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Tsunami Ready, a public engagement tool for risk mitigation: The Italian experience

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Abstract

In this article, we describe the functioning of a Tsunami Warning (and mitigation) System (TWS), with particular attention to its downstream component. Besides the scientific and technological developments of such systems, it is important that scientists get involved with society at various levels to help reducing the tsunami risk, supporting actions by local communities and authorities, and supporting the interface between science and policy. In particular, we point our attention to the importance of involving citizens in the risk reduction strategy, starting from the background of the UN Sendai Framework for Disaster Risk Reduction (SFDRR) 2015-2030 which focus on people and their needs: There has to be a broader and a more people-centred preventive approach to disaster risk. The approach of the Italian Tsunami Alert Center of the Istituto Nazionale di Geofisica e Vulcanologia (INGV) for tsunami risk mitigation involves several activities aimed at increasing people's awareness and preparedness, including the UNESCO IOC Tsunami Ready Recognition Programme (TRRP) discussed in this contribution. After describing the study of tsunami risk perception carried out in recent years in Italy, we focus on the experience gained in our country over the past four years, particularly examining the TRRP of Minturno, the first Italian municipality to receive this recognition in July 2024.

Keywords: Tsunami risk; Risk perception; Tsunami ready; People-centred early warning; Safe Ocean

1. Introduction: Tsunami Warning Systems, upstream and downstream

The UN Sendai Framework for Disaster Risk Reduction 2015-2030 (SFDRR)[1], moving from the outcome of the Hyogo Framework for Action 2005-2015: Building the Resilience of Nations and Communities to Disasters (HFA)[2], recommends *to invest in, develop, maintain and strengthen people-centred multi-hazard, multisectoral forecasting and early warning systems (…); develop such systems through a participatory process; tailor them to the needs of users, including social and cultural requirements*. It is clear the increased emphasis on people and on their needs compared to what was envisaged in the HFA. SFDRR acknowledges that after the publication of the HFA, *progress has been achieved in reducing disaster risk at local, national, regional and global levels by countries and other relevant stakeholders*. However, it also recognizes that in the ten years following HFA disasters have continued hitting heavily many countries: *over 700 thousand people have lost their lives, over 1.4 million have been injured and approximately 23 million have been made homeless as a result of disasters*. For this reason, the SFDRR set new goals for Member States efforts to reduce disaster risk, requiring *an all-of-society engagement and partnership*. A special emphasis is given to people-centred Early Warning Systems.

Like all the warning systems, the TWS (Tsunami Warning System) is basically composed of an “upstream” and a “downstream” component. The first part consists in all the scientific and technological components (hardware and software) useful to provide a rapid assessment of an impending tsunami and the dissemination of a warning message. The second part includes the way through which the warning messages reach the people at risk and trigger a self-protective behaviour. This is a simplification since these two components are somehow connected to each other and partly overlapping. In particular, the “downstream” part includes many relevant

[1] https://www.undrr.org/publication/sendai-framework-disaster-risk-reduction-2015-2030 (accessed 30 January 2025).
[2] https://www.undrr.org/publication/hyogo-framework-action-2005-2015-building-resilience-nations-and-communities-disasters (accessed 30 January 2025).

aspects related to risk communication in different social contexts. Also, it is clear that without adequate people's awareness and preparedness, the effectiveness of a rapid and accurate warning would be greatly reduced if not nullified [Rafliana et al., 2022]. Both TWS components are important, of course, and both need to be rapid and effective. This contribution describes the efforts made in Italy in the last few years to mitigate the tsunami risk, with a particular emphasis to the downstream component. In this introductory section we will briefly describe the two components and the relationship between them, then in the following sections we focus on the historical and recent tsunamis in the Mediterranean and the related hazard, then we stress the importance of people's awareness and preparedness, and finally we concentrate on the Tsunami Ready Recognition Programme (TRRP)[3], one of the tools that have been proven to be more effective for the downstream component. The programme has been implemented in many UNESCO Member States in the last few years, including Italy and other countries belonging to the Intergovernmental Coordination Group (ICG) for the North East Atlantic and Mediterranean and connected seas (NEAM) Tsunami Warning and mitigation System (TWS), one of the four ICGs constituting the global tsunami warning and mitigation system coordinated by the UNESCO Intergovernmental Oceanographic Commission (IOC).

The NEAMTWS formally started its activities in 2005, soon after the 2004 Indian Ocean tsunami. This dramatic event motivated UNESCO to assign to the IOC the task of coordinating a global "system of systems" for tsunami warning and mitigation[4]. Besides the Pacific Tsunami Warning System, already operating from the middle part of 20th century, three more ICGs were established, namely the Indian Ocean TWS, the Caribbean TWS, and the NEAMTWS, covering the European and North-African coasts of the Atlantic, and all the European, African and Asian countries facing the Mediterranean Sea, the Marmara Sea and the Black Sea [IOC, 2017].

In the following years, all major oceans were covered by tsunami monitoring and warning systems. These were based on the monitoring of large earthquakes that occur at sea or along the coasts, and therefore needed to be fed by real time seismic networks able to detect and measure earthquake location and magnitudes with a time delay and spatial accuracy good enough to allow tsunami warning (i.e., a few minutes of delay and less than 10-20 km location accuracy). In the first decade of the 21st century this was not so easy to realize, but at the end, thanks to the efforts of the Member States and the first trans-national seismic networks experiences, such as MedNet, Geofon, Geoscope, besides the global networks managed by USGS, IRIS, and the European consortium ORFEUS, it was possible to

[3] https://tsunami.ioc.unesco.org/en/tsunami-ready (accessed 30 January 2025).
[4] https://tsunami.ioc.unesco.org/en/history (accessed 30 January 2025).

