is consistent with the PADM model.
- Higher percentage of Crescent City residents would wait for an official warning and check social media before evacuating.
- Most of the respondents would prefer to evacuate by car. Significantly lower percentage by foot.

Brief conclusion: The study highlights how important it is to integrate different methodologies within a single survey tool to obtain a framework that allows effective tsunami risk mitigation policies to be developed quickly and without significant effort. Moreover, the tool developed by the authors is part of a toolbox that can be applied to other contexts with minor adaptations.

4.2.10 Hazard proximity and risk perception of tsunamis in coastal cities: Are people able to identify their risk?

Study location: The survey data were collected in Iquique, Chile (Arias et al., 2017, PLOS ONE).

Tsunami local history: Since 1900 Chile has been impacted by 25 tsunamis, caused by both local and distant sources (e.g., Japan 2011; Tonga 2022; *etc.*). Among the largest tsunamis that affected Chile it is necessary to mention the 1922 tsunami (which caused about 200 casualties), the 1960 tsunami (which caused over 2,300 casualties and extensive damage), the 2010 tsunami (which caused 229 casualties), and the 2015 tsunami (8 casualties) (NCEI/WDS, 2022).

Sample and methods: 487 interviews on earthquake and tsunami risk perception recorded in Iquique, were extrapolated from the 2,054 interviews collected by Bronfman et al. (2013) in a large face to face survey involving the Chilean population on assessment and perception of natural hazards, and trust in the institutions. The geographic coordinates of each respondent's residence were loaded into ArcGIS software and placed on the map to divide the respondents into 1) those living in the tsunami safe zone, 2) those living in the tsunami inundation zone.

Main results:

- People living in Iquique show a high and widespread tsunami risk perception.
- Data show no differences by gender.
- Among the most significant findings is a higher tsunami risk perception by young people (29 and younger) living in the risk zone than peers living in the safe zone. In general, elderly people have a higher tsunami risk perception.
- The socioeconomic status does not affect tsunami risk perception.

Brief conclusion: The positive correlation between tsunami hazard proximity and relatively high-risk perception emerges concurrently with some relevant factors such as inherited social memory of past events. Therefore, the memory of recent and non-recent events is alive and increases awareness and preparedness. Local authorities and experts play a key role in making people aware, keeping them informed and prepared for a tsunami warning.

4.3 Surveys conducted in the NEAM region

Not many studies on tsunami risk perception have been carried out in the NEAM region.

Most of them have been realized during the EU-funded project ASTARTE (Assessment, STrategy And Risk Reduction

for Tsunamis in Europe, 2013–2016 (https://cordis.europa.eu/project/id/603839). We will briefly describe here some studies from this project that have been published either in peer-reviewed journals or in the project final report, available online (https://cordis.europa.eu/project/id/603839). Moreover, a few other analyses carried out in Italy in the last few years are described below.

One of the objectives of ASTARTE, a 3-year European Union-funded project from 2013 to 2016, was the assessment of tsunami risk perception. The goal was to identify key components of tsunami resilience and their implementation in the NEAM region. The study involved ten test sites where tsunamis have occurred one or more times in the past: seven on the Mediterranean coasts (Spain, France, Italy, Greece, Romania, and two in Turkey), two on the Atlantic coast (Portugal and Morocco), and one in Norway. All of these sites are exposed to earthquake-related tsunamis (Álvarez-Gómez et al., 2011) and several to eruptions of submarine and island volcanoes located in Italy, the Canary Islands, and Greece.

Among the surveyed topics, respondents were asked about their source of information (TV, school, newspapers, internet) and if the area where they lived could be affected by a tsunami.

Interviewees were also asked whether the government makes the right information about the tsunami risk and whether the natural hazard preparedness measures are satisfactory. The questionnaire, translated into nine different languages, also discusses evacuation plans and, in addition, respondents are given the opportunity, in a section of the questionnaire, to suggest how they can reduce the tsunami risk.

The project's output, regarding the study on tsunami risk perception and assessment of population preparedness, was published in some papers (Sections 4.3.1–4.3.3 below). whereas other studies are described in a report (http://194.117.20.221/index.php/deliverables.html– *D9.7–Report on preparedness skills, resources and attitudes within the communities*) that includes some unpublished work (Dogulu et al., 2014) and will not be discussed here.

More recently, tsunami risk perception studies have been addressed in Italy, where past tsunamis affected mainly southern Italy (Sicily, Calabria, Apulia, Campania and the islands of the Aeolian arc) but also the Ligurian coasts (in 1887) and the Adriatic (in 1,627, 1743, *etc.*). Given the widely recognized tsunami hazard and given the need to activate tsunami risk mitigation policies in a context of strong urban and coastal settlement development, CAT-INGV and Civil Protection have been supporting this type of community-based studies since 2018.

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

Study location: The survey was conducted in Norway between spring 2014 and autumn 2015 (Goeldner-Gianella et al., 2017, Geoenvironmental Disasters).

Tsunami local history: Norway experienced three major "rockslide tsunamis" in the 20th century (1905, 1934, 1936) causing a total of 174 victims (Harbitz et al., 2014). In the Norwegian county of Troms, the banks of the fjord Lyngen are highly exposed to a rockslide tsunami hazard.

Sample and methods: The survey used the ASTARTE questionnaire, with 99 random interviews collected in different places: 62.5% within Lyngseidet, 21% on the ferry crossing the fjord between Lyngseidet and Olderdalen, and around 17% in the neighboring villages.

The authors note that the small sample size and sampling methodology does not give statistical robustness to the survey to make it representative of the population.

