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TSUNAMIS IN PANAMA – HISTORY, PREPARATION AND FUTURE CONSEQUENCES

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ABSTRACT

In the last two decades, the vulnerability of coastal populations to the occurrence of natural phenomena such as tsunamis has increased, among other hazards that have existed throughout the development of civilizations and have constantly kept at risk the resources that a population needs for its development. The current study presents a representative sample of the perception of the population regarding the possibility of the occurrence of a natural phenomenon such as the tsunami on the Panamanian coasts. Although Panama is not at the top of the list of countries with high risk of current tsunamis, it does maintain an index that must be considered for the development of prevention strategies, so it is necessary to determine the perception of the population in order to execute contingency plans. The performed survey clearly demonstrates the poor preparation of the Panamanian population and the need for a drastic increase in the carrying out of all kinds of preventive activities towards tsunamis and their respective hazards.

Keywords: population vulnerability, survey, historic tsunamis, degree of exposure.

1. INTRODUCTION

Among any seismic movements, tsunamis are one of the most destructive and deadliest hazards of natural origin, especially in areas adjacent to oceanic environments (Pararas-Carayannis, 1969; Pararas-Carayannis, 2002; Adger et al., 2005; Pararas-Carayannis, 2006; Raschky, 2008; Alongi, 2008; Daniell et al., 2010; Seng, 2013; Esteban et al., 2018). Recently several studies documented with detailed evaluations the vulnerability of coastal areas with their corresponding strategic infrastructure as well as the degree of preparation of their habitants towards the impact of tsunamis and other associated natural occurring hazards of one or multiple origins (Latter, 1981; Scheffers, & Kelletat, 2003; Liu et al., 2007; Bryant, 2014; González-Riancho et al., 2015; Toulkeridis et al., 2017). In this respect, the 2004 tsunami with a magnitude of 9,3 struck in Indonesia and surrounding countries causing 350,000 deaths and 15 billion US$ of immediately economic lost (Athukorala and Resosudarmo, 2005; Jayatillekeand Naranpanawa, 2007), while in the case of Japans 9,0 magnitude tsunami of 2011, besides the 15,853 deaths, some 6,023 were injured and 3,282 remained missing, while approximately 300,000 building were destroyed, besides the 4,000 roads, 78 bridges and 29 railways, which were severely affected (National Police Agency of Japan, 2015). The economic damage reached approximately 210 billion US$ (Aon Benfiedl, 2015). Furthermore, the 8.8 magnitude tsunami of Chile in 2010, has led to some 500 deceased, while at least 1,5 million homes got damaged of which one third were completed destroyed, leaving an economic loss of approximately 30 billion US$ (Barcená et al., 2010).

On the other side the memory, education and awareness of occurred and potential tsunami disasters may be decisive in the preparation of the public (Frankenberg et al., 2013; Takeuchi, & Shaw, 2014; Benadusi, 2014). There has been statistical evidence of the degree of education and preparedness about natural disasters including tsunamis (Shaw et al., 2006; Muttarak, & Pothisiri, 2013; Esteban et al., 2013; Karanikola et al., 2015; Bronfman et al., 2016). Even worse, disaster education has not been included in public education in many areas even after the recent impact of tsunamis in a variety of countries in the surrounding of the Pacific (Gusiakov et al., 1997; Wood et al., 2002; Tang et al., 2008; Wood et al., 2010; Bisri and Sakurai, 2017).

However, in order to reduce such vulnerabilities and also in order to obtain a better knowledge of the degree of preparation of the general public, it should be considered fundamental to conduct studies with the goal to determine the level of vulnerability towards tsunami hazards for the corresponding population including their degree of knowledge, perception and preparation (Pararas-Carayannis, 1983; 1988; Taubenböck et al., 2009; Celorio-Saltos et al., 2018). Therefore, we have chosen to perform these aforementioned studies in a country in Central America, which is vulnerable of several tsunami sources such as Panama (Fernandez et al., 2000).