achieve a good level of real time monitoring of moderate to large earthquakes in the NEAM region.
On the sea level monitoring side, things were even worse, with a lack of ability to share national data for many years. This problem was also solved, and tide gauge data in the Atlantic and the Mediterranean became a basic component of the emerging NEAMTWS.
This is the reason why it took several years to establish the first candidate Tsunami Service Providers (TSPs) for NEAM, which started their monitoring activity in 2012-2013. After a few years of testing, by the end of 2016 four official TSPs were operating in the NEAM region (CENALT in France, NOA in Greece, INGV in Italy, KOERI in Türkiye), joined in 2018 by IPMA, the Portugal's TSP. The operations, achievements, limits, gaps of the NEAMTWS are discussed in Amato et al. [2021] and in Lorito et al. [2021].
These five TSPs cover the whole NEAM seas, with some overlapping which warrants redundancy. In the last 8 years, several tens of earthquakes in the magnitude range 5.5 to 7.8 have generated tsunami information or alert messages in the region. Some of these earthquakes did actually trigger tsunamis, in a few cases with runup (i.e., the maximum topographic height reached by the tsunami) of 2-3 meters, damages, and even one death (in Türkiye for the M7.0 2020 Samos event) [Yalciner et al., 2020; Triantafyllou et al., 2021; Kalligeris et al., 2022]. Diffuse damage was also produced by a similar, smaller event that occurred near the island of Kos (Greece) and the city of Bodrum (Türkiye) in 2017 [Dogan et al., 2019]. This kind of events have emphasized the risk posed by "small" tsunamis, that are not as dangerous as the mega-tsunamis (like the M9.2 2004 Sumatra-Andaman or the M9.1 2011 Tohoku events) of course, but still can produce local damage and loss of life. Furthermore, their frequency of occurrence is higher. Risk perception surveys carried out in the last few years have shown that the awareness of tsunami risk in Italy is generally low, and that small tsunamis are not considered as a real hazard [Cerase et al., 2019; Cugliari et al., 2022a].
In the next two sections, after a review of the history and the tsunami hazard studies of the NEAM region, we describe the results of risk perception studies carried out with the Italian citizens, students, tourists in different environments, and what can be derived from these studies for risk mitigation. Then, we will describe the principles of the TRRP approach, which implies the active participation of authorities, citizens and local associations in risk mitigation strategy. After that, we report on the Italian experience about the TRRP, with the first municipality which obtained the recognition in 2024, and on other communities that are on the way to it.

2. Tsunamis in the Mediterranean Sea

The NEAM region has a well-documented history of tsunamis, recorded through instrumental, historical, and archaeological sources, as well as geological evidence such as paleotsunami deposits and geomorphological features [Mastronuzzi et al., 2007; Maramai et al., 2014, 2019; Papadopoulos et al., 2014; De Martini et al., 2017; Stiros, 2020; Triantafyllou et al., 2022]. According to the Euro-Mediterranean Tsunami Catalogue [Maramai et al., 2019], nearly 300 tsunamis have been documented in the NEAM region from prehistoric times to the present, with varying intensities. Approximately 83% of these tsunamis are of seismic origin, mostly triggered by submarine earthquakes, with a smaller percentage resulting from onshore seismic events. This distribution aligns with the global patterns of tsunami occurrence (provided by the US National Centers for Environmental Information, formerly the US National Geophysical Data Center[5]).

A small fraction of past tsunamis, less than 5% of the total, were caused by volcanic activity, primarily from Mediterranean volcanoes. Notable examples include the 2002 Stromboli event, which generated a run-up height of up to 10 meters [Tinti et al., 2006], and the late Bronze Age Santorini tsunami, whose full impact is still an open question for researchers [e.g., Novikova et al., 2011]. Most of the highly destructive tsunamis in the NEAM region - 9 out of 11 events rated at an intensity of 6, the highest level on the Sieberg-Ambraseys scale [Ambraseys, 1962] - occurred within the Mediterranean Sea. This region contains zones with high tsunamigenic potential, including the Hellenic Arc, Cyprus Arc, and the Ionian subduction zone. The most catastrophic Mediterranean tsunami on record occurred on July 21, 365 A. D., triggered by an earthquake along the Hellenic Arc subduction zone with an estimated magnitude above 8.0. This event had devastating effects across the central and eastern Mediterranean, and extensive archaeological, geological, and historical records have allowed for precise dating and detailed reconstructions of its impact across the region [De Martini et al., 2010; Stiros, 2020].

Other seismically active marine and coastal zones have also experienced tsunamigenic earthquakes, including among others, the one at Antioch (Türkiye) in 115 A. D. [Reinhardt et al., 2006]. Italy's documented most destructive tsunami occurred in the Strait of Messina on December 28, 1908, following an earthquake with an estimated magnitude slightly over 7.0. Historical records describe how a powerful tsunami struck the coasts of eastern Sicily and Calabria (southern Italy) just minutes after the earthquake, compounding the devastation [Baratta, 1909; Omori, 1909]. On Sicily's eastern coast, the tsunami's maximum run-up reached

[5] NCEI/WDS Global Historical Tsunami Database, 2100 BC to Present. https://doi.org/10.7289/V5PN93H7.

nearly 12 meters above sea level, and south of Reggio Calabria, a run-up height of 13 meters was recorded in Pellaro. This tsunami is estimated to have caused around 2,000 fatalities in addition to the approximately 80,000 deaths from the earthquake. In recent years, Mediterranean coastlines have continued to experience tsunamis, such as those triggered by the Mw6.6 Kos-Bodrum (Greece-Türkiye) earthquake in 2017 [Dogan et al., 2019] and the Mw7.0 Samos-Izmir (Greece-Türkiye) earthquake in 2020. This event, while not classified as catastrophic, still caused significant damage both in Greece and Türkiye and resulted in one fatality. A run-up of about 3 meters above sea level was recorded on the island of Samos (Greece), with other affected areas experiencing run-up heights of at least 2 meters [Yalciner et al., 2020; Triantafyllou et al. 2021; Kalligeris et al., 2022].

Historically, the eastern and central Mediterranean have been the most tsunami-prone regions. Since the late 18th century, around 30 tsunamis of various intensities have been recorded every 50 years, consistent with findings from the 2018 NEAM Tsunami Hazard Model [Basili et al., 2021], named NEAMTH18 (Figure 1).

This hazard model has been compiled by an international effort in the framework of the EU project TSUMAPS-NEAM, funded by the DG-ECHO in 2016-2018 [Basili et al., 2021]. The result of this project is a probabilistic hazard assessment for tsunamis of seismic origin (S-PTHA), which takes into account not only the historical data mentioned above but also the geological and seismological knowledge (Figure 1). In other words, all potential tsunami sources (of seismic origin) have been compiled, including subduction earthquakes in the Hellenic, Cyprus, Calabrian arcs, and crustal faults in other regions. Both are able to generate tsunamis, although of different sizes. Each of the individual potential tsunami sources has been attributed specific characteristics based on the current knowledge, for example maximum magnitude, probability of occurrence, and other parameters (see Basili et al. [2021], for a detailed description of the method and of the model).