Main results: Data analysis shows a widely high tsunami risk perception (rockslide-induced).

- Respondents associate the term Tsunami with the adjective "big" (40%) and the word "wave" (50%) and prefer to use the word "flodbølge" that translates as "a wave that causes flooding." Moreover they are aware that in their area a tsunami can be caused by a rockslide (55%) or an earthquake (25%).
- TV is the primary medium through which residents get most of their information about tsunamis, followed by school education and general media coverage, especially after the 2004 Indian Ocean tsunami.
- More than 30% of local respondents do not know how much time would be available for evacuation, are unaware that a warning system exists, and do not know how they would evacuate.

Brief conclusion: The warning and evacuation system installed in the past years thus does not appear to be sufficiently well-known and the population is not sufficiently prepared for evacuation. While citizens show a good level of trust in local institutions for how they manage the risk and for the dissemination of information in schools and among the local population. Tourists shows a lack of knowledge of tsunami risk due to a lack of information provided.

4.3.2 Perception and preparedness of the tsunami risk within the Black Sea (Romania) communities

Study location: The research was carried out in 2014 in Eforie Nord, in Romania (Constantin et al., 2017; Section Applied and Environmental Geophysics).

Tsunami local history: The Eastern side of Romania faces the Black Sea and the whole area is at risk of strong earthquakes that could generate tsunamis. Two strong earthquakes and a submarine landslide generated tsunamis that affected the Black Sea coast, including the strong 544 earthquake (M7.5), the 1901 earthquake (M7.2) and the landslide that occurred in 2007. Tsunamis have reached a maximum height of 2–3 m.

Sample and methods: The survey's goal was assessing the tsunami knowledge, the risk perception and the possible attitude to evacuate. The questionnaire was administered to eighty-four respondents of which 17% residents or people working in the area, and 83% tourists on vacation in the area, among whom 48% from Bucharest.

Main results:

- Tsunamis are not considered a major hazard by respondents, compared to earthquakes and storms. The majority of those mentioning tsunamis are tourists, describing the tsunami as a "big wave."
- TV is the major information source through which people get informed about the tsunami phenomenon, then the internet and the other mass media coverage that have spread images and descriptions after the great events of the Indian Ocean and Japan.
- Respondents consider sirens the best warning system and claim that exercises for natural tourihazards are not satisfactory. Moreover, in North Eforie there are no signals, warning systems or evacuation maps.

Brief conclusion: Tsunami risk perception is diffusely low and respondents are not aware of any tsunamis that have affected the area in the past.

4.3.3 La perception du Risque tsunami a sines, Portugal: De L'importance du paysage dans La perception sociale du Risque (in French)

Study location**:** Liotard et al. (2017) conducted a tsunami risk perception study in the city of Sines in Portugal (Liotard et al., 2017, Finisterra - Revista Portuguesa de Geografia).

Tsunami local history: Since 1900, Portugal has been affected by four tsunamis induced by strong earthquakes. These events caused small sea level changes. Although not very frequent, large-scale events have occurred in the past, such as the Lisbon tsunami of 1755.

Sample and methods: In addition to including questions reported in the questionnaire common to ASTARTE test sites, the authors used a photo-elicitation technique, consisting of showing four photographs illustrating different hazards on various coastal areas and asking if they can perceive any risk based on the images. A total of 133 people in Sines were interviewed including residents, workers, and tourists. 77% of the interviewed people work in Sines but do not live there. 86% of the total respondents lived in coastal areas.

Main results:

- The respondents classified the risk of a tsunami on the fifth position, after pollution, earthquake, explosion and storms.
- However, 71% of the respondents proclaim that a tsunami could affect Sines city again.
- The workers and inhabitants associate a tsunami with a destructive phenomenon.
- A significant result is that 51% of the respondents mentioned the school as their source of information about tsunami risk.
- The individuals have a relatively high level of knowledge about the precursory signs of a tsunami: 31% cited a seismic activity, 28.6% the sea retreat, while 17.1% mentioned an unusual animals' behavior. Moreover, 90% of the respondents would evacuate the beach in case of seismic activity.

Brief conclusion: Regarding the photo-elicitation method, the conclusion after analyzing the remarks provided by the respondents is that in general, they underestimate the risk of a tsunami, which are seen as a spectacular phenomenon and compared to typical ocean storms. For the coastline inhabitants, who are familiar with adverse weather phenomena or sea storms, it is problematic to distinguish tsunamis from the other coastal phenomena from the proposed images. The authors encourage increased knowledge that distinguishes the two different events and does not underestimate the tsunami risk.

4.3.4 Tsunami risk perception along the Tyrrhenian coasts of Southern Italy: The case of Marsili volcano

Study location: The survey was done on a non-probability sample of the population living in Campania, Calabria and Sicily (Italy) between 2015 and 2016 (Gravina et al., 2019, Natural Hazards and Earth System Sciences).

Tsunami local history: Southern Italy has been repeatedly hit by tsunamis in the past. The most recent events are the devastating 1908 Messina-Reggio earthquake-induced tsunami, and the damaging tsunami triggered by a volcanic collapse in Stromboli in 2002.

Sample and methods: The survey used a structured questionnaire consisting of five sections with open and closed questions aimed to analyze knowledge, perception, and citizens' opinions about the tsunami phenomena.

The 888 questionnaires collected (regarding respondents' estimate of tsunami arrival times) were compared with a tsunami scenario due to a Marsili seamount flank collapse elaborated by Mari and Gravina (2015).

