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ANALYSIS OF LOCAL RISK PERCEPTION IN THE EVENT OF A TSUNAMI – A CASE STUDY IN MANTA, COASTAL ECUADOR

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ABSTRACT

Local perception of risk is a determinant of urban vulnerability. Accordingly, this research addresses the analysis of local perception of the risk of tsunami hazards occurrences and this case study focuses on an area of the Tarqui parish in the city of Manta in coastal Ecuador. This work also presents the possible tsunamigenic seismic source in the subduction zone of the study area. The Tarqui Zone is located within a coastal and fluvial landscape that currently the enlargement of the urban limit has obstructed the free flow of these systems. Based on the tsunami hazard map for the city of Manta, we determined that there are 392 sites in an area with high susceptibility to flooding. There are also 996 sites with medium susceptibility to floods in a zone of maximum influence between the levels of 7 to 20 m.a.s.l, sites in which the flood processes and corresponding erosion may not be very intense. In addition, the perception of this hazard was strengthened using context indicators on local tsunami risk perception based on a survey format for heads of households. In this regard, the given surveys indicate that 29 per cent of the population is in a state of high vulnerability, 63 per cent are in a situation of medium vulnerability and only 8 per cent are in a position of low vulnerability. With the obtained results we realized curves of frequency of perception of the population regarding this hazard, which will serve for the authorities to improve their response plans

Keywords: Tsunami, hazards, flooding, social vulnerability, Ecuador.

1. INTRODUCTION

Ecuador is a country which suffers of a variety of natural hazards due to its geodynamic setting, based on the conjunction of several oceanic and continental plates such as the Pacific, Cocos and Nazca oceanic plates on the one side as well as the Caribbean and South American continental plates on the other side (Meschede & Barckhausen, 2000; Meschede, 1998; Gutscher et al., 1999; Gutscher, 2002; Lonsdale, 2005; Chunga et al., 2017). Based on this constellation, there is active and even long-lasting volcanism (Aguilera and Toulkeridis, 2005; Toulkeridis et al., 2007; Toulkeridis et al., 2015; Vaca et al., 2016; Toulkeridis and Zach, 2017; Toulkeridis et al., 2021; Melián et al., 2021), yearly multiple events of mass mass movements such as landslides and subsidence (Zafrir Vallejo et al., 2018; Jaramillo Castelo et al., 2018; Chunga et al., 2019a; Suango Sánchez et al., 2019; Palacios Orejuela and Toulkeridis, 2020; Reyes-Pozo et al., 2020; Poma et al., 2021; Salcedo et al., 2022; Albán-Campaña et al., 2022), drought and extensive flooding of a wide area in various parts of the country (Mato and Toulkeridis, 2017; Toulkeridis et al., 2020; Sandoval et al., 2022; Moncayo-Galárraga et al., 2023; Gutiérrez Caiza and Toulkeridis, 2023), severe earthquakes with corresponding geological faults (Toulkeridis et al., 2017; Toulkeridis et al., 2018; Mato, F. and Toulkeridis, T., 2018; Chunga et al., 2019b; Toulkeridis et al., 2019; Salocchi et al., 2020; Aviles-Campoverde et al., 2021; Toulkeridis et al., 2019; Ortiz-Hernández et al., 2022; Sani et al., 2023) and also tsunamis (Chunga and Toulkeridis, 2014). These natural hazards are often destructive to man and infrastructure, especially when preparation or mitigation is lacking (Toulkeridis, 2016; Rodriguez et al., 2017; Navas et al., 2018; Sandoval-Erazo et al., 2019; Echegaray-Aveiga et al., 2019; Sánchez-Carrasco et al., 2020; Padilla-Almeida et al., 2020; Robayo et al., 2020; Herrera-Enríquez et al., 2021; Padilla Almeida et al., 2022; Suango et al., 2022; Mosquera López et al., 2022). Hereby, tsunamis of different proportions in their destructive power and reach are the result mainly but not exclusively due to the interaction of the subduction of the Nazca plate with the South American continent, which is represented by the Caribbean and South American continental plates (Fig. 1; Pararas-Carayannis, 1974; Pararas-Carayannis, 1986; Pararas-Carayannis, 2012; Rodriguez et al., 2016; Matheus Medina et al., 2016; Yamanaka et al., 2017; Pararas-Carayannis, & Zoll, 2017; Vera San Martín et al., 2018; Suárez-Acosta et al., 2021; Del-Pino-de-la-Cruz et al., 2021; Toulkeridis et al., 2021; Ballesteros-Salazar et al., 2022).

Other origins of tsunamis may be from continental glacial lake impacts, regional or distant sources, such as the tsunamis of Chile in 2010, of Japan in 2011 and of Tonga in 2022 (Pararas-Carayannis, 2010; Pararas-Carayannis, 2011; Moreano et al., 2012; Chian et al., 2019; Ioualalen et al., 2011; Pararas-Carayannis, 2014; Toulkeridis et al., 2022). However, of the 58 tsunamis that have reached the Ecuadorian coast in recorded history, some 19% turned out to be destructive (Contreras López, 2014). Based on the past events of tsunami impacts and documented history, some lessons have been learned and resulted in several studies of tsunami resistance constructions, vertical evacuation assessment, relocation areas and a few programs of tsunami hazard awareness, which still are lacking towards a real tsunami hazard education of the public and the authorities (Pararas-Carayannis, 2014; Toulkeridis et al., 2017; Rodríguez Espinosa et al., 2017; Celorio-Saltos et al., 2018; Matheus-Medina et al., 2018; Martinez and Toulkeridis, 2020; Edler et al., 2020). In this respect, serious evaluations of the risk and hazard perception and awareness are useful tools in the planning of safe zones, land use and management as well as very valid for decision-making processes of authorities and first responders (Pararas-Carayannis, 1988; Yépez et al., 2020; Bird & Dominey-Howes, 2008; Lindell et al., 2021; Johnston et al., 2005; Dengler, 2005; Wei et al., 2017; Imamura et al., 2019).

Therefore, the current research addresses the analysis of the local perception of risk in the event of a tsunami and for this it is focused on a case study in the area of Tarqui, within the city of Manta in coastal Ecuador (Fig. 2). In addition, it is intended to determine the tsunamigenic subduction seismic source for the city of Manta, besides the description of the geomorphology of Tarqui, and a subsequent analysis through hazard mapping. This may identify the areas exposed to flooding due to tsunami occurrence, considering a flood height of 7 m.a.s.l. as a high risk level and a level of 20 m.a.s.l. as the level of maximum influence of flooding within the study area (Fig. 3). Finally, we intend to estimate the context indicators, local perception of risk, as well as aspects that are indicated in the surveys directed to heads of households.