In Italy, the NEAMTH18 results have been used for defining the inundation zones for the two alert levels used in the warning: Advisory and Watch [Amato et al., 2021]. The first implies a maximum expected run-up of 1 meter, while the second means expected run-up higher than 1 meter. The upper limit for the inundation distance in the latter case has been chosen according to the hazard level, after an interaction among the SiAM components (Sistema nazionale di Allertamento per i Maremoti di origine sismica; national alerting system for seismically generated tsunamis) composed by the national Civil Protection Department (DPC), the Tsunami Alert Center of the Istituto Nazionale di Geofisica e Vulcanologia (CAT-INGV), the Istituto Superiore per la Protezione e la Ricerca Ambientale (ISPRA). The DPC decided to adopt a specific level of protection (in particular, an Average Return Period - ARP, of 2,500 years at the 84th percentile of the epistemic uncertainty distribution).

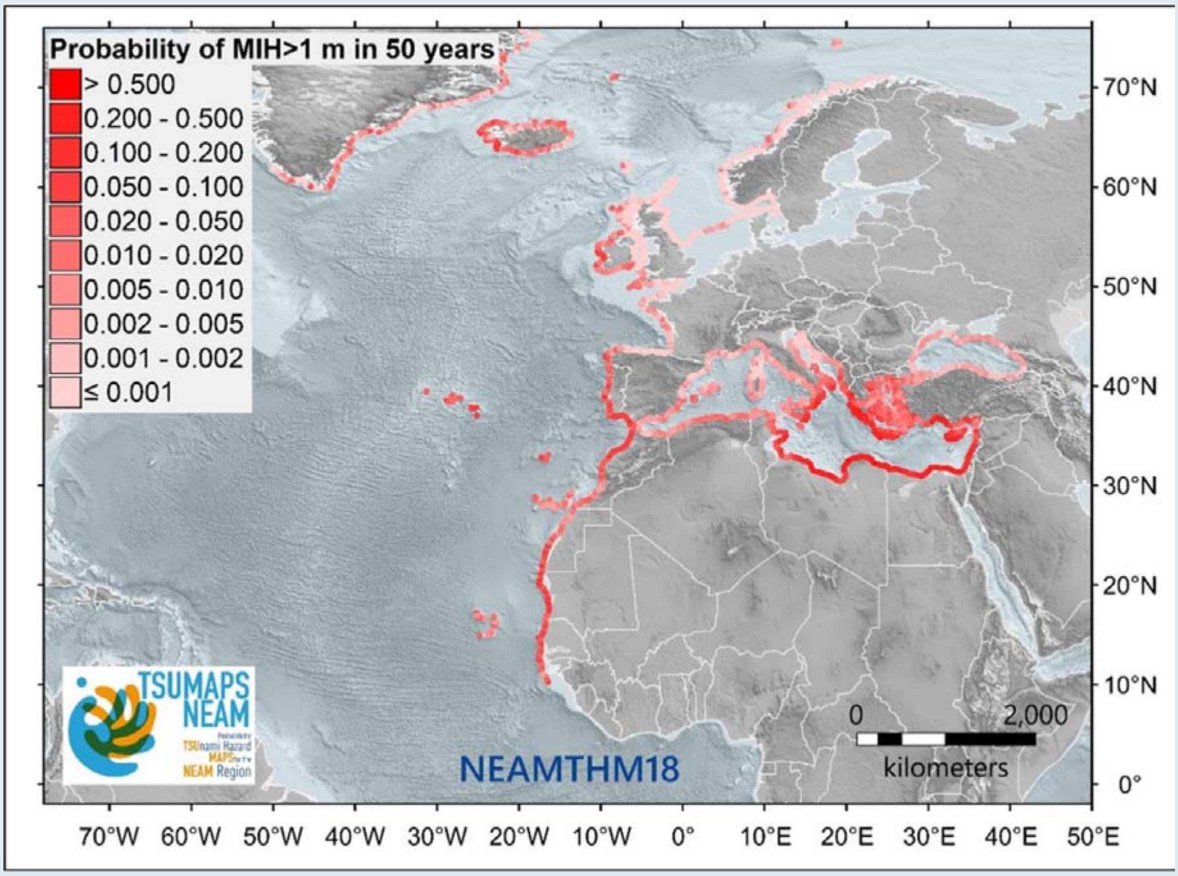

Figure 1. *Map showing the NEAM Tsunami Hazard Model 2018 (NEAMTHM18) [Basili et al., 2018] for the NEAM region [after IOC, 2022]. The different colours on the PoIs (Points of Interest) give a measure of the hazard level (shown are the probabilities of a Maximum Inundation Height - MIH - of 1 meter over a 50-year period). See Basili et al. [2021] for details of the hazard model (figure modified after UNESCO-IOC [2022a]).*

These inundation areas have been formalized and are published on the ISPRA website[6], where the methodology to convert hazard values into inundation areas is explained in detail [see also Tonini et al., 2021].

These zones are the official reference values for the whole coastal regions of Italy and should be adopted by the municipalities for their civil protection plans, unless some official, local high-resolution studies will replace them. A comparison for some selected sites in Italy between the national planning and high-resolution local studies has been carried out by Tonini et al. [2021]. To date, the municipalities running for the TRRP have adopted the national hazard values for their planning.

[6] https://sgi2.isprambiente.it/tsunamimap (accessed 30 January 2025).

In the next section we describe the importance of raising awareness and preparedness in an early warning system framework, and then we discuss the TRRP and its value both for communities and for civil protection officers also from a legal perspective, and finally the application to the NEAM region and to the Italian case.