Main results:

- Respondents show a widespread consciousness that a tsunami may occur.
- However, they also say that in case of a tsunami they would not know how to behave because of a lack of preparedness.
- A comparison of response percentage shows slightly greater preparedness in Campania than in Calabria and Sicily, possibly due to a drill carried out in 2013.

- Questionnaire answers underlined that participants address tsunami risk in the Tyrrhenian Sea as due to both submarine earthquakes and volcanic eruptions.

Brief conclusion: The research emphasizes the importance of designing adequate tsunami risk information campaigns and of helping the population to understand that tsunamis could be triggered not only by earthquakes, but also by landslides or volcano flank collapses, that could not be perceived by the population acting as precursors of tsunamis.

4.3.5 Tsunami risk perception in Southern Italy: First evidence from a sample survey

Study location: Cerase et al. (2019) investigated tsunami risk perception in coastal municipalities of two regions in southern Italy (namely Apulia and Calabria) (Cerase et al., 2019, Natural Hazards and Earth System Sciences).

Tsunami local history: As described in the previous Section 4.3.4, Southern Italy has been affected by several tsunamis in the past. Also Apulia had at least three tsunamis that occurred in the 17th and 18th century.

Sample and methods: The research was based on a stratified sample of 1,021 people, interviewed by telephone (CATI methodology), representative of about a total of three million coastal inhabitants.

The questionnaire consisted of 27 items with closed questions and Likert scales.

Main results:

- In both surveyed regions, tsunami risk is generally perceived as low, despite the high hazard.
- Risk perception appears to be influenced by both socio-demographic variables.
- However, the study highlights a remarkable difference between the two regions, highlighting the importance of the collective memory in risk perception.
- People appear to acknowledge that earthquakes are the most frequent cause of tsunamis, even though they consider volcanoes as another relevant source of tsunamis, possibly underrating landslides.
- An interesting finding is that the interviewed ignore or neglect the risk posed by small tsunamis, whose probability of occurrence is significantly higher than that of large tsunamis.
- Also, according to the respondents the words “tsunami” and “maremoto” refer to different phenomena, the first being associated with the televised imagery of Sumatra 2004 and East Japan 2011 events, whereas the word maremoto is more influenced by the memory of local past events such as the 1908 Reggio Calabria - Messina tsunami.

Brief conclusion: The collective memory is very important and needs to be kept alive. Many people do not understand the physical difference between tsunami waves and those due to normal sea storms, resulting in misleading assumptions about the real hazard posed by (even small) tsunamis. In risk communication, attention must be given to the terms used for describing the phenomena.

4.3.6 Tsunami risk perception in Central and Southern Italy

The detailed analysis of these surveys is ongoing and will be part of a comprehensive study (Cugliari et al., 2022).

Study location: The surveyed regions were Sardinia, Lazio, Molise, Campania, Basilicata and Sicily (Italy). Moreover, a national panel of about 1,500 interviews covering all Italian regions has been surveyed, in order to have a landmark of people representative of the Italian population, therefore including tourists visiting coastal areas for vacation.

Tsunami local history: see previous sections. Among the surveyed regions, there are relevant differences in terms of number and impact of past tsunamis. This is also shown by the tsunami hazard model of TSUMAPS-NEAM (Basili et al., 2021).

Sample and methods: Two surveys were carried out in 2020 and 2021 using the CATI methodology with the same questionnaire used for the study described above (Section 4.3.6), collecting 614 and 4,027 questionnaires, respectively. It was administered to a rigorously selected sample divided by proportional shares taking into account age, gender, education level, and coastal slope.

Main results:

- In general, about 40% of respondents believe that a tsunami can occur in the Mediterranean Sea. This percentage decreases among respondents living along the coast of the Adriatic Sea who for 60% believe that a tsunami cannot occur.
- Comparison of tsunami risk perception in metropolitan cities for the coastal reference side shows a general data alignment. Except for the city of Rome, which has a lower perception of risk than the Tyrrhenian slope on which it is located, and the city of Reggio Calabria, which shows a very high risk perception compared to the Tyrrhenian and Ionian coastal slope.
- 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.
- Respondents with higher educational degrees would be more conscientious in case of a tsunami. Conversely, a lower educational level corresponds to insecurity and incorrect behaviors.

- Most of the respondents believe that tsunamis are mainly caused by earthquakes. Volcanoes represent the second possible cause of tsunamis. A higher percentage of responses on volcanoes were given by those living on the Thyrrenian coasts, due to the presence of Stromboli and Vulcano islands, and of submarine volcanoes such as Marsili and Palinuro Mts., often mentioned by the media.
- The comparison of tsunami risk perception (likelihood of a tsunami occurring in the Mediterranean Sea) surveyed through the national population sample (national panel) and the coastal sample (CATI) shows that perception is significantly higher among those living on the coast than the national average.

Brief conclusion: The study shows that people in general are aware of the possible effects of a tsunami. However, the knowledge appears to be influenced and distorted by the media. Historical memory of past events plays a key role in developing effective tsunami risk mitigation policies shared by the population. Conversely, the loss of historical memory of past events increases the difficulty of making the community aware of the hazard posed by tsunamis and makes mitigation interventions less effective. The study is also of fundamental importance for the development of the UNESCO Tsunami Ready program in Italy.