Central America has documented some fifty tsunamis in the last five centuries, which has led that Panama is threatened by tsunamis of the Pacific Ocean and the Caribbean Sea, which have been generated either by seismic movements or from volcanic activity

(Fernandez et al., 2000; NGDC/WDS, 2015; Intergovernmental Oceanographic Commission, 2018). In this sense, the main objective of the current study has been to contribute to the generation of knowledge about the factors that contribute to the increase or decrease of vulnerability towards tsunamis based on the degree of knowledge and preparedness of the academic population of Panama.

2. GEODYNAMIC SITUATION AND TSUNAMI HISTORY OF PANAMA

The country and the Isthmus of Panama, which are part of Central America, just adjacent to the northwestern corner of South America, are in between of some interesting plate tectonic constellation (Fig. 1). To the south there is the subduction of the northeastern trending oceanic Cocos as well as part of the oceanic Nazca plates, which subducts below the Caribbean plate along the Middle American Trench (Johnston, S. T., & Thorkelson, D. J. (1997; Johnston, S. T., & Thorkelson, D. J. (1997; Lonsdale, P. (2005).

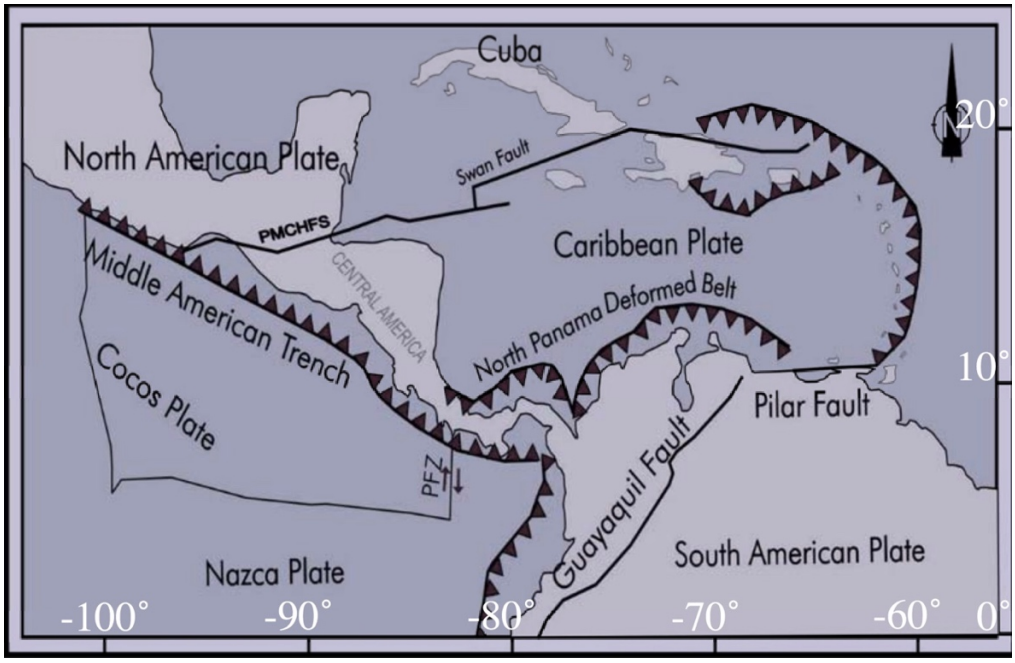

Fig. 1. Geodynamic setting of Central America including Panama situated west of the Caribbean plate (gray color), representing a volcanic islands arc, which has been formed by the subduction of the northeast moving Cocos plate under the Caribbean plate. Hereby, the PMCHFS is the Polochic-Motagua-Chamalecon Fault System and the PFZ represents the Panama Fracture Zone. Adapted from Fernández Arce and Alvarado Delgado, 2005.