3. The importance of awareness and preparedness

Large tsunamis occur relatively infrequently but have a strong destructive potential. For this reason, they are called High Impact - Low Frequency events. This peculiarity explains why tsunami risk is often underestimated, especially in the Euro-Mediterranean and Italian context. Small tsunamis, however, can occur more frequently and still cause damage and threaten the lives of people near the coast, but also these events are relatively rare, if compared to other risks, and are not considered a priority in risk mitigation policies in the NEAM region [Amato, 2020]. Consequently, mitigation actions by the responsible authorities and scientists must be continuous and long-term oriented. In fact, among the major challenges scientists face to mitigate tsunami risk of the population are i) increasing knowledge of the physical phenomenon, ii) increasing awareness related to the individual and collective capacities to react and response, iii) improving individual and collective preparedness, also through dissemination campaigns and drills.

The importance of awareness and preparedness aspects emerged strongly following tsunamis in the recent past. For awareness the authors refer to the understanding and knowledge individuals and communities have about tsunamis, their causes, impacts, and appropriate responses [Esteban et al., 2013; Goltz and Yamori, 2020; Dhelemmes et al., 2021]. With preparedness the authors mean the ability of people to activate measures and plans developed to reduce the risks and impacts of tsunamis on communities and infrastructure [Lindell and Prater, 2010; Mat Said et al., 2011]. Both contribute to risk mitigation, that is, a combination of preparedness, early warning systems, community education, and structural adaptations [Bird and Dominey-Howes, 2006; Syamsidik et al., 2006; Oetjen et al., 2022].

The 2004 Indian Ocean tsunami demonstrated how varying levels of awareness and preparedness could mean the difference between people's life and death. Indeed, in some cases, awareness and the adoption of appropriate behaviour (preparedness) led to both individual and collective survival. Conversely, a poor example of preparedness was seen in those who, in some locations, attempted to escape using personal vehicles such as cars and scooters but were unable to evacuate in time. Another example is that of tourists staying in the affected areas who, unaware of the phenomenon, failed to recognize the 'premonitory' signs and were tragically swept away by the tsunami. On the other hand, there are at least two remarkable examples of great awareness and preparedness. The first, well known in the tsunami experts' community, is a testimony of the importance of recognizing tsunami warning signs. Tilly Smith, at the time an 11-year-old girl on vacation with her family in Thailand, saved about 100 people on a crowded tourist beach before the 2004 tsunami struck. She had learned about natural tsunami warning signs in school, including the crucial indicator of sea withdrawal before inundation. This knowledge enabled her to alert those around her, allowing them to react correctly and save themselves.

The Simeulue indigenous community, consisting of about 70,000 people living on an island in the Indian Ocean west of Sumatra, is another example of effective self-protection practices. In this case, however, tsunami awareness comes from the community experience transmitted from generation to generation and still alive today in the cultural traits of the Indonesian islanders [McAdoo et al., 2006]. This community, following the impact of tsunamis in the past (mainly the 1907 event) has adopted self-protection mechanisms summarized in a folk song called *Smong* [Syafwina, 2016; Rahman et al., 2018]. The text of the song evokes the phenomena associated with the arrival of a tsunami and connects them to the behaviour that the community must adopt when premonitory phenomena are observed. This last example recalls historical memory and anthropological traditions into play, elements that influence tsunami risk perception and response. This follows one of the indications of the SFDRR, according to which it is important that *Indigenous peoples, through their experience and traditional knowledge, provide an important contribution to the development and implementation of plans and mechanisms, including for early warning*.

An example emerged in Japan during the earthquake and massive tsunami of March 11, 2011. This event occurred in a different cultural context, with an effective tsunami warning system in place (unlike the situation in the Indian Ocean in 2004). Once again, it was observed how knowledge of tsunamis and the warning messages sent by authorities through various media prompted rapid evacuation reactions from the population. This demonstrates the extent to which drills, trust in institutions, and strong community preparedness contribute to coherent behaviour in emergency situations and then lifesaving. On the other hand, during mega-events like the 2011 tsunami, very rapid warnings and responses are essential. In such cases, the large uncertainty during the first few minutes can cause breakdowns in crisis communication. Indeed, shortly after the event, the initial information disseminated by the authorities was incorrect and misleading, prompting people to react quickly according to inappropriate evacuation procedures. This may have resulted in additional casualties and missing persons, which ultimately numbered around

19,000 [Oki and Nakayachi, 2012]. We thus observe how awareness and preparedness are related. Indeed, good awareness is not effective if it lacks preparedness; conversely, preparedness may not be assimilated if there is no proper awareness. There are multiple dynamics and different variables involved in this discourse that we will not address here. Certainly, a central role is played by continuous proper risk communication ("peacetime communication") and effective communication during crises ("emergency communication").

An essential factor for any attempt of increasing people's awareness and response is the understanding of risk perception. The tsunami risk perception includes variables such as socio-demographic issues, the knowledge of the phenomenon and its representation as it is assimilated through external stimuli (media mainstream, social media, scientific information etc.) and/or handed down by distinctive cultural traits that characterize each territorial context. In the perception of risk, there are also psycho-social aspects affecting individual and collective dynamics, as well as elements connected to personal experiences or transmitted by peers also through storytelling of past events.

Assessing the degree of awareness and preparedness of a community with respect to tsunami risk is not easy. For this reason, since 2018, the Tsunami Alert Centre, with the support of the DPC, has conducted a systematic study on tsunami risk perception in Italy.

At the time we write (February 2025), the opinions of 11.192 residents in coastal municipalities all over Italy have been collected, through the administration of a structured questionnaire in four survey phases (2018 - 2020 - 2021 - 2024). The sample was designed to be representative of the whole coastal population of Italy, that is, about 16.9 million people living in about 1,600 municipalities of 15 Italian regions, from Liguria and Sardinia to the West, to Veneto and Friuli-Venezia-Giulia to the East (Figure 2).

In six years, one of the largest tsunami risk perception surveys worldwide using a statistically robust survey instrument has been completed. The survey, consisting of 27 questions, was conducted with CATI (Computer Assisted Telephone Interview) methodology by expert companies. In addition, in the survey phases completed in 2021 and 2024, we surveyed tsunami risk perception on a stratified sample of the entire Italian population. The latter survey is useful as a benchmark between the population residing in coastal municipalities and the nationwide sample to understand variations in perception, and is useful also to target communication interventions according to different needs. Last but not least, surveying the opinion of those who do not live on the coast allows us to find out the opinion of potential tourists who will spend their Summer holidays in coastal areas.

All the details on the methodology and on the panel's characteristics (age, class, gender, education, etc.) are described in the papers by Cerase et al. [2019] and Cugliari et al. [2022a].