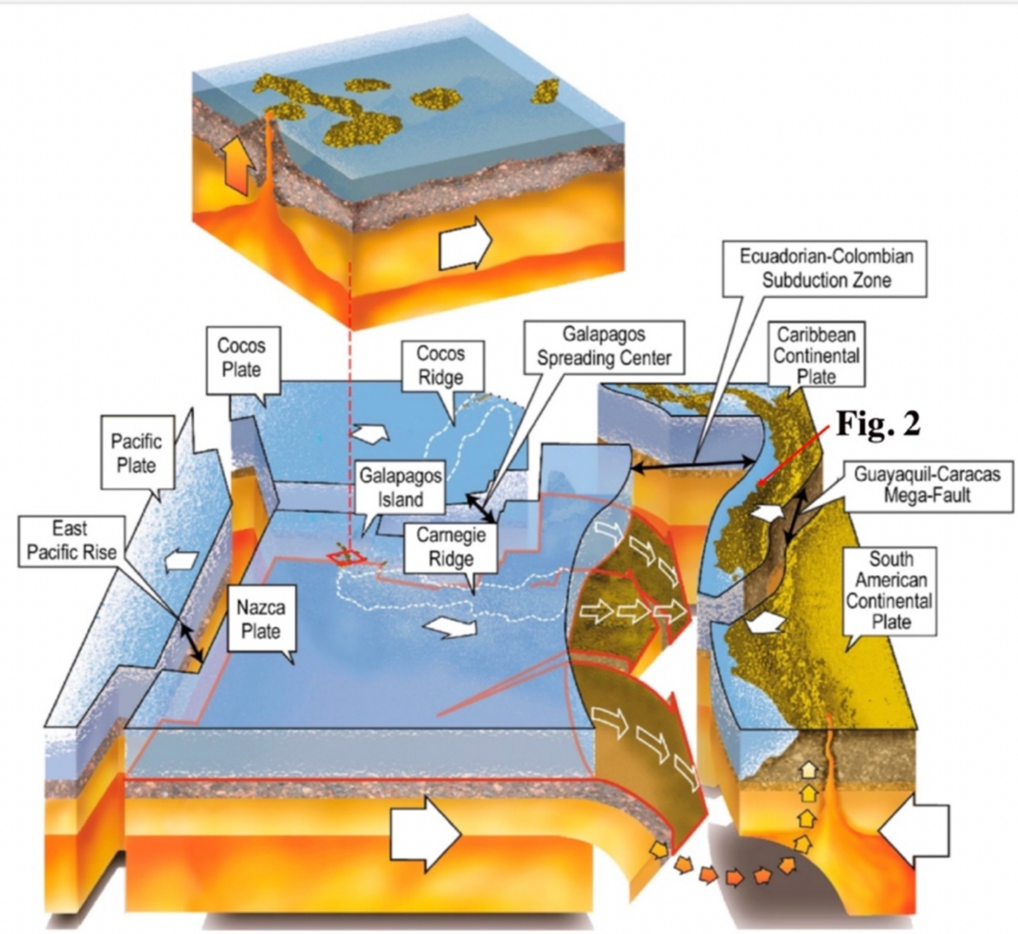

Fig. 1. Geodynamic setting of Ecuador with associated oceanic and continental plates and a variety of plate boundaries, such as the divergent plate boundaries named East Pacific Rise and Galapagos Spreading Center, the convergent plate boundary represented by the Ecuadorian-Colombian Subduction zone, as well as the transcurrent plate boundary represented by the Guayaquil-Caracas Mega-Fault. Also shown the Galapagos Islands and the Carnegie Ridge. Adapted from Toulkeridis et al., 2022.

In a post-disaster context, it may allow that both, the education of the head of the household and the health conditions of the family group, are key groups when facing highly complex contexts. Most likely as seen in a variety of other studies with similar issues, a low educational level is associated with precarious work and lower income, while the health of the family group, including the presence of at least one physically or mentally disabled person, translates into medical costs and dependency and even the loss of an individual who is able to contribute with income to the home in order to face the conditions of vulnerability typical of the given context (Polak et al., 2014).