Hereby, the division of the both oceanic plates is given by the presence of the Panama Fracture Zone (Lonsdale & Klitgord, 1978; Adamek et al., 1988). Furthermore, to the north of the country strikes a submarine fold and thrust belt known as the North Panama Deformed Belt (Camacho, & Víquez, 1993; Marshall et al., 2000; Camacho et al., 2010). Even further to the north there are the active island-arc tectonics of the Lesser Antilles as a

product of the subduction of the oceanic parts of the North and South American plates (Mattson, P. H. (1984; Wadge, G., & Shepherd, J. B. (1984; Speed, R. C. (1985).

All aforementioned tectonic regimes characterize a seismically active region which has generated subduction related tsunamis, as well as tsunamis based on volcanic activity and by landslides (Fernandez et al., 2000; Lander et al., 2002; O'loughlin, K. F., & Lander, J. F. (2003; Pararas-Carayannis, G. (2004). However, tsunamigenic earthquakes are the most frequent origin of tsunamis in Central America (Fig. 2).

Hereby, there are some 54 registered tsunamis for Central America of the last 500 years (Fernandez et al., 2000; NGDC/WDS, 2015; Intergovernmental Oceanographic Commission, 2018). Of these, there are also a few reported and documented seismic events, that have generated tsunamis in Panama within the last 220 years (Fig. 3 and 4).