Figure 2. *Distribution of tsunami risk perception interviews done in Italian coastal municipalities. The different colours identify the four survey phases between 2018 and 2024.*

In another recent project funded by the DPC, a revised and contextualized version of the questionnaire on tsunami risk perception was administered in the Summer of 2022 and 2023 to tourists visiting Stromboli Island, where tsunami risk is mainly associated with volcanic activity. Moreover, during the Summer of 2024, a group of Stromboli residents was interviewed face-to-face with qualitative methodology through a set of open-ended questions. Specifically, the survey outputs on tsunami risk perception in Stromboli are discussed in Moreschini et al. [2024]. Also, Cugliari et al. [2022b] published a literature review on tsunami risk perception, reviewing 23 internationally distributed scientific papers. Another survey was conducted between 2022 and 2023 in a high school near Rome, with a longitudinal study conducted in three subsequent steps on a group of four classes [Amato et al., 2024]. The main results of the research produced so far from the survey on tsunami risk perception in Italy can be summarized as follows:

- A large uncertainty was found among respondents regarding the possibility of a tsunami occurring in the Mediterranean Sea. Specifically, 28% of respondents indicated that it is likely to occur, while 29% indicated that it is unlikely. The remaining 43% selected the median response, indicating that they consider it neither likely nor unlikely.
- However, if a tsunami hit the Italian coasts, for 43% of the respondents this would not hit the coasts of their municipality of residence. 24% of respondents indicated that they did not know whether a tsunami would ever hit the coasts of their municipality of residence and the remaining 33% thought this might happen.
- The survey results also allowed us to make a careful distinction between ‘real’ hazard (estimated hazard that a tsunami could hit the Italian coasts) and perceived risk (risk perception by the coastal community). In this regard, in the article by Cugliari et al. [2022a] the tsunami risk perception by interviewees residing on the coasts of Metropolitan cities in central and southern Italy (cities characterized by high population density and territorial extension, e.g. Rome, Naples, Reggio Calabria, Catania) was compared to the tsunami hazard (S-PTHA) estimated in the same stretch of coast by Basili et al. [2018].
- Several differences in terms of tsunami risk perception emerge between the different Italian coastal slopes (Adriatic and Tyrrhenian Seas), as well as comparing southern Italian regions e.g. Calabria, Apulia, eastern Sicily and Sardinia. Detailed outputs are described in the papers by Cerase and Cugliari [2023] and Cugliari et al. [2022a].
- The questions concerning communication aspects are also interesting: those with higher educational levels have a better tsunami risk perception. The younger age group has a lower tsunami risk perception and the 50+ age group a higher tsunami risk perception. TV is confirmed, as in other studies, as the

largest source of information on tsunamis, and most respondents said they would prefer to receive the tsunami warning through TV.
- Learned notions on tsunami risk (after presentations, lessons, discussions, etc.) need to be refreshed often and integrated into didactic or educational paths at various levels.

The summary points described above show the need to increase awareness and preparedness of the tsunami risk through interventions aimed at target audiences. The population living in Italian coastal municipalities needs to receive information regarding natural risks contextualized to their territory, continuously so that their memory and awareness remain at sufficient levels to be able to activate appropriate behaviours and reactions in the event of an emergency.
We have thus seen how important it is to increase both awareness and preparedness in the community, and how these two concepts can be assessed through the risk perception study. An element that we would like to emphasize is the need to use robust and structured tools for assessing the impact of tsunami risk mitigation interventions. A strategic plan with continuous interventions requires adaptation and updating according to the level reached by the target population and, even more, according to the rapid evolution of the means of communication and individual and collective abilities to use information and convert it into appropriate behaviours. This last aspect has undergone a notable acceleration in the last twenty years. It is necessary for the risk managers to take this into account by using every means that facilitates the mitigation process.
In this framework, the introduction of the TRRP provides a standard and schematic tool, easily interpretable at various levels as it is structured with a limited though exhaustive set of indicators that need to be reached to get the recognition.

4. The UNESCO TRRP

The idea and first applications of the “Tsunami Ready” Recognition Programme (TRRP) were proposed in the U.S.A. with the goal of standardizing the actions for tsunami risk mitigation of communities. From 2015, the UNESCO-IOC Intergovernmental Coordination Group for Tsunamis and other Coastal Hazards for the Caribbean and Adjacent regions (ICG-Caribe) recommended the approval of the TRRP guidelines, and the IOC General Assembly approved this recommendation. The goal of the TRRP is to improve coastal community preparedness for tsunami emergencies and to minimize the loss of life and property, through a collaborative effort aimed at achieving a standard level of tsunami preparedness [UNESCO-IOC, 2022a]. Soon after, also the ICG/NEAMTWS endorsed the TRRP approach and took it as a reference programme to improve tsunami risk mitigation of coastal communities. In the NEAMTWS Strategy 2030 [UNESCO-IOC, 2022b], the TRRP is one of the strategic objectives in the framework of Pillar 3 (Awareness and Response). Each candidate community must nominate a Tsunami Ready Local Committee (TRLC) that follows the advancement of the programme and reports to the Tsunami Ready National Board (TRNB). UNESCO-IOC leaves a high flexibility in the composition of both the TRNB and the TRLC, depending on how the national Civil Protection (CP) system is managed, and how the local communities are organized in the territory. One important issue, however, is that the TRLC includes, besides local authorities (e.g., the mayor, the CP responsible, the local police or local coast guard coordinators), also citizens' associations (e.g., volunteers) as well as commercial activities associations (e.g., hotels, campings, stores, etc.). The TRRP includes a suite of twelve indicators that must be pursued by local communities, divided in the three main categories of a) Assessment, b) Preparation, c) Response (Figure 3).