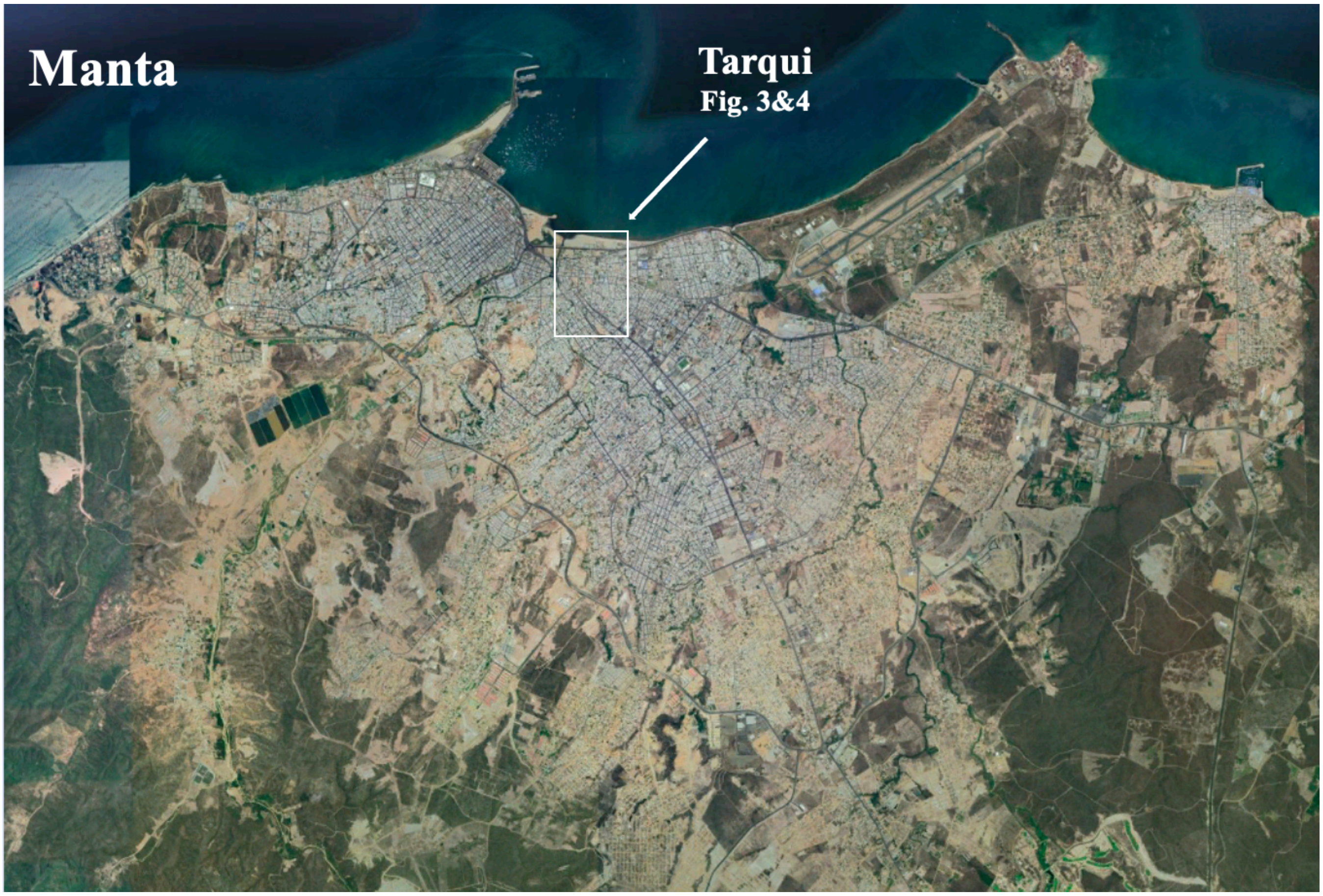

Fig. 2. The study area of Tarqui, within the city of Manta in the Manabí province. Image from Google Earth™. Width of approximately 16.6 km.

Additionally, processes of exclusion and social segregation may be observed, becoming to a permanent and systematic human occupation of areas exposed to natural hazards, in which the population with fewer resources has been located or chose to settle. The perceptions of natural risks, the forms of social organization and the expectations and frustrations of local communities constitute valuable lessons that should be the bases of the necessary social learning to prevent these tragedies from continuing to be repeated in still vulnerable countries such as Ecuador.

2. METHODOLOGY

In this study, a non-experimental, descriptive, explanatory and field research was developed. In this sense, it is a non-experimental investigation, because in the given and stated problems, the researcher do not have control of the causes that produce it and consequently the effect is already given. Non-experimental research is a retrospective approach, because the researcher do not manipulate the cause variable, as it is based on variables that also have already occurred (Hernández, 2014). The effect variable is known, but the cause variable is unknown. Therefore, the applied methodology is a design

in which no modifications are made to the independent study variables (Lavayen, 2010). It is based on observing events as they unfold in their natural state and then studying them. In fact, there are no conditions or stimuli to which the study subjects are exposed, they are only observed in their reality.
By using location maps and seismotectonic environment of the Intergovernmental Oceanographic Commission, segment number two corresponding to the Isla de la Plata around the Manta peninsula was determined as the tsunamigenic seismic source for the study area, with a rupture area 100 to 120 km from Bahía de Caráquez to Machalilla, where the estimated magnitude shall be approximately M7.8 (Avilés-Campoverde et al., 2021). Also, through ArcGIS tools, a hazard mapping was performed in order to identify the areas exposed to flooding due to the occurrence of tsunami between levels 0 to 7 m.a.s.l. and also levels of maximum influence between 7 to 20 m.a.s.l., in the Tarqui area of the city of Manta in coastal Ecuador (Fig. 3).

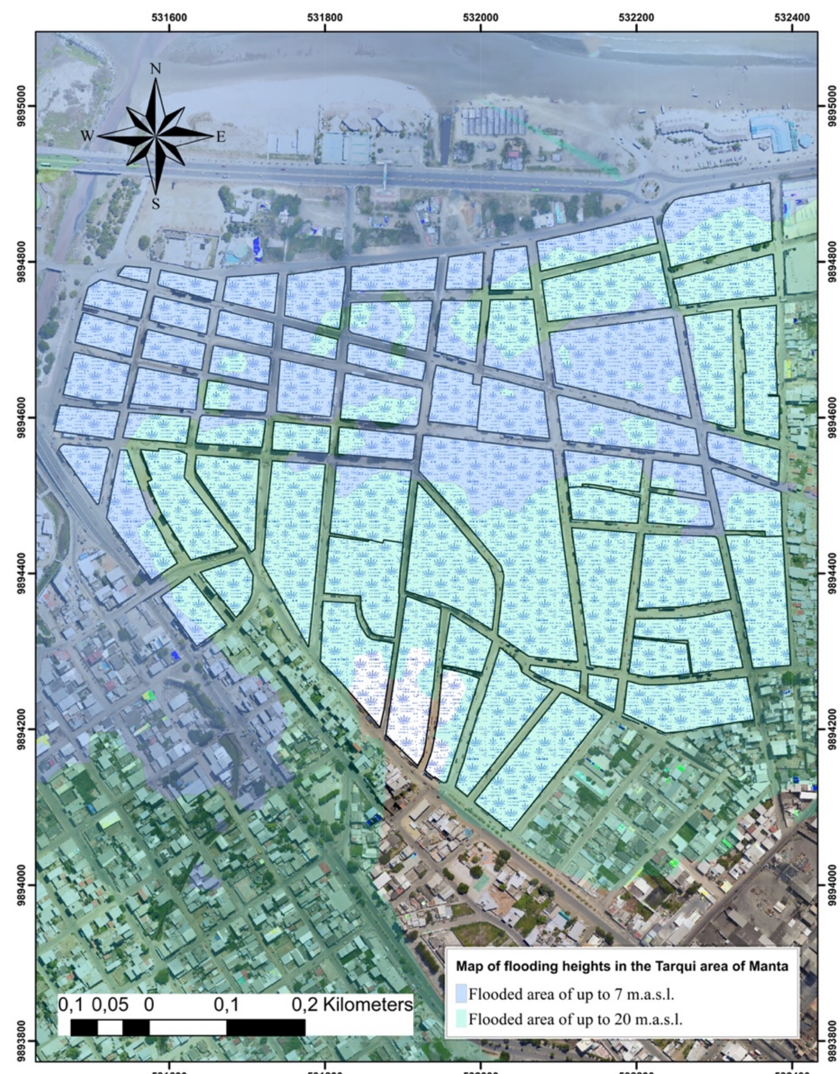

Fig. 3. Map of flooding heights within the study area of Tarqui, in the city of Manta.

An analysis of other studies focused on determining the geomorphology of the Tarqui Zone of Manta and research on local perception of risk in the event of exposure to flooding by tsunamis was conducted in order to collect baseline information for the application of context indicators. For this, some aspects needed to be considered. The geomorphological position of the axis of the hydrographic basin and the direction of the seismogenic structure (generating the earthquake) should be considered for seismic hazard studies, due to the attenuations of seismic waves that may be less in the area of few compact alluvial deposits. In the province of Manabí, the seismogenic source is located to the west (between 50 km for the Manta peninsula, and 98 km for Pedernales, the farthest point from the coastline), determined from the continental edge. In the Pacific Ocean, therefore, if the orientation of the hydrographic basin is in an East to West direction, there would be an unfavorable condition for the seismic behavior of the terrain (Chunga, 2016).