5 Comparative analysis of the surveys

In this review we have analyzed several studies dealing with people's knowledge and perception of tsunami risk. The series of papers analyzed in our study covers a period of about 15 years, the two major ICGs (Intergovernmental Coordination Groups) regions coordinated by UNESCO IOC, including the Pacific and the Indian Oceans TWS, and finally the NEAM region (North-East Atlantic, Mediterranean and connected seas). As described above, the twenty-three studies show heterogeneities, both in the methodology used to assess people's perceptions and in the sampled population, number of respondents, *etc.* As a result, survey outputs, being projections of different territories and various socio-cultural contexts, also appear heterogeneous in their different approaches to studying tsunami risk perception.

However, some relevant similarities and differences emerge, and allow us to draw some first conclusions on people's attitudes towards tsunami risk, also suggesting some future directions both for designing similar studies, and for applying the results of the current literature in the definition of communication strategies.

In Table 1. We synthetically resumed the information listed in Section 4, as to provide a quick overall view of the whole considered papers, based on the methodology being used, sample characteristics, past tsunami history at local/regional level, points of strength and *weakness*, and above all the most important *lessons to be learned*.

15 out of the 23 considered papers used only questionnaires as a survey tool (69,6%). The questionnaires–structured, semi-structured, were administered in different modalities (pen/sheet, by mail, by phone, *etc.*). 6 studies out of 23 rely on mixed methods (26,1%) integrating both quantitative and qualitative methods such as surveys with qualitative method such as "in-depth interviews"; "focus groups"; "document analysis"; "GIS data" and so on, whereas strictly qualitative methods such as the semi-structured in-depth interview has been used in only one paper (4,3%).

Most of the papers have dealt with residents, only four surveys involved tourists. 6 out 23 papers (about one-third) rely on a mixed method approach, combining different types of data (both quantitative and qualitative) to throw light on blind spots emerging from the field and to get the best out from the research. Finally just a single paper relies solely on qualitative methods (in-depth interviews).

As mentioned above, the strong heterogeneity of samples and methods prevents a comprehensive evaluation of people's perception of tsunami risk worldwide. However, in order to have a synthetic view of the responses, framing the highlights emerging in the analyzed papers, we chose to employ a table of analysis that allows us to summarize the *strengths*, the w*eaknesses and* the lessons learned of risk perception studies.

This table is reported here to stimulate future in-depth analysis and surveys on tsunami risk perception (Table 1). The result of the table of analysis in the three outputs, could encourage to use existing survey methods or to create new ones, e.g., it could stimulate the creation and validation of a commonly recognized tsunami risk perception index, or stimulate the creation of a repeatable analysis model that may be used in longitudinal studies. The highlights in the table are simple, concise commonalities noted in the literature review.

Among the *strengths* evidenced in the analyzed papers, we note 1) an increase of risk perception studies over time, starting after the 2004 Indian Ocean tsunami and particularly in the last 5 years; 2) the interest in testing and combining different methodologies to assess tsunami risk knowledge and perception as to get a more comprehensive picture of tsunami risk perception and understanding; 3) the presence of a larger number of studies in high hazard regions, where tsunami events have occurred in a recent past. On the other side, points of *weakness* include 1) the lack of a shared theoretical framework and in turn of repeatable research designs for this kind of study; 2) the lack of a consistent design of the study among different ICGs; 3) some weakness in methodological approach, and 4) some poorly statistically representative samples.

Along with strengths, *opportunities* and *lessons learned,* this review allowed us to point out some relevant points,

TABLE 1 Tsunami risk perception research: Review table.