	TSUNAMI READY INDICATORS
I	**ASSESSMENT (ASSESS)**
1	**ASSESS-1**. Tsunami hazard zones are mapped and designated.
2	**ASSESS-2**. The number of people at risk in the tsunami hazard zone is estimated.
3	**ASSESS-3**. Economic, infrastructural, political, and social resources are identified.
II	**PREPAREDNESS (PREP)**
4	**PREP-1**. Easily understood tsunami evacuation maps are approved.
5	**PREP-2**. Tsunami information including signage is publicly displayed.
6	**PREP-3**. Outreach and public awareness and education resources are available and distributed.
7	**PREP-4**. Outreach or educational activities are held at least three times a year.
8	**PREP-5**: A community tsunami exercise is conducted at least every two years.
III	**RESPONSE (RESP)**
9	**RESP-1**. A community tsunami emergency response plan is approved.
10	**RESP-2**. The capacity to manage emergency response operations during a tsunami is in place.
11	**RESP-3**. Redundant and reliable means to timely receive 24-hour official tsunami alerts are in place.
12	**RESP-4**. Redundant and reliable means to timely disseminate 24-hour official tsunami alerts to the public are in place.

Figure 3. *The twelve TRRP indicators (see text for explanation).*

The first section (Assessment) in Figure 3 deals with the definition of hazard zones and with the exposure and vulnerability indicators. The other two sections

(Preparedness and Response) and the related nine indicators focus on people and on their ability to understand the risk and to be ready to act. Emphasis is posed on outreach/educational resources and activities, exercises, response plans. This reflects one of the relevant indications of the SFDRR that encourages the adoption of "people-centred" early warning systems.

5. Involving authorities and citizens with TRRP: a new paradigm of responsibility

The process of involving the population in preventive and operational choices in the event of an emergency constitutes, in the Italian legal system, the point of greatest emergence of a broader reconsideration of civil protection measures, inspired by international protection paradigms. Most of the programs in this field are coordinated by the United Nations Office for Disaster Risk Reduction[7].

Therein also lie the choices of the Italian legislator who, with Legislative Decree 1/2018 ("Codice della Protezione Civile"[8], i.e., Civil Protection Code), takes small but significant steps towards the recognition of non-structural mitigation activities, as well as an increasing role to the self-protective capacities of citizens. An example of this are the provisions of Article 31 of Legislative Decree 1/2018, which states that "The National Service promotes initiatives aimed at increasing the resilience of communities, encouraging the participation of citizens, both individual and associated, including through training of a professional nature, in civil protection planning as regulated by Article 18, and the dissemination of civil protection knowledge and culture". The components of the National Service of Civil Protection, within their respective powers, provide citizens with information on risk scenarios and on the organization of the civil protection services in their territory, also in order to enable them to adopt self-protective measures in emergency situations referred to in Article 7, paragraph 1, letters a), b) and c), during which they have the duty to comply with the provisions issued by the civil protection authorities in accordance with what is set out in the planning tools. Even if the objective of creating a real duty to act has not yet been achieved, the empowerment of a trained and informed population constitutes the acknowledgement of how the correct behaviour of the potential victim of disasters represents a primary guarantee of the effectiveness both of the warning mechanisms and risk reduction measures adopted by municipal, regional or national authorities.

[7] https://www.undrr.org/ (accessed 30 January 2025).
[8] https://www.protezionecivile.gov.it/it/normativa/decreto-legislativo-n1-del-2-gennaio-2018-codice-della-protezione-civile/ (in Italian, accessed 30 January 2025).

It was precisely the intention to enhance the population's skills in risk management that led to the decision to adopt, on an experimental basis, the TRRP aimed at involving the population in civil protection choices designed to mitigate the consequences of potential tsunamis. The programme, created in the early 2000s, was immediately implemented by the US National Weather Service (NWS) of the National Ocean and Atmospheric Administration (NOAA) and envisages coastal communities becoming better prepared to cope with tsunami risk through processes of urban planning, education and preparation of the population for emergency management. TRRP, adopted in 2011 under the aegis of UNESCO, has seen the involvement of a large number of communities in the Pacific and Indian Oceans as well as a number of NEAM municipalities as a pilot project in most recent years. The valorisation of the local dimension in the process of choosing and adopting civil protection measures determines a strong assumption of awareness by the population, which must itself take part in the training activity instrumental to risk prevention and to overcoming the criticalities connected to it. Moreover, the shared determination of life-saving precautions certainly increases their effectiveness and allows them to be more easily known and implemented by civil protection operators. TRRP is in fact an international protocol for risk prevention and management that dictates supplementary rules with respect to those dictated by the national legislator, which are certainly suitable for integrating the panorama of precautionary rules in a worthy way. The circumstance is apt to favour the choice of a more selective profile of criminal negligence which seems as desirable as it is complex to implement.

6. The pathway to TRRP in the NEAM region and in Italy

In 2019, some NEAM countries started to explore the possibility of using the TRRP framework to increase risk mitigation measures and activate a process that could involve the local communities to actively participate in this strategy. It must be considered that both the North-East Atlantic and the Mediterranean did not experience large tsunamis in the past few decades, therefore people's and authorities' tsunami risk awareness is generally very low (with a few exceptions in areas where the memory of past tsunamis is still alive). This represents an obstacle for reaching a good level of response by a community. However, thanks to the efforts of the ICG/NEAMTWS and of some UNESCO member states, the idea of getting an official UNESCO recognition has been successful. Indeed, after at least three years of activities, in 2024 six municipalities in six countries of the NEAM region have succeeded in obtaining the TRRP recognition (Cannes in France, Chipiona in Spain, Büyükçekmece in Türkiye, Samos in Greece, Alexandria in Egypt, Minturno in Italy). Other communities are on their way to get it in these and in other countries, like Portugal, Malta, Cyprus, and Israel. In Italy, the TRRP was introduced in three pilot sites in 2020. The three sites were chosen for different reasons, but basically for the documented sensitivity of the local authorities to the risk reduction policy. These are: Minturno in Latium, facing the central Tyrrhenian Sea; Palmi in Calabria, near the Messina Straits area (hit by the 1908 tsunami); Marzamemi (Pachino municipality, in Sicily) facing the Ionian Sea. The three areas have different levels of tsunami hazard [Basili et al., 2021]. Between the end of 2020 and 2021 all three municipalities nominated their TRLC. The Italian TRNB was established in May 2021 by the DPC Head. The TRNB was kept very simple, in order to have a more effective action: It is composed by representatives of the three Institutions composing the so called SiAM (Sistema nazionale di Allertamento per i Maremoti di origine sismica; national alerting system for seismically generated tsunamis) [DPC, 2017]. More recently, two other Italian communities have manifested their will to participate in the TRRP, namely Otranto in Apulia, another high hazard region, and the volcanic island of Stromboli, in the Tyrrhenian Sea, where the tsunami risk is high for the instability of its northwestern flank (the Sciara del Fuoco) where most of lava and pyroclastic products of the volcano tend to deposit (Figure 4).