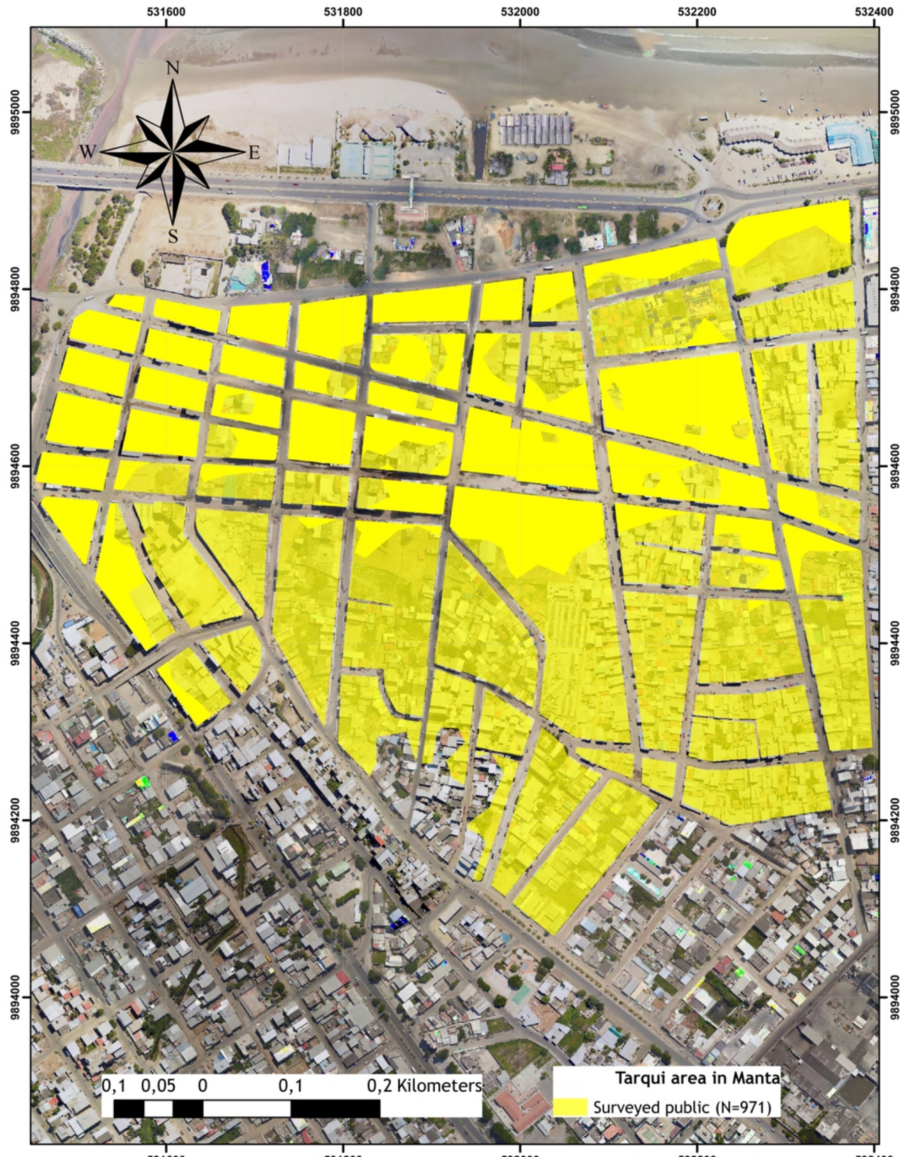

Fig. 4. Surveyed area of Tarqui.

In this regard, it is relevant that a study by Chunga (2016) served to identify this type of phenomenon in the study area under study. Hereby it was determined that another tsunami deposit at the Jaramijó site, near the canton of Manta, where it was estimated that it occurred some 1,170 years ± 30 years ago, a tsunami possibly of local origin reached these coasts with a run-up height of 6 to 7 meters. Recent studies determine that potential evidence of tsunami deposits has been found in several pits in the Tarqui area, close to the Burro riverbed, which could be related to the event recorded in Jaramijó. In order to perform a survey of the degree of preparation, perception and awareness of the public in Tarqui, we considered the complete population of 971 heads of family in the parish (Fig. 4, 5). The questionnaire included some 13 questions (Table 1).

Fig. 5 Aerial view of Tarqui from the seaside, meaning from north to south. Note the river Río Burro on the far right side of the image.

Table 1. Questionnaire of the perception of vulnerability

VARIABLES	Vulnerability perception	
	Indicator value Yes	**Indicator value No**
1. Within your area, do you identify tsunamis as a source of a geological hazard?	0	1,00
2. Do you think that tsunami hazards are identified in your community?	0	1,00
3. Do you know if your home is located in a high risk area for tsunami?	0	1,00
4. Do schools in your area teach about the risks and disasters generated by tsunamis?	0	1,00
5. Have information campaigns about the danger of tsunami ever been performed in your community?	0	1,00
6. In the event that information campaigns have been conducted, how did you find out about them?	0	1,00
7. Is there an early warning system for tsunamis in your community to notify the population about an emergency?	0	1,00
8. Have you ever participated in a tsunami evacuation drill?	0	1,00
9. Do you think that an earthquake with characteristics similar to those of the 16 April 2016 (16A) could cause a tsunami?	0	1,00
10. Based on the experience of the 16A earthquake, do you consider that your community is ready to face a tsunami disaster situation?	0	1,00
11. Do you know the evacuation route to take in case of a tsunami?	0	1,00
12. Do you know of any institution that works to reduce the effects of tsunami (construction of early warning systems, buildings for vertical evacuation in case of tsunamis, dissemination of information, drills, etc.)?	0	1,00
13. Referred to the danger tsunami and if you were living in a risk area, would you be willing to relocate?	0	1,00
TOTAL/AVERAGE (VULNERABILITY INDEX)	**Average**	

3. ANALYSIS AND DISCUSSION OF THE RESULTS

3.1 The concept of risk

The approach of the local perception of risk for the approach of the proposed investigation in the framework of the eventuality of a tsunami in the Tarqui area, Manta canton, Manabí province, is highly relevant. An approximation to this concept makes it possible to identify it as the core part to assess the magnitude and impact of future natural or anthropogenic events, since it is directly related to social conditions, the quality of housing and infrastructure, and in general the level of development of an area. The results of the first question ("Within your area, do you identify tsunamis as a source of a geological hazard?") of the survey indicate that 68.8% of the heads of household do identify tsunamis as a source of geological hazard, while 31.2% do not (Fig.6a;b). In this regard, geological risks include internal processes of the earth, such as earthquakes, volcanic activity and gas emissions, as well as other geophysical processes related to them, such as mass movements, landslides, etc. land, rockfalls, surface collapses, and debris or mud flows (Molerio, 2018). Furthermore, hydrometeorological factors are also major forces. Hereby, tsunamis associated with earthquakes are difficult to categorize. Although they are triggered by mainly by marine earthquakes and other geological events, they are essentially an oceanic process that manifests as a coastal water-related hazard.