Reference	Method	Sample	Place	Tsunami history	Strenght	Weakness	Most important lesson to be learned
Kurita et al. (2007)	Survey	3000 interviews	Indian Ocean (Sri Lanka, Maldives, Indonesia)	Since 2000 to date, 9 tsunamis in Indonesia. 4 in Sri Lanka and Maldives was affected by 2004 Indian Ocean Tsunami (IOT)	First large-scale survey; data highlight Simeulue as a relevant matter of interest	Descriptive statistics, does not provide explanatory model	Lack of pre-existing knowledge about tsunami, also from civil protection officers
Hall et al. (2019)	Survey	Stratified sample, 304 interviews (tourist from 40 countries)	Indian Ocean (Bali, Indonesia)	Since 1900, 5 earthquake induced tsunamis and 2 volcanic eruptioninduced tsunamis	Investigates tourist's risk perception and their sources of information andknowledge	Subsamples were too small to have convincing data on single countries	Lack of available information sources on place, prior knowledge in their home country
Akbar et al. (2020)	Survey	174 interviews (victims of 2018 Sunda tsunami in Bantan)	Indian Ocean (Bantan district, Indonesia)	Many historical tsunamis, in 2018 Sunda strait tsunami caused by the Anak Krakatau volcano eruption	Considers people affected by a recent tsunami event	Questionnaire items are neither presented nor discussed, research is only on aggregate indicators	"The higher disaster risk perception of a person, the higher disaster preparedness level"
Harnantyari et al., (2020)	Survey	197 valid interviews	Indian Ocean (Sulawesi, Indonesia)	Since 1900 there have been 10 events (8 caused by strong earthquakes, 2 by volcanic eruptions)	Considers people affected by a recent tsunami event, investigates individual response andmitigation measures	Official tsunami warnings failed to reach residents; road congestion resulted in further difficulties to evacuate (near- field tsunami)	High level of tsunami awareness, sometimes coming with a low understanding of phenomena. For 82.5% evacuation was triggered by witnessing others evacuating (imitation)
Alam (2016)	Mixed methods(quantitative / qualitative)	30 interviews+ in-depth interviews	Indian Ocean (Bangladesh)	1762 earthquakeand tsunami and 2004 IOT	Joint use of different methods	Small, non-probabilistic sample	Low risk perception, religious based fatalism
Mengal et al. (2020)	Survey	264 interviews	Balochistan, Pakistan (Gulf ofOman)	2 strong earthquake and tsunamis. In 1945 the largest	Considers information source and individual ability to address risk	Strong gender polarisation in sample, women were not allowed to participate survey	Strong use of smartphones as information source, individual ability to compare tsunami with other risk sources
Salah and Sasaki (2016)	Mixed method	153questionnaires + in-depth interviews	Southern Iran (Gulf of Oman)	Since 1945 4 minor tsunamis events	First survey in the area; relevance of survivors of past tsunami experience	Sample size (low number of cases)	Lack of awareness, low risk perception, role of religion, low trust in institutions
Bird and Dominey-Howes, (2008)	Survey	30 interviews	Pacific Ocean (Sidney, Australia)	Sea level changes for the 1960 Chilean tsunami and 2011 Japan tsunami	It is focused on the development and improvement of questionnaire surveys on tsunami risk perception	The very small sample can only validate tool, it is not consistent and useful to draw sound conclusions about respondents' risk perception	Low level of risk perception and knowledge on tsunami; most of respondent never heard about it before 2004 event. Authors recommend using also qualitative interviews
Couling (2014)	Semi-structured interviews (qualitative approach)	15 interviews	Pacific Ocean (North Island of New Zealand)	Since 1900, 15 minor tsunamis impacted New Zealand	Author adopts a qualitative approach, thus obtaining a rich figure of people's understanding of tsunami	The low number of respondents is unfit to generalize conclusion, researcher bias can affect results	Very low or non-existent Tsunami risk perception; relevant misbeliefs about tsunami physics an anticipatory sign; low level of preparedness (prompt evacuation); imperative need to improve risk communication and community engagement
Crawford et al., (2017)	Mixed methods (Semi-structured qualitative interviews + document analysis)	23 interviews	Gisborne, Hawke's Bay, and Wellington regions (New Zealand)	Since 1900, 15 minor tsunamis impacted New Zealand	The research is focused on the way tsunami risk is perceived by citizen and on their	Selection criteria being applied to interviewees are not clear	Tsunami risk communication is not able to provide a realistic account of phenomena and its consequence; people are

(Continued on following page)

TABLE 1 (*Continued*) Tsunami risk perception research: Review table.

Reference	Method	Sample	Place	Tsunami history	Strenght	Weakness	Most important lesson to be learned
					expectations on risk mitigation policies		stressed by long return period and high uncertainty and not motivated to change their way of life; visual risk communication (Risk Scapes) might be very effective
Wei et al., (2017)	Survey	589 valid interviews, 257 in Christchurch city (New Zealand) and 332 from Hitachi city (Japan)	Christchurch (New Zealand) Hitachi city (Japan)	For New Zealand see above. In Japan from 2000 the catalogue reports 36 events. The majors in 2003 and 2011	Comparative approach, rigorous research design and use of statistical methods, including logistic regression	Possible biases in sample composition, data presentation is somewhat redundant and might be not clear for non-specialists	Research is based on a consistent theoretical model; significant differences between Hitachi and Christchurch with
Dhellemmes et al. (2021)	Survey (Comparative approach, panel study)	874 completed questionnaires	Ten different communities in New Zealand East Coast	Since 1900, 15 minor tsunamis impacted New Zealand	Research duplicates previous research to address changes occurred over time	Questionnaires were self- administered thus involving the possibility of condescending and biased responses	Data show a dramatic increase in tsunami risk perception from 2003 to 2015. EQ and tsunamis are recognized as the main risks that could affect the local community in 2015, whereas coastal erosion and storms were most feared in 2003
Thomas et al. (2021)	Mixed methods (GIS data, dasymetric population maps, rapid field interviews	12 interviews	New Caledonia (Pacific Ocean)	From 1900 to date, 17 earthquake- induced tsunami are mentioned in catalogue	Survey is based on seven questions, both closed ended and open ended: risk perception survey is combined with GIS data	The application of the "low- cost toolbox" built upon survey and GIS data appears to be a bit less straightforward than expected	Most people live between 0m and 50m above sea level. Risk perception data and GIS combination can help tailoring ad hoc risk mitigation policies. Natives hold that tsunamis are real threats, also considering reefs and mangroves as natural defence against tsunami effects
San Carlos Arce et al., (2017)	Mixed methods (key informant interviews, field visits, analysis of risk communication strategies and field surveys)	163 valid questionnaires (survey) on tourists	Kamakura City (Sagami Bay, Japan)	In Japan from 2000 the catalogue reports 36 events. The majors in 2003 and 2011	Survey is based on both closed ended and open- ended question, providing a further opportunity to explore emerging qualitative issues; tourists being recognized as a relevant group	Results are not necessarily generalizable to all of Japan, and sample composition could not reflect the actual variability and composition of the reference universe	Increased awareness on tsunamis, just few respondents are able to identify potential tsunami risk and self-evacuate; lack of viable risk information in the city
Buylova et al., (2019)	Survey	211 completed questionnaires	Cascadia Subduction zone (Seaside, Oregon, United States	From 1900 to date the NOAA catalogue reports 16 earthquake- induced tsunamis	Rigorous research design and use of statistical methods, including Ordinary Least Squares (OLS) regression analysis	Possible biases due to small number of responses, survey nonresponse errors, and measurement; data presentation is somewhat redundant and might be not clear for non-specialists	Research is based on a consistent theoretical model. People engaged in risk planning and exercises are more likely to evacuate and less willing to be engaged in pre-evacuation actions. People who experienced extreme events have higher risk perception. Research confirms a significant connection between risk perceptions, self-efficacy, and behavioural outcomes

(Continued on following page)

TABLE 1 (*Continued*) Tsunami risk perception research: Review table.