Figure 4. *The five municipalities running for the TRRP. Minturno (in Latium) obtained the UNESCO recognition in July 2024. Palmi (in Calabria) and Marzamemi (in Sicily) are working for it since 2021, Otranto (in Apulia) and Stromboli (in Sicily) manifested their interest in 2023 and 2024, respectively.*

7. The Minturno (Latium, Tyrrhenian Sea) case

The municipality of Minturno, located in the province of Latina, on the Tyrrhenian coast of central Western Italy, was the first municipality in the NEAMTWS area to adopt the tsunami risk mitigation programme promoted by UNESCO. The path started in 2020 with the presentation of the TRRP at the municipality's headquarters, in the presence of the Mayor and his staff. The Tsunami Ready Local Committee, formally established soon after, has been following the accreditation process until the achievement of the objective, in July 2024. Minturno's coastal area had no tsunami risk mitigation system at the time the programme was proposed. There were just inundation maps of the area implemented by ISPRA for the whole Italian coast, not yet included in the civil protection plan.

In fact, following the establishment of SiAM in 2017, specific Guidelines were issued the year after by the DPC Head requiring municipalities to update their civil protection plans considering the tsunami risk [DPC, 2018]. However, the Minturno community and institutions, as well as those of many other coastal regions in Italy, did not know about tsunamis and related risks. Furthermore, there were no mitigation tools for tsunami risk or other hazard protection purposes such as sirens, vertical signage boards, or redundant means of communication to disseminate the alert throughout the territory. Municipal efforts have been considerable and continuous and also included the allocation of specific funds to install the mitigation elements indicated in the table of indicators, such as sirens and signals (Figure 5).

During the process, several meetings both with local authorities and emergency managers, and with the local population (mainly teachers and students) were held. The overall aim of the meetings was to increase knowledge and awareness of tsunami risk, starting from the discussion on defining the evacuation areas based on the hazard maps available on the ISPRA Tsunami Map Viewer website (see footnote 6 and Figure 6). Some of these meetings were held for specific occasions such as NEAMWave exercises, WTAD (World Tsunami Awareness Day), some of which were table top exercises and involved only local authorities, research institutes and local emergency managers. Some of these appointments also included vertical evacuation drills (e.g., in schools of various levels, from nursery schools to high schools) followed by didactic activities with teachers and students. In a meeting with students of the Leon Battista Alberti scientific high school in Minturno, a questionnaire on tsunami risk perception was administered in "*tabula rasa*" mode, before providing students any scientific information on tsunamis. On that occasion, 80 students as well as teachers and civil protection personnel were present in the lecture hall of the high school.

Figure 5. *One of the tsunami signs located along Minturno's seaside for the TRRP. There are dozens of these signs along the coast. Note that they are in both Italian and English.*

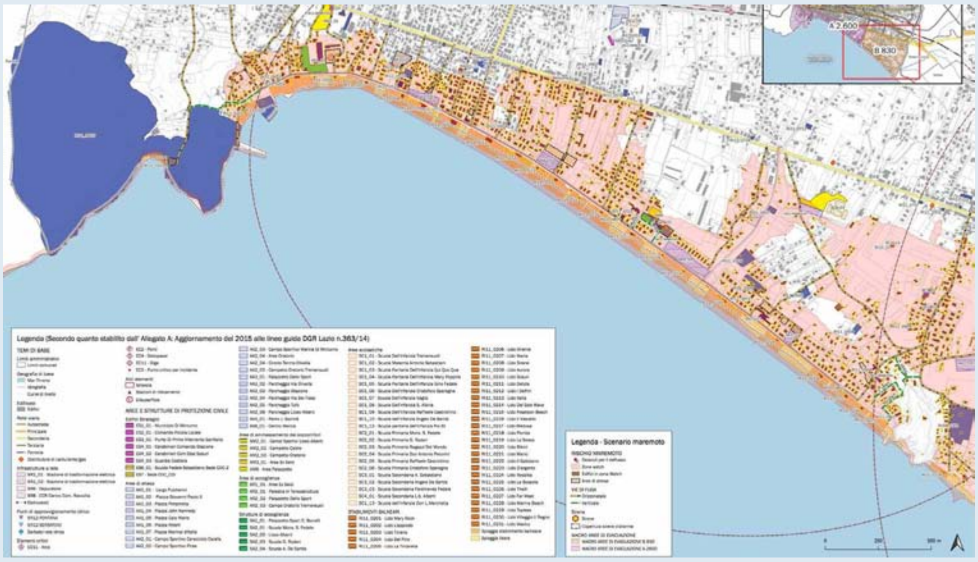

Figure 6. *Detail of Minturno's tsunami civil protection plan. The pink area along the coast represents the zone to be evacuated in case of a Watch (Red) alert. Evacuation routes, along with other elements, are shown on the map and described in the "Legenda".*

The same questionnaire used for the previously mentioned national study was administered for the survey. Data analysis showed that, as in the national sample, students associate different phenomena with two synonymous terms: *maremoto* (Italian word) and *tsunami*. For example, when asked, “What phenomenon do you associate with the word *maremoto* (the Italian term for tsunami)?” most respondents associated it with *terremoto* (earthquake) and *mareggiata* (storm surge), as shown in the word cloud (Figure 7). Similarly, when asked, “What phenomenon do you associate with the word *tsunami*?” most respondents associated it with *grande* (big), *onda* (wave), and *inondazione* (flood), as shown in the word cloud (Figure 7).