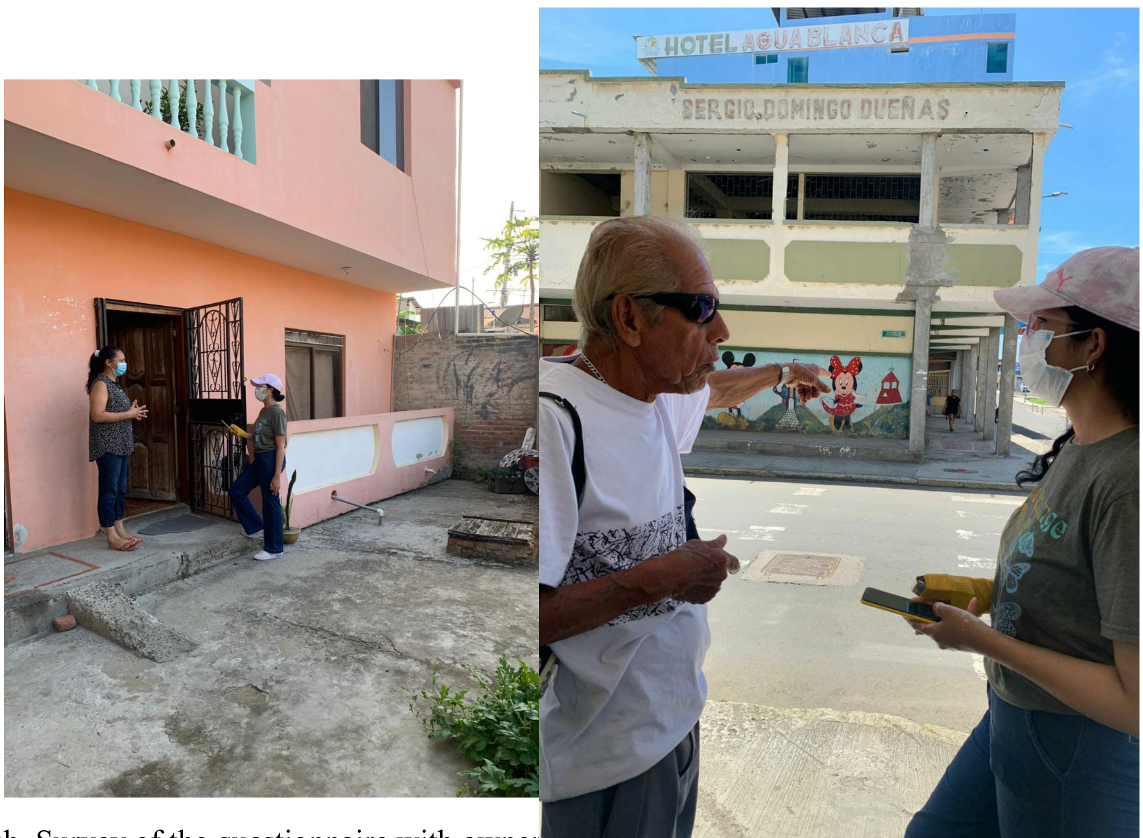

Fig. 6a;b. Survey of the questionnaire with owners of households in action.

In the second question of the survey ("Do you think that tsunami hazards are identified in your community?"), 62.5% of the heads of households consulted affirm that the dangers of tsunami are identified in their community, instead, 37.5% mentioned the opposite. In a previous study, it has been indicated that the dangers of tsunami are felt in various ways by the population as a whole and not all communities are prepared for an event of these characteristics (Pararas-Carayannis, 1999; Geist et al., 2006; Becker et al., 2022). Therefore, it has been suggested that when a tsunami occurs and if you were at home, at school or at work, keep in mind that in threatened coastal areas, you have only a few minutes to act, being as short as 5 to 10 minutes, so one needs to evacuate immediately (Eisner, 2005; Mat Said et al., 2011; Morgan et al., 2006). Once the tsunami has passed, evacuate as quickly as possible on foot. Always follow the instructions on the evacuation plans. Some beaches have tsunami evacuation signs.

In the third question of the survey, 62.7% of the heads of households consulted affirm that their home is located in a high-risk area due to tsunami. On this aspect, it has been considered that to avoid problems with nature, families must acquire land in habitable areas to locate their homes (Amri & Giyarsih, 2022; Tanikawa et al., 2014; Alexander et al., 2006). The destructive potential of a tsunami is the result of flooding, wave impact on buildings, and erosion. Tsunami waves apply forces on structures in the form of hydrodynamic pressure, buoyancy, uplift, scour, and impact of objects carried by the current. The damage produced by tsunami originates when the mass of water, followed by a strong current, impacts the built space and its surroundings. At that time, the tsunami demonstrates its tremendous destructive force and destroys everything in its path, especially homes (Fig. 7, 8).

Fig. 7. Residential building in Tarqui, Manta, where the exterior walls collapsed. The roof also fell in this property. Adapted from Nicolaou et al. 2016.

In the fourth question of the survey ("Do schools in your area teach about the risks and disasters generated by tsunamis?"), 68.5% of the heads of households consulted affirm that in the educational centers of their area they do not teach about the risks and disasters generated by a tsunami. In this sense, it has been established that the education provided at school about a tsunami is essential (Khew et al., 2015; Onoda et al., 2018; Maly, 2018). For example, disaster reduction begins from these institutions. Therefore, it must be ensured that disaster risk reduction is fully integrated into school curricula in high-risk countries and that school buildings are modernized to withstand natural hazards.

In the fifth question of the survey ("Have information campaigns about the danger of tsunami ever been performed in your community?"), 81.9% of the heads of households consulted assured that information campaigns about the danger of tsunami have not been conducted. Contreras (2014) points out that information campaigns about the occurrence of a tsunami are important, since they teach people to immediately look for a high point and protect themselves. Therefore, it is fundamental to periodically instruct the local community, and with trained personnel, on how to act in the event of an eventuality. It must be considered that the common citizen has little knowledge of the phenomenon and of the actions to adopt.