Reference	Method	Sample	Place	Tsunami history	Strenght	Weakness	Most important lesson to be learned
Chen et al. (2021)	Survey	483 completed questionnaires (258 from Coos Bay, 225 from Crescent City)	Cascadia Subduction zone (Coos Bay Peninsula, Oregon; Crescent Bay, California, United States)	From 1900 to date the NOAA catalogue reports 16 earthquake- induced tsunamis	Rigorous research design and use of statistical methods, including Ordinary Least Squares (OLS) regression analysis, binary logistic regression analyses	Possible biases due to small number of responses, survey nonresponse errors, and measurement; data presentation is somewhat redundant and might be not clear for non-specialists	Research is based on a consistent theoretical model; survey results show that more than 40% of the sample believes a moderate likelihood that a strong earthquake might occur in the next 10 years. Respondents are confident in their tsunami hazard knowledge, being positively influenced by previous evacuation drills. Risk perception, hazard knowledge, and self-efficacy are affected by bothdemographic variables and past experiences
Arias et al. (2017)	Survey	487 interviews	Pacific Ocean (Iquique, Chile)	Since 1900, Chile has been impacted by 25 tsunamis. The majors were 1922, 1960, 2010 and 2015	Authors consider together several variables, including socio-economic status, inherited social memory of past events, distance from coastal borders	Despite the quality of research design, authors did not manage to find causal relationship between relevant variables	Hazard proximity proved to be a relevant factor in risk perception; memory of past events increases awareness and preparedness
Goeldner-Gianella et al. (2017)	Survey	99 face-to-face interviews	Lyngen Fjiörd (Norway)	Norway's rockslide tsunamis in the 20th century (1905, 1934,1936)	Paper comes from wider research on Natural Hazards (ASTARTE). It tries to integrate quality within a mostly quantitative approach	Small, non -probabilistic sample (respondents were randomly approached in different places)	Local population has clear perception of tsunami hazard, related to rockslides and trust local institutions; lack of available information for tourists
Constantin et al., (2018)	Survey	84 face-to-face interviews	Eforie (Black Sea, Romania)	544, 1901 Shabla EQ and Tsunami, 2017 submarine landslide	Paper comes from wider research on Natural Hazards (ASTARTE)	Small, non -probabilistic sample (respondents were randomly approached in different places)	Preparedness level is average: some are well informed and aware of tsunami hazard, while others know about tsunami only from movies. Locals are less informed about tsunamis in comparison to tourists, regarding some aspects. Lack of knowledge is associated to the low level of education
Liotard et al., (2017)	Mixed methods (Survey + photo elicitation)	84 face-to-face interviews (locals, workers, and tourists)	Sines (Atlantic Ocean, Portugal)	Since 1900, Portugal experienced sea level change by 4 tsunamis. The 1755 Lisbon EQ and Tsunami was the major in itshistory	Paper comes from wider research on Natural Hazards (ASTARTE)	Small, non -probabilistic sample (respondents were randomly approached in different places)	Relatively high level of knowledge about the precursory signs of a tsunami; 9 out of 10 interviewees are likely to evacuate the beach in case of a strong earthquake.Photo-elicitation method suggests that people are uneasy in understanding differences between tsunamis and sea storms
Gravina et al., (2019)	Survey	888 respondents across three Thyrrenian regions	Randomized sample of three Italian Thyrrenian Regions (Campania,Calabria and Sicily)	1783, 1887, 1905 and 1908 Messina Reggio EQ and Tsunami triggered by the volcanic eruption from Hellenic Arc (Stromboli 2002)	Research stress the importance of designing effective tsunami risk communication campaigns to help people population to understand tsunamis	Research considers a hypothetic event which has been subjected to a wide media coverage across the time. This aspect is not discussed	Although respondents are conscious about the probability of a tsunami event only few knew how to neither properly behave in case of an event nor consider themselves prepared to face a tsunami wave

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TABLE 1 (*Continued*) Tsunami risk perception research: Review table.

Reference	Method	Sample	Place	Tsunami history	Strenght	Weakness	Most important lesson to be learned
Cerase et al. (2019)	Survey	1021 respondents	Stratified sample of people living in coastal municipalities of two Southern Italian regions (Apulia and Calabria)	1783, 1887, 1905 and 1908 Messina Reggio EQ and Tsunami triggered by the volcanic eruption from Hellenic Arc (Stromboli 2002)	Paper is based on a large sample research and considers together several variables including socio- demographic, geographic and cultural	Research provides a general descriptive account through mono and bivariate analysis	The paper highlights a generally low tsunami risk perception, and different understanding of the phenomena under the label "Tsunami" and "Maremoto". Relevant differences emerge in risk perception emerge from different coastal areas. Finally, people totally ignore or neglect the risk posed by small tsunamis, supposed to be more frequent in those areas. Television is the main source of information, while scientific sources appear to have a very limited impact
Cugliari et al. (2022)	Survey	5842 respondents	Stratified sample of people living in coastal municipalities of eight Italian coastal regions, representative of more than 12 million people	1783, 1887, 1905 and 1908 Messina Reggio EQ and Tsunami triggered by the volcanic eruption from Hellenic Arc (Stromboli 2002)	Paper is possibly based on the largest sample for this kind of research. It continues the research published by Cerase et al, 2019 extending and widening it with a more stratified sample to increase statistical robustness	Research provides a general descriptive account through mono and bivariate analysis	The paper confirms a low tsunami risk perception as well as a different understanding of the phenomena under the label "Tsunami" and "Maremoto". Coastal areas affected by tsunamis in the recent past preserve a historical memory and have higher level of risk perception. The tsunami risk perception by coastal side in some cases differs from the perception surveyed in metropolitan cities that subsist on the same side (Rome, Reggio Calabria). The tsunami risk perception of the wide national panel (Telepanel) is lower than the perception detected in coastal areas