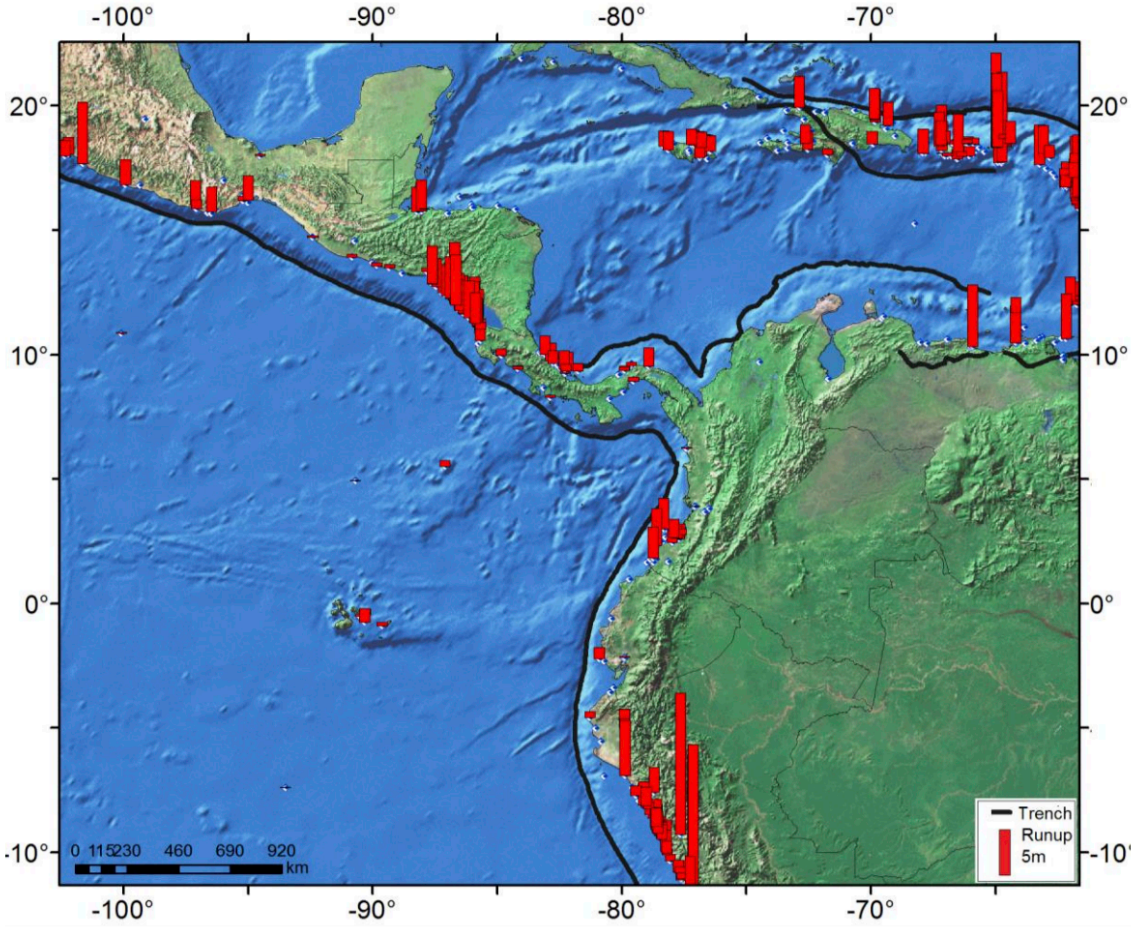

Fig. 2. Run-up and tsunamigenic earthquakes along Central America in 500 years. Source modified from Fernández et al. (2000) and NGDC/WDS (2015). Adapted from Intergovernmental Oceanographic Commission, 2018.

The first within the several events has been reported of February 22 in 1798 at Matina, near the Costa Rican border, where only some unusual noises have been eye-witnessed, which has been followed by another questionable tsunami at Panama City on the October

1873, where the city and Aspinwall shall have been affected by such seaquake (Molina, 1997; Lander et al., 2002). Shortly later, on the September 07 1882, the so far strongest documented earthquake and subsequent tsunami affected Panama, based on a 7.9 Ms earthquake, originating at the San Blas Archipelago, being observed also in Nicaragua, Colombia and Venezuela, leading to considerable damage and killing up to hundred people in San Blas in northern Panama (Milne, 1912; Sieberg, 1932; Ambraseys, 1995; Camacho & Víquez, 1993; Camacho, 1994).

This has been followed by another tsunami event of which validity is questionable at the November 5 1884 originated in the Panama Isthmus, having left destruction in Colombia as well as Panama (Grases, 1990). Just a little further to the south of the event of 1884, occurred on January 20 1904 another seismic event with a magnitude of 7 generating a questionable local tsunami with no significant reported damage (Oddone, 1907; Ambraseys, 1995; Ambraseys and Adams, 1996).