In the sixth question of the survey ("In the event that information campaigns have been conducted, how did you find out about them?"), 13.6% of the heads of households consulted assured that through the dissemination of information campaigns through social networks they found out about the tsunami risks, while the vast majority, the 83.3% mentioned that they were not aware of any activity in this regard. In this context, it is relevant to determine the enormous influence that social networks have due to their potential to disseminate information. Recent studies highlight that currently social networks are a useful tool to shorten times, mobilize resources and improve disaster response (Kim & Hastak, 2018; Houston et al., 2015; Phengsuwan et al., 2021; Abedin et al., 2014). Through these platforms help is requested, the situation of the affected community is reported, attempts are realized to locate missing persons and images of disaster damage are indicated in real time and with a worldwide expansion.

Fig. 8. This is how the building looked after the earthquake in Tarqui, due to the collapse of two floors it was decided to demolish it.

In the seventh question of the survey ("Is there an early warning system for tsunamis in your community to notify the population about an emergency?"), 98.9% of the heads of households consulted assured that there is a tsunami early warning system in their community to notify the population of an emergency. Ecuador possesses of an Early Warning System (Fig. 9), but not for mass dissemination, which allows citizens to be alerted to the risks of tsunami and overflow of rivers and dams, which prevents the population from being transmitted in advance and with certainty when a tsunami or overflow can trigger imminently dangerous situations. In this context, the alarm to citizens who are in potential risk areas could not be disseminated sufficiently in advance. It is thus that, before the generation of a tsunami or the overflow of rivers or dams in our country, a significant loss of life, personal injuries, damage to property and the environment could not be avoided, due to the absence of essential technological equipment. so that the activation of an evacuation alert is effective (Inamhi, 2016). Early Warning System for tsunami risks, river overflows or dams is a set of instruments through which a threat of tsunami or overflows is monitored from its generation, captures and automatically processes your information, instantaneous forecasts of action and possible effects are obtained and the population living in the sectors of probable affectation are immediately alerted (Sayers et al., 2015). Millions of people around the world save their lives and their livelihoods thanks to the implementation of these systems.

Fig. 9. Early warning system (right side of the image) represented by the siren in Tarqui.

In the eighth question of the survey ("Have you ever participated in a tsunami evacuation drill?"), 94.7% of the heads of households consulted stated that they had not participated in any tsunami evacuation drill. Recent investigations established that the improvement of the environment and the ability of the community to react adequately when faced with a great disturbance is essential, since poor preparation gives rise to vulnerable environments (Mas et al., 2015; Chen & Zhan, 2008).

Therefore, the fact that citizens actively participate in simulation activities is essential to help save lives when a natural phenomenon such as a tsunami occurs. It is relevant, to recognize the existence of evacuation routes, as well as public spaces that are planned for multiple uses that also allow evacuation due to the occurrence of a tsunami, and the evaluation of the conditions given by the existing environment (León et al., 2019; Fathianpour et al., 2023).

In the ninth question of the survey ("Do you think that an earthquake with characteristics similar to those of the 16 April 2016 (16A) could cause a tsunami?"), 56.3% of the heads of households consulted assured that they do believe that an earthquake with characteristics similar to those of 16A could cause a tsunami. It is important to highlight that from the earthquake in 2016 a high part of the population in Manabí was left with a deep trauma (Fig. 10).

In the tenth question of the survey ("Based on the experience of the 16A earthquake, do you consider that your community is ready to face a tsunami disaster situation?"), 51.3% of the heads of households consulted assured that they do not consider that their community is ready to face a tsunami disaster situation, taking prevention efforts into consideration. No one is prepared enough for the worst adversities. The community needs to be better prepared for complex circumstances in the event of events such as earthquakes or tsunamis. Both the unpredictability of the event and its immediate consequences can cause the lives of millions of people to depend on decisions that must be made in a matter of seconds. Hence the importance of being prepared for these events (Equal et al., 2017).

Fig. 10. Destroyed building due to 16A in Tarqui

In this eleventh question of the survey ("Do you know the evacuation route to take in case of a tsunami?"), 86.3% of the heads of households consulted assured that they do know the evacuation route to take in the event of a tsunami, while the remaining 13.7% indicated the opposite. A report from Inamhi (2016) indicates that communities are permanently trained in carrying out the drill, informing them of the evacuation routes, meeting points and safe areas. Several preparatory exercises were conducted, where the public is accompanied while carrying out the drill and at the end the drill is evaluated.

In addition, they are trained on how to act in cases of emergency or in a situation generated by an adverse event, in a way that allows decision-making in a timely manner in order to safeguard life. In addition, the preparation of the Family Emergency Plan is a very useful tool, since it is the set of activities that a family must conduct in order to reduce the risks that could affect their well-being. It also allows preparations to react appropriately in case of an emergency.

In the twelfth question of the survey ("Do you know of any institution that works to reduce the effects of tsunami (construction of early warning systems, buildings for vertical evacuation in case of tsunamis, dissemination of information, drills, etc.)?"), 82.8% of the heads of households consulted assured that they do not know of the existence of any institution that works to reduce the effects of tsunami. In this regard, it has been determined that the institutions in charge of the security of citizens must diversify the way of publicizing their programs and emphasizes the fact that the technology of social networks has made access and dissemination easier information quickly and easily ((Lovari & Bowen, 2020; Kongthon et al., 2014; Zhang et al., 2019). Internet users spend about 101.4 minutes a day browsing social networks. Communication has also adapted to this growing technological development. Therefore, social networks are useful and essential tools to facilitate communication during disasters and emergencies.

In the last question of the survey ("Referred to the danger tsunami and if you were living in a risk area, would you be willing to relocate?"), 80.8% of the heads of households consulted stated that they would not be willing to relocate because they are in a risk area due to the tsunami. This is a sensitive point for the community, since most citizens are reluctant to abandon the place they own, since it has been, in most cases, the product of their efforts. From the perspective, the tsunami hazards to homes should not be interpreted as a restriction on urban and rural development in coastal areas (Khew et al., 2015; Onoda et al., 2018; Maly, 2018). However, the lessons learned in the last decade should allow to reflect on how people build their homes on the coast, where they located them, and what their response would be in the presence of a tsunami. Certainly, a whole line of research is presented for the design and construction of anti-tsunami housing. It should not be forgotten that large tsunamis are infrequent events, however, when they do occur they are highly destructive.

3.2 Analysis of the social perception of the tsunami risk hazard

The results are linked to the equation proposed by the Colombian National Risk Management Unit (2017). For this research, the indicators evaluated in the surveys were analyzed and those of the factors which had the greatest incidence on the local perception of risk were identified. From the weights obtained for each of the surveys applied, it was possible to determine that 29% of the population is in a condition of high vulnerability, on the other hand, 63% in a situation of medium vulnerability and finally, 8% in a low vulnerability position (Table 2).