among which 1) the chance to involve citizens and tourists in areas where recognition programs (such as Tsunami Ready) are going on; 2) the need to increase young generations' awareness on tsunami risk; 3) the opportunity to develop some robust synthetic indexes measuring risk perception.

Finally, it is worth mentioning 1) the widespread lack of correct policies for dealing with tsunami risk; 2) the low trust in public institutions; 3) the presence of a fatalistic attitude, eventually due to religious believes; 4) the low interest of local authorities in facing the tsunami risk, considered as not likely to occur, not important or too difficult/costly to face.

6 Discussion

In order to mitigate the impact from future tsunami events, besides improving monitoring and alerting systems, it is necessary to study the way tsunamis are perceived and to understand the "last mile" segment of the warning chain. A correct response of people to both natural and official warnings is fundamental to reduce the tsunami risk.

The review presented in this paper highlights some relevant points related to people's perception of tsunami risk and the way in which this kind of research can be useful for risk management. First, before planning tsunami

risk mitigation actions, governments, stakeholders and local administrations should analyze tsunami risk perception and place it in context by identifying the distinguishing traits of local cultures. In fact, our review shows that tsunami risk is not homogeneously perceived, past experience and cultural aspects playing an essential role in shaping the way tsunamis are perceived and understood. Therefore, studying tsunami risk perception within different geographical, social, political and local contexts is, at the same time, a necessary and indispensable means to achieve an effective implementation of local (and intergovernmental) mitigation actions.

Second, as we have seen in this review, tsunami risk is not homogeneously perceived even within the same community, as it is affected by different socio-demographic variables such as gender, age, education level, average income and presence of children in the household/family (see Alam, 2016; Wei et al., 2017; Akbar et al., 2020; Buylova et al., 2020; Dhellemmes et al., 2021), as well as hazard proximity and social memory of past events (see Fraser et al., 2016; Arias et al., 2017; Cerase et al., 2019; Cugliari et al., 2021; Cugliari et al., 2022). These variables are directly or indirectly related to social stratification (e.g., owning a house close to the coastline) as well as to particular risk cultures or worldviews co-existing in the same society (e.g.: egalitarian, hierarchical, individualists and fatalists) (Mamadouh, 1999; Douglas, 2007) which are likely to result in significant differences within a given population; in general, we can hypothesize that those who feel to have more to lose have a higher risk perception than those who feel to have less, thinking to be safe from tsunamis. Furthermore, these differences could be very difficult to understand by people with limited access to scientific knowledge (Cerase et al., 2019; Cugliari et al., 2021; Cugliari et al., 2022) and by some target populations such as tourists from other countries that have never experienced or even heard about such events and may be totally unaware of tsunami risk in their holiday locations, thus requiring additional resources to develop effective risk mitigation strategies (Arce et al., 2017; Hall et al., 2019).

Third, tsunami risk perception is in part related to psychological features of individuals, and in part to local cultures. Different local cultures may provide both a set of correct information about natural signs that may anticipate the arrival of a tsunami wave, and other cultural artifacts such as legends, stories as well as a set of shared norms about proper conducts to be held, and some criteria to address individuals' responsibility and accountability. Such norms do not lie exclusively on scientific expertise and are always consistent with wider conceptions of social goods, as these always embody somewhat cultural and normative conception of what is held to be considered morally, aesthetically, or logically acceptable/desirable (Kluckhohn, 1951). Consequently, different cultures may develop different ways to represent tsunamis and act accordingly: it can be seen as an inescapable act of God rather than a call for individual action (even in apparently extreme forms such as the Tsunami-tendenko[1] in some coastal areas of Japan, see Yamori, 2014; Nakasu et al., 2018).

In general terms, the cultures which are more likely to face a tsunami event within few generations or those who have experienced large damages, deaths and disruption due to a large event tend to develop stronger and more consistent set of responses, that may involve both spontaneous sharing of knowledge about tsunamis, and institutional responses (e.g., evacuation drills, educational programs and ad-hoc disaster risk mitigation programs to increase awareness and resilience) Rahman et al., 2017. It should be also considered that some physical features of tsunamis (e.g., the hazard posed by small waves) are not understood in the same way and in some cases people are uncomfortable to believe scientists as their understanding of such a physical phenomenon does not match with native explanations, which are often based on analogies (e.g., storm waves/tsunami waves) or on media portrayals of past big tsunamis such as those of Sumatra 2004 and East Japan 2011.

Finally, some methodological considerations on social research should be kept into account, as sample size, research design, and questions' formulation could heavily affect validity and reliability of data. In general terms, the type and the size of the investigated sample and the research design are very important if one wants to avoid reaching misleading conclusions. As an example, small samples and snowball sampling should be used only to get a first descriptive analysis of risk perception but are unfit to draw causal explanations of key factors and, of course, should not be used to ground disaster risk mitigation measures in larger areas. Furthermore, the way to set up structured surveys and quantitative social research may reflect researchers' approach in setting up the research problem rather than the point of view of people who are asked to respond, thus downplaying or neglecting possible relevant factors (e.g., local culture, familiarity and native knowledge) that may have a pivotal role in drawing a comprehensive and satisfactory description and explanation of the considered phenomena.