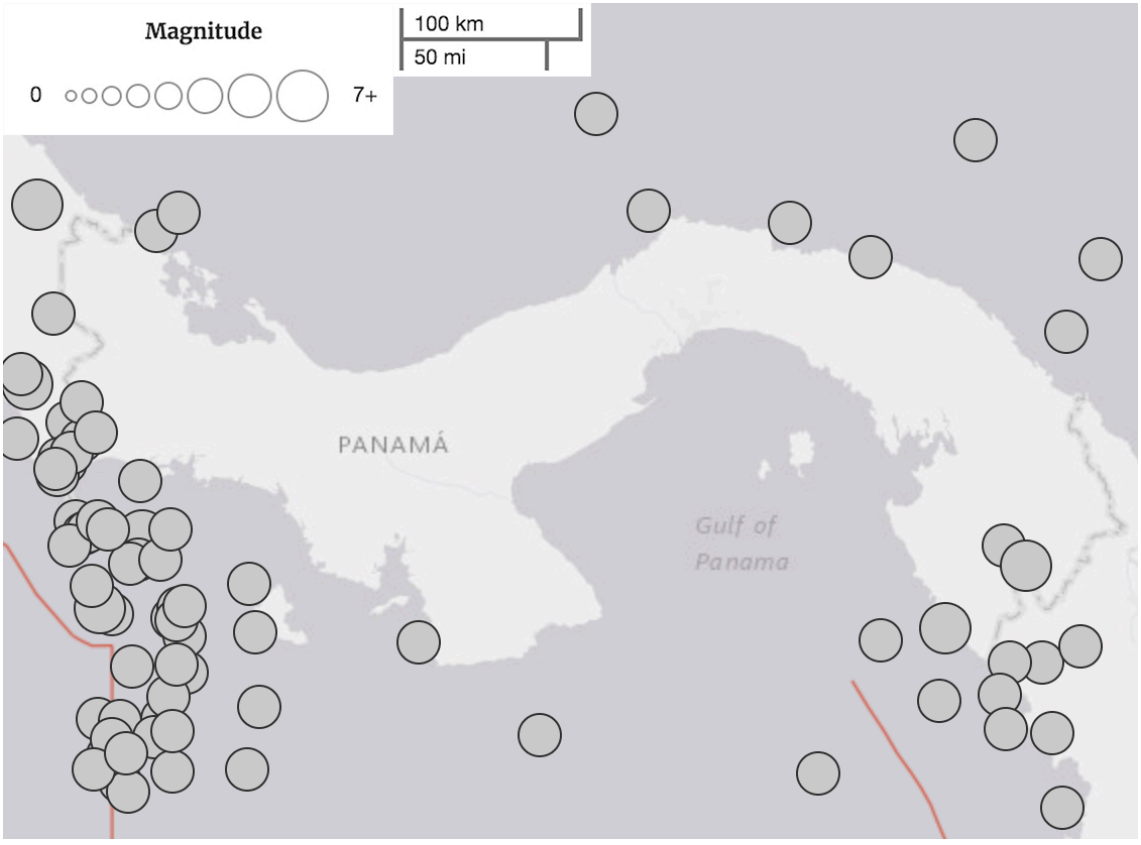

Fig. 3. Illustration of 79 seismic events with a magnitude of above 6.0 during the time period of 1924 and 2020 based on the earthquake catalogue of the United States Geological Survey (https://prod-earthquake.cr.usgs.gov/earthquakes/map), which are usually but not exclusively related to the given plate boundaries.

The October 2, 1913 seismic event in southern Panama has generated severe destruction, including effects of extensive cracking, liquefaction and landslides, leading to the

disappearance of Pedasi village with its inhabitants and a sudden rise of the sea level probably misinterpreted as a tsunami (MacDonald and Johnston, 1913; Kirkpatrick, 1920; Ambraseys and Adams, 1996). Two further seismic events in 1934 and 1962 occurred on the Pacific side of the Costa Rican border, where marine quakes with magnitudes of 7 and 6.8 generated tsunamis with local inundation, even in the Galapagos Islands, but lacked of reported major destructions (Lander and Cloud, 1964; Iida et al., 1967; Soloviev and Go, 1984; Camacho, 1991; Fernandez et al., 2000). On July 11 1976 occurred the most recent seismic event with a magnitude of 6.7 along the southern Colombian border, which generated a minor local tsunami and some documented damages (Garwood et al., 1979; Grases, 1994).

Later, a regional tsunami on April 22 of 1991 originating from Costa Rica produced considerable inundation and damage in Panama, without human casualties (Plafker and Ward, 1992; Denyer *et al.*, 1992, Barquero and Rojas, 1994; Camacho, 1994; Ambraseys and Adams, 1996).

Fig. 4: Time of the known epicenters of tsunami events in the area of Panama, taken from (https://maps.ngdc.noaa.gov/viewers/hazards/?layers=0) as indicated by the National Oceanic and Atmospheric Administration´s (NOAA) National Centers for Environmental Information (NCEI). Explanation see text.

3. TSUNAMI RISK ASSESSMENT IN PANAMA

The institution in charge of preventive and reactive care in disasters in Panama is the National Civil Protection System (Sistema Nacional de Protección Civil), created by Law 22 of November 15, 1982 (Gaceta oficial No. 19695, 1982), and administratively regulated

by Law 7 of February 11, 2005 (Gaceta oficial No. 25236, 2005). As the entity in charge of risk management and assessment in the Panamanian territory, its main objective is to execute specific mitigation and prevention measures to reduce hazards from any source, exposure and decrease the vulnerability of people to a catastrophe, in addition to carrying out response actions to any national emergency.