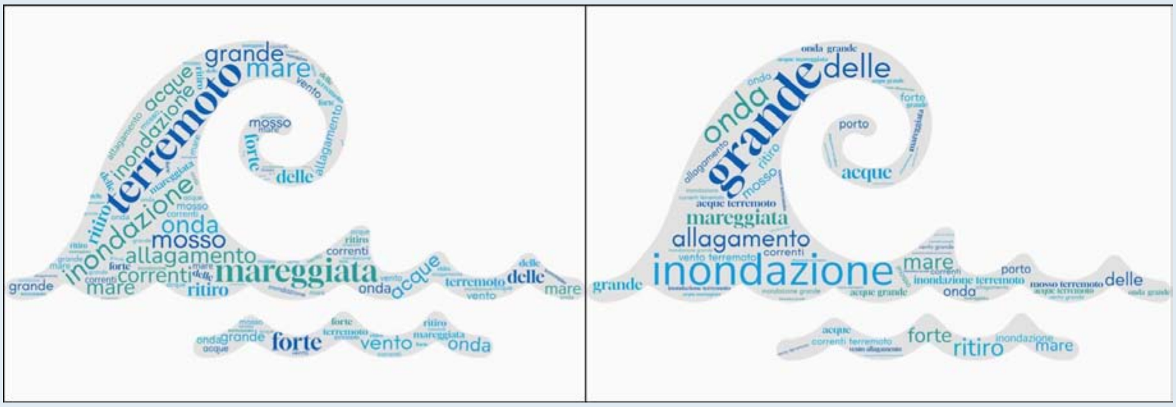

Figure 7. *Word cloud representations for the terms maremoto (left) and tsunami (right) in the survey carried out in the Minturno school. The size of the words is proportional to the number of times each word is mentioned by the interviewed.*

The fact that different terms are associated with two synonyms creates confusion and misalignment in understanding the phenomenon (tsunami) and, consequently, in determining the appropriate behavior to adopt in a real event.

Moreover, about 40% of respondents said that only a 3 meter or higher tsunami wave could be dangerous for a person; while it is known that even a 50-centimeter tsunami can drag an adult. More than 43% of respondents said that the Italian coast cannot be hit by a tsunami and about 30% said that they do not know. These are just some of the results obtained from the questionnaire and highlighted the need for more education on the topic. The accreditation process concluded in July 2024 when the Municipality of Minturno was recognized as a Tsunami Ready municipality by the UNESCO-IOC. Officially, from the appointment of the Local Board in 2021 to UNESCO recognition, the process took three years. The recognition ceremony was held in October 2024 (Figure 8).

Figure 8. *The Mayor of Minturno, Mr. Gerardo Stefanelli (right), discovers the Tsunami Ready recognition plaque received by the NEAMTWS Technical Secretary, Mr. Denis Chang Seng (left), during the ceremony in the Municipal Council room.*

8. Conclusive remarks

In this article, we illustrated some of the functions of the Italian Tsunami Alert Center, which operates as a NEAM Tsunami Service Provider for the DPC and UNESCO Member States in the Mediterranean region. We focused on the downstream component of the warning system, describing risk perception studies conducted in Italy and the implementation of the TRRP in our country. In particular, we highlighted the experience of the first Italian community to achieve this important recognition, i.e., Minturno, a municipality on the Tyrrhenian coast of central Italy. We described how this programme can help improve risk mitigation strategies at the local (municipal) level through a participatory approach. To obtain the recognition, municipalities can use the TRRP's framework to effectively guide their activities in reducing tsunami risk, following a structured scheme of twelve required indicators.

The TRRP has numerous strengths but also some weaknesses. Our experience with the communities that we have followed in Italy during the last few years, including Minturno, has shown that the Tsunami Ready strategy is well understood and appreciated by the local authorities and the local society. In particular, the formalization of a collegial organism like the TRLC is a good tool to address the strategy. Probably, something more can be done to reach a full involvement of the citizens in this approach. Indeed, it is true that the TRLC includes representatives of the society like touristic facilities and volunteers, however the full involvement of citizens, of all the touristic operators working in the territory, of teachers and students, is not easy to obtain, particularly in large municipalities with tens or hundreds of thousands of residents. Another criticality that we have experienced is the lack of a continuous activity and attention within the municipalities. This is understandable because local priorities are numerous, and addressing tsunami risk in areas where tsunamis are not part of people's collective memory is very difficult. The Minturno case was particularly challenging, as the area had no history of tsunamis, not even in the distant past. As a result, securing local engagement was even more difficult. Indeed, following the announcement of the recognition, some criticism emerged on social media, highlighting other municipal priorities and suggesting that funds should be allocated to initiatives other than tsunami risk mitigation. It is likely that citizens, authorities, and even local media operators feel that there are other priorities, both in the field of natural hazards—such as extreme weather events, forest fires, and pollution—and in other societal issues, including traffic, road conditions, parking areas, schools, and gyms. An additional criticality that may occur (fairly common in Italy) is the renewal of institutional positions and the related election periods at the local level. In the months leading up to an election (for the mayor and the municipal council, for instance) most activities are deprioritized. Additionally, the lack of dedicated personnel and funding can further hinder the process. Becoming Tsunami Ready requires personnel and financial resources to meet the twelve indicators. Often, Many municipalities lack sufficient expert staff to carry out the required activities and need funding to implement warning systems, such as sirens and apps, or to hire emergency planning specialists. Specific funding should be allocated to virtuous communities that choose to participate in such initiatives. The Municipality of Minturno managed to secure the necessary resources from its ordinary budget, but this is uncommon.

Scientific and institutional partners (such as INGV, universities, and civil protection bodies at national and regional levels) can make a significant contribution to some of the targets, particularly those involving citizens, school teachers, and students. In our experience, the direct involvement of people in initiatives like the "Io Non Rischio"[9] (I don't take risks) campaigns, as well as in lessons, meetings, drills, and focus groups, serves as a key driver in fostering proactive behaviour within communities. As with other 'citizen science' activities, sharing knowledge about

[9] https://www.iononrischio.gov.it/en/ (accessed 30 January 2025).

tsunami science and risk, engaging in discussions with students and citizens, addressing doubts and questions together, and assessing risk perception levels are keys to fostering active and ethical participation of both scientists and citizens in risk mitigation strategies [Peppoloni et al., 2019].

We believe that scientists working on natural hazards, in addition to scientific and technological advancements, must engage with society at various levels to help reduce tsunami risk, support actions by local communities and authorities, and strengthen the interface between science and policy. Like many other risks, tsunami risk can be reduced if people understand their role in the mitigation process by increasing their awareness, preparedness, and response. It is also important to note that the TRRP approach can easily be applied to other risks. Once the mechanism is activated and the local committee begins meeting, discussing, and actively participating in decisions regarding public safety, it can be encouraged to address other community issues, with the goal of fostering improved participatory democracy.

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