Table 2. Results of the range of the vulnerability conditions of the current questionnaire

Range	Vulnerability condition	N	%
> 9	High	281	29%
4.1 - 8.9	Average	614	63%
0 - 4	Low	76	8%

The results determine that the local perception of risk is culturally determined by society. Additionally, it is conceived as the probability that the disaster will occur as a consequence of the combination of hazards with conditions of vulnerability. In this respect, various studies have addressed this perspective. One of them, refers to the fact that vulnerability is an internal risk factor of a subject, object or system, exposed to the hazard, which corresponds to its intrinsic willingness to be damaged (Dake, 1992; Beck, 1992; Earle & Cvetkovich, 1994). While when social is added to this type of vulnerability, it refers to the extent to which it expresses the socioeconomic conditions of the population, the prevention and response capacity of civil protection units and the local perception of risk, in the face of a phenomenon and the local perception of the risk of the same population.

4. DISCUSSION

4.1 Local perception of risk in the context of hazard detection

A hazard is defined as the probability of a potentially disastrous event occurring during a certain period of time at a given site. According to Ley et al. (2016), the perception of risk is, in many aspects, an elaborated and socially shared appreciation, which implies the symbolic marking of images and their recovery in a context of meaning, since one of the functions of the cultural process is to provide ready categories to store and retrieve information, without forgetting that the use that the subject makes of classification systems depends on his position in a social group. Ante (2017) points out the following precision, that unlike the hazard that acts as a trigger, the local perception of risk is a condition that remains continuously over time and is closely linked to cultural aspects and the level of development of the communities.

The hazard or external risk factor of a subject or system is represented by a latent danger associated with a physical phenomenon of natural or technological origin that can occur in a specific place and at a certain time, producing adverse effects on people, goods and/or the environment (Yang et al., 2001). Mathematically it is expressed as the probability of exceeding a level of occurrence of an event with a certain intensity in a certain place and in a certain period of time. It has been considered that the hazard or danger refers to the potential occurrence of physical events of natural or anthropogenic origin that may have adverse effects on vulnerable and exposed elements (Calvo et al., 2012). In other words, the hazard or threat is only one of the risk elements and, therefore, it should not be assumed that they are similar terms. In this context, the hazard is conceived as a phenomenon, substance, human activity or dangerous condition that can cause death, injury or other health impacts, as well as property damage, loss of livelihood and services, social and economic disruption, or environmental damage (Wachinger et al., 2013; Chen et al., 2006; Joyce et al., 2009).

Hazards are related to the environment and define them as extreme expressions of natural phenomena (Martínez and Aránguiz, 2016). For example, the climate, composed of a series of elements that vary in periods or seasons and facilitate agricultural production, the provision of services and populations adapt to its operation. However, this same regular climate undergoes sudden changes and becomes storms, hurricanes or, depending on its intensity, becomes floods, droughts that threaten the development of a society. The occupation and development of society are eventually threatened by the manifestation of extreme climatic phenomena, as phases of the same process.

The hazard is interpreted as a physical phenomenon that could harm society and is assumed based on its relationship with a vulnerable social group. The hazard does not exist as an object external to society, while vulnerability is defined based on the social conditions created, not only in reference to losses and damages, but as the one responsible for disaster processes (Dake, 1992; Beck, 1992; Earle & Cvetkovich, 1994).

It is for this reason that studies conceive the hazard as the possible condition of alteration or disorder of a continuous process (Yoon, 2012; Zhou et al., 2014; Wei et al., 2004). This condition would be caused by a change in the complex interrelationship of various elements and processes, influenced by factors of various types such as physical, natural, social and human environmental that occur in uncertain places and times. In short, the hazard can also be considered as a condition of the nature-society interrelation processes, being a social interpretation that presents different perspectives.

A hazard is a fundamental component of the disaster risk structure (Thomalla et al., 2006). It is defined as a phenomenon, object or activity that can cause harm. Therefore, an infinity of phenomena and situations that exist and can alter an environment must be considered from a diversity of forms where multiple elements, factors and specific space-time conditions are interrelated.

Hereby, the fundamental difference between the threat and the risk is that the hazard is related to the probability that a natural event or a provoked event will manifest itself, while the risk is related to the probability that certain consequences will manifest, which are closely related not only to the degree of exposure of the elements subjected, but also to the vulnerability of said elements to being affected by the event (Roncancio et al., 2020; Aksha et al., 2019; Davis, 2013; Lixin et al., 2014).

In this context, floods can be defined, as a temporary coverage of the land by water outside its normal limits and can occur in basins, estuaries, coasts, urban areas, among others (Papathoma et al., 2003; Tarbotton et al., 2015; Dominey-Howes & Papathoma, 2007). Flooding in most cases is a natural phenomenon that, for example, in natural floodplains cannot be classified as a hazard. However, floods are generally influenced by humans through inappropriate land use.

4.2 The risk perspective

The risk can be estimated by the probable number and characteristics of human losses, injuries, damaged properties and interruption of economic activities that could occur after a disaster (Wachinger et al., 2013; Chen et al., 2006; Joyce et al., 2009). Risk is the result of the interaction between the dynamics of the natural environment and the built environment, however, the expression built for risk implies exposure to a natural hazard, hence the concept is taken up again for a better understanding of the topic to be investigated (Dall'Osso et al., 2009; Omira et al., 2010).

Natural risk has been also considered as an aggregate of elements of the physical and biological environment that are harmful to people and caused by forces outside of them and being defines as the possibility that a territory and the society that inhabits it may be affected by a natural phenomenon of extraordinary range (Stoleriu et al., 2020). Hereby, the risk is considered as a latent condition, that is to say that by not being modified or mitigated by the human being or by means of a change in the physical-environmental environment, the risk announces a level of social and economic impact for the future. This level of risk will be conditioned by the intensity or possible magnitude of the physical events, and the degree of exposure and vulnerability (Vega, 2016).

In this context, the basic components of risk management are prevention, mitigation, transfer, preparation and care as well as rehabilitation and reconstruction (Freeman & Kunreuther, 2002). Hereby prevention serves to prevent risk situations from being generated, being a process that starts with the identification of potential risk through perception and evaluation, and anticipatory measures are taken to prevent the risk from consolidating. The mitigation corrects or reduces risk (reduces vulnerability and increases resilience, it is done based on the risk that already exists). Risk reduction encompasses not only its physical dimension, but also includes social, political and economic aspects. In this sense, risk transfer, as the risk management component that seeks to transfer the replacement cost associated with losses among a greater number of citizens than those directly and mostly exposed, is considered a reduction or mitigation measure of the risk. Preparation and care includes emergency management, preparations, planning and response protocols, institutional coordination for the efficient management of disaster situations (the risk is not acted upon, the level of physical exposure is not reduced). Finally, rehabilitation and reconstruction includes the post-disaster management, which seeks to restore the normal flows on which social and economic development depends. In many cases, rehabilitation and reconstruction are processes of creating security conditions that did not exist before the occurrence of the triggering natural or socio-natural phenomenon.