This institution has its own legal status and is under the directive of the Ministry of Government and Justice of Panama and being in charge of leading the Joint Task Force, created by Executive Decree No. 2 of January 7, 2015 (Gaceta oficial No. 27696, 2015). The Joint Security and Tourism Task Force (Fuerza de Tarea Conjunta de Seguridad y Turismo) is in charge of coordinating a timely and efficient response to a national emergency or disaster in a coordinated manner, and is made up of the National Civil Protection System (Sistema Nacional de Protección Civil - SINAPROC), the National Police, the National Naval Air Service (Servicio Nacional Aeronaval - SENAN), National Border Service (Servicio Nacional de Fronteras - SENAFRONT), Institutional Protection Service (Servicio de Protección Institucional - SPI), Benemérito Fire Department of the Republic of Panama (Benemérito Cuerpo de Bomberos de la República de Panamá - BCBRP), Panama Red Cross, Panama Maritime Authority (Autoridad Marítima de Panamá - AMP), National Environment Authority (Autoridad Nacional del Ambiente - ANAM), the Panama Tourism Authority (Autoridad de Turismo de Panamá - ATP), the Ministry of Health (MINSA), and the Single Emergency System (Sistema Único de Emergencias - SUME – 911).

A further initiative in risk management that Panama has been developing is the adoption of a National Policy for Comprehensive Disaster Risk Management (Política Nacional de Gestión Integral de Riesgo a Desastres - PNGIRD) through executive decree No. 1101 of December 30, 2010, which aims to "*provide to the Panamanian state and its institutions a regulatory framework to develop an integrated risk management associated with the impact of natural hazards and technological threats through a systemic and comprehensive approach to reducing vulnerability and promoting prevention, mitigation and effective response to disasters* "(Gaceta oficial No. 26699-B, 2011). This policy includes, in the context of disaster risk reduction, that Panama, due to its history, is exposed to risks associated with phenomena such as waterspouts, earthquakes, tsunamis, among others. It incorporates concrete actions that can be developed in the formal and non-formal educational infrastructure with a view to reducing the vulnerability of the population, working together with the civil society, local governments, universities, the Ministry of Education in the field of research, the academy and extensions.

One of the strategic allies of the National Civil Protection System, which receives and disseminates updated technical and scientific information regarding earth science, is the Geosciences Institute (IGC), which is part of the University of Panama. This was created by means of the Directive Council Resolution No. 6-77 of July 5, 1977. It is a research, teaching and higher extension entity with scientific and academic independence that have among its functions the continuous surveillance and monitoring of the country's seismic activities is in charge of alerting and guiding the National Civil Protection System and the community in general in the event of a disaster caused by seismic activity at the national level. It also maintains direct communication with the World and Regional Seismological Network and the Tsunami Warning System for the Caribbean and the Pacific.

Panama has been participating in a series of concrete actions on tsunami warnings, among which the European Commission Humanitarian Aid department's Disaster Preparedness Programme (DIPECHO) project for all Central America and Panama carried out by UNESCO, in conjunction with the Intergovernmental Oceanographic Commission-IOC, stands out (UNESCO-DIPECHO, 2019). It aims to strengthen early warning systems in the region, strengthening institutional capacities for tsunami warning and response. It includes a series of activities such as workshops, making flood maps and evacuating before Tsunamis, early warning drills in the coastal zone.

This DIPECHO project was developed from 2018 to 2019, with the participation of the National Civil Protection System-SINAPROC, Panama Maritime Authority -AMP, Geoscience Institute of the University of Panama-UP, Coordination Center for the Prevention of Natural Disasters in Central America - CEPREDENAC, Central American Integration System-SICA, Benemérito Panamanian Fire Department, National Tsunami Committee in Panama, Red Cross and the Tommy Guardia National Geographic Institute and leaves around 10,000 people trained in the event of a tsunami, from the communities of Puerto Armuelles, Baco, Limones, Rodolfo Aguilar and El Progreso, in the Barú district, Chiriquí Province.

4. METHODOLOGY

We have conducted a representative enquiry to the academic public in a variety of sites throughout Panama. Within the different sites where our survey has been applied, a coastal site has been included called Taboga Island, which is located south of the panama Channel inside the Gulf of Panama. This survey consisted of eleven basic questions and has been applied to 476 persons, of which 204 have been females, while the age range has been from 18 up to 70 years old, with a dominance of the age group between 18-28 (52,3%). The twenty different questions of the single sheet questionnaire should cover the perception, knowledge and awareness of the academic citizens and selected public about tsunami hazards versus the usual used term of a marine quake (maremoto) and its impacts (Scourse et al., 2018). Furthermore, the questions covered topics about the vulnerability of Panama towards tsunami hazards, risk awareness, historic knowledge of occurred tsunamis, which have impacted the country´s shorelines, evacuation plans, personal participation in tsunami drills, responsibilities of the corresponding authorities, types and forms of given tsunami alerts and source of information.

Based on the data that have been collected, a better idea may rise on social resilience and disaster risk reduction in Panama (Janes et al., 2010; Price and Narchi, 2018; Moreno et al., 2019). In the case of a tsunami, the ability to function and to act on the part of the citizens is crucial in order to behave appropriately and to be safe. The long-term objective of the study is therefore to derive measures for the optimization of disaster risk reduction, in particular through education, from the given results. This makes it possible to optimize the development of a risk-aware action competence and to increase the resilience to the natural hazard tsunami. This recent survey has also been conducted, as unfortunately, so far

there is a lack of general and particular studies about tsunami awareness, science, preparation, perception and resilience such those in the nearby localities and the region (Pararas-Carayannis 2012; Matheus-Medina et al., 2018; Celorio-Saltos et al., 2018; San Martín et al., 2018), which may lead to an better improved coastal hazard assessment (Fernández-Arce and Alvarado-Delgado, 2005; Engel et al., 2016).

5. RESULTS AND DISCUSSION

The initial question of our survey, about the knowledge and awareness of a tsunamis has been responded positively with some 97,2%, while only 89,2% are aware of marine quakes (maremotos), for many a synonym for tsunamis in the region (Scourse et al., 2018). Surprisingly, only 61,1% of the surveyed are sure that Panama is vulnerable of tsunami hazards, while 30,9% are unsure if this is the case and some 7,7% discard any potential vulnerability. However, when specifically asked if there would be any memory of any tsunami which have impacted in past Panama, only some 11,1% have had that memory and of them the answer has been mainly about the 80´s of the last century. None of the recollected or knew of any historic tsunami impact in Panama. Besides, some 88,5% of the surveyed of the Island of Taboga answered that they are aware of potential impact of their habitat in case of a tsunami. While 20,3% have been informed about what to do in case of an incoming tsunami, some 34,2% answered to have knowledge form other sources about what to do if a tsunami would occur. Such other sources include mainly social media (66%). Nonetheless, only 10% of the interviewed have a knowledge of a given evacuation plan. However, when specifically asked what would be the potential source to be warned of an incoming tsunami, with the given options of a foghorn, radio, TV, seismic movement or none, inside the islands community of Taboga, the predominant answer (85,4%) has been that there is no form to be warned. However, 88,5% of the islanders would know where to evacuate to, in case of an incoming tsunami, while only 25% would know what alert warnings to recognize, although only 3,2% have ever participated in a tsunami evacuation drill. Only 17,6% are aware which organization is monitoring tsunamis in Panama, while in Taboga nobody knows these corresponding