1 In Japanese, tsunami-tendenko refers to the "everyone her/himself" mentality, which requires a quick tsunami evacuation without waiting for others, even one's own parents or children.

7 Conclusive remarks

The review presented in this paper reveals many interesting aspects of the tsunami risk perception worldwide. As a general starting point, we can say that most of the cases reported here point out the low consideration of tsunami risk by people living in the coastal areas, independently from the region of the world and from the frequency of past tsunamis. There are some exceptions to this, especially in areas where recent tsunamis have occurred (Arias et al., 2017; Thomas et al., 2021). Also people's recent experience of other extreme events (different from tsunamis) determines a better attitude towards mitigation actions and correct response, particularly when the impact of these events on the interviewees has been strong (Buylova et al., 2020).

In general, it appears that in many regions the risk posed by "small" tsunamis is strongly underrated. It has been observed in many cases that even tsunamis with instrumentally measured runup of less than 1 m could generate important inundation and severe damage, as happened for instance in Turkey and Greece with the Samos-Izmir event of 30 October 2020 (Dogan et al., 2021). It seems that the collective image of tsunamis is dominated by the huge inundations provoked by the 2004 and 2011 tsunamis in Indonesia and Japan and broadcasted worldwide. The impact of small tsunamis (i.e., 1–2 m runup) is certainly lower than the mega-tsunamis just quoted, but it is not negligible. Moreover, these events are certainly more frequent than the giant ones. In Italy, after the surveys conducted by Cerase et al. (2019) and Cugliari et al. (2022) particular attention has been given to this concept in the communication with stakeholders, students, and citizens.

Somehow related to this, another interesting aspect emerging from different studies is the use of the term "tsunami" (as known, a Japanese language term) and of other terms traditionally used in the local language, such as for instance "maremoto" in Italian and Spanish (Cerase et al., 2019), or "flodbølge" in Norwegian (Goeldner-Gianella et al., 2017). Although tsunami scientists prefer to use the word *tsunami* for any type and size of the phenomenon, it seems that people prefer the local term. Also, they tend to associate the word *tsunami* to a giant wave (or series of waves), while the local term is considered more familiar and the phenomenon less dangerous.

Another common aspect emerging from our analysis is the importance of memory in people's perception of tsunami risk (Arias et al., 2017; Wei et al., 2017; Cerase et al., 2019). In this sense, the need for frequent drills has emerged in several areas (Gravina et al., 2019; Buylova et al., 2020; Chen et al., 2021), as important tools for stimulating the response of citizens towards the tsunami risk.

The perception of tsunami risk appears to be modulated depending on several socio-demographic characteristics, but there is not a homogeneous behavior among different countries or even nearby cities (Kurita et al., 2007). Cerase et al. (2019) find a positive correlation between education level, risk perception and adopted behaviors, but other authors in different countries do not (Wei et al., 2017).

Another important matter emerging from some of the analyzed studies is the recognized importance of the so-called "natural warnings" that come before or along tsunami events, and the need to make people aware of them. It is clear to the scientific community that for local tsunami sources, especially for those generated by earthquakes occurring along faults very close to the coasts (near-field tsunamis), the time of response must be very short, less than 5 min. The recent case of the Palu, Sulawesi tsunami in 2018 (Harnantyari et al., 2020) and the Samos, Greece, event of October 2020, as well as other past events, such as the 1908 Messina Strait one, demonstrate the need for a rapid and effective response by the population in the very few minutes after the onset of the seismic event, that should be independent from (or better complimentary to) the response expected in case of official warnings (alerts from civil protection authorities). This can be reached with a correct and continuous education of the population to face the tsunami risk.

Another element emerging from some of the studies analyzed here is the importance of traditional media, mainly TV, as the main source of information for people (New Zealand, Italy, Romania, Norway), and as one of the preferred ways to receive alert messages (Kurita et al., 2007; Cerase et al., 2019; Dhellemmes et al., 2021).

From the methodological point of view, we note the lack of a common strategy for evaluating people's awareness and perception of the risk. The twenty-three papers analyzed in this review use different methodologies and samples, not always representative of the whole population exposed at tsunami risk. The majority of the studies investigate local communities, and only a few papers deal with tourists (Arce et al., 2017; Constantin et al., 2017; Liotard et al., 2017; Hall et al., 2019). This is a drawback of this type of studies, since many of the regions under study are vacation destinations, in which the population increases by an order of magnitude during the summer season. In the Italian case, besides residents, we have also started to sample citizens living in non-coastal regions of Italy by administering the questionnaire (as in Cerase et al., 2019) to a national panel representative of the Italian citizens living all over the Country, thus including tourists traveling to the seaside in the summer (Cugliari et al., 2022). However, more detailed studies with specific target population groups are being planned, especially in complex contexts such as the Stromboli volcano, where both a multi-risk (volcanic explosions, tsunamis) and a multi-source tsunami risk (from flank collapse, landslide, pyroclastic flow) must be faced.

Finally, the analysis presented in this review reveals a strong heterogeneity in the adopted methodological approaches and in the sampled population, making it difficult to compare the results among different regions and situations. A more standardized approach in this type of studies would allow a more comprehensive assessment of tsunami risk perception worldwide.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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