Regarding risk analysis and assessment, it has been defined as the process that consists of the identification and characterization of hazards, the determination of vulnerabilities and the assessment of the result of the interaction of these variables (Batista, 2018; Giannakidou et al., 2019; Surjan et al., 2016). The risk scenario is an anticipated vision of what could happen if a hazard to a community or to a vulnerable system were to appear or become real. In other words, it is the space and time where the risk components come together (hazards and vulnerabilities) together with the forecast of the possible consequences of this confluence (Fig. 11). Risk can be organized or broken down into activities such as identification of the nature, extension, intensity and magnitude of the hazard; determination of the existence and degree of vulnerability; identification of the measures, capacities and resources available; construction of probable risk scenarios; determination of acceptable levels of risk, cost-benefit considerations of possible measures aimed at avoiding or reducing it; assigning of priorities in terms of time and movement of resources; and designing effective and appropriate management systems to implement and control the above processes (Kulawiak & Lubniewski, 2014; Godschalk, D. R. (2003; Burby et al., 2000; Zou et al., 2017).

Fig. 11. Tarqui after the 16A. API FOTO / Ariel Ochoa

Concomitant with the aforementioned, for the risk analysis a six-step procedure needs to be followed (Cutter, 2010; Lummen & Yamada, 2014; Douglas, 2007). It starts with the identification of the hazards, meaning identification of all activities or hazards that imply risks.

Secondly follows the estimation of the probabilities. Once the hazards or possible aspects initiating events have been identified, the probability of occurrence of the incident or event must be estimated, based on the specific characteristics. The third step includes the estimation of the vulnerabilities. Estimation of the severity of the consequences on the so-called vulnerability factors that could be affected such as people, environment, systems, processes, services, goods or resources. The fourth step handles the risk calculation. The risk level calculation or assignment needs to be realized. The Risk (R) is defined based on the hazard(s) and vulnerability as the product between Probability (P) and Severity (S) of the scenario. The next step treats the prioritization of the scenarios. The results of the risk analysis allows to determine the scenarios in which intervention should be prioritized. Finally follows the intervention measures, where it is necessary to establish the need to adopt planning measures in order to control and reduce risks.

Risk is the combination of hazard and vulnerability. This is important to the extent that risk is assumed as the probability of suffering economic, social, and environmental negative consequences (damages and losses) that may occur in the event of a dangerous phenomenon, in relation to the ability to resist and recovery of the different social actors in the face of this phenomenon. The risk scenario is the representation of the interaction of the different risk factors (threat and vulnerability) in a territory and at a given time and, in addition to this, it must represent and allow the identification of the type of damage and losses that may occur in in the event of a dangerous event occurring in given conditions of vulnerability.

4.3 Local perception of tsunami risk

Vulnerability represents a configuration of objective and subjective conditions of existence and is associated with fragile elements of a community or human group that generate a predisposition to suffer harm. According to Martínez and Aránguiz (2016), these fragile elements or conditions can be grouped into different dimensions, such as physical, social, organizational, educational, and others. The factors that originate it depend on the degree of exposure to the event, social fragility and the lack of resilience or inability to respond to absorb the impact. Within the framework of local risk perception, a tsunami is defined, according to a study by Sulla and Tavera (2016), as a wave or series of waves in a train of waves generated by the vertical displacement of a water column. The gravity waves of tsunamis propagate through the vast ocean, being very different from ordinary wind waves, so, due to the longer wavelengths and periods, the tsunami wavelength can travel from ten kilometers up to hundreds of kilometers.

It has been argued that when analyzing the scope and consequences that a tsunami can bring, it is considered to carry out a vulnerability study, since it is an important factor for determining risks, knowing its variables and indicators (Zuccaro et al., 2018; Castro et al., 2017; Mignan et al., 2016; Marulanda Fraume et al., 2020). This allows the understanding of risk scenarios (in this case of natural origin). Many times the exposed elements can present low intensity threats. Therefore, vulnerability analysis is a platform for the achievement of three fundamental aspects. Understanding the usefulness of information generated by different institutional sources and its application to vulnerabilities. The construction of information based on variables and indicators necessary to understand vulnerabilities and easy replication for local authorities. The inter-institutional and multidisciplinary work of actors responsible for information, territorial management and development at a national and cantonal level.

In the field of vulnerability analysis, it is pertinent to address the origin of tsunamis. The source of tsunamis is mainly produced by earthquakes, which represent the majority and are approximately 96%, on the other hand, volcanic eruptions represent 3%, likewise, there are also tsunamis generated by

submarine or coastal landslides represent 0.8%, and lastly, although they are very anomalous, the tsunamis that are generated by the impact of meteorites (Paris, 2015). Seismic events with magnitudes greater than 7.0 Mw are considered the main source of tsunami generation, if the earthquake is generated on the seabed or very close to it at focal depths of less than 60 km. Usually these anomalous events occur near the convergence of tectonic plates that cause the rise and collapse of the continental crust. In this phase, the mass of water is violently propelled by the plate to release accumulated energy. These explosions of energy can generate huge waves that can be very destructive.
According to Chunga (2016), the tsunami alerts associated with the intermediate and far fields allow establishing better response plans during an emergency due to the range of sufficient hours before the first wave impact, for example a strong earthquake generated in the area of subduction of Chile that would generate Tsunami, would take between four to five hours to have its first impact on the coasts of the Jambelí archipelago, in the province of El Oro, south coast of Ecuador, which displays enough time to displace people through evacuation routes to safe places.

5. CONCLUSIONS

The social development of a community vulnerable to natural phenomena such as a tsunami is linked to the local perception of risk, because this perception plays a preponderant role in people's decision-making.

The characteristics of the population and social groups determine their level of incidence in the face of natural hazards and influence their ability to respond and recover adequately. Likewise, population dynamics and economic activities influence this type of perception. The spatial location of the population is decisive in the magnitude of the impact of disasters.

With regard to a tsunami, it is clear in pointing out that the role played by the local perception of risk in the affectation by disasters is essential. Some sectors of the population due to the economic and physical conditions they live in, or due to the difficulty of recovery, they have are extremely vulnerable to events that affect their living conditions, or their means of production. The causes of a greater local perception of risk are complex and constitute an argument for debate in society. The hazard or danger refers to the potential occurrence of physical events of natural or anthropogenic origin that may have adverse effects on vulnerable and exposed elements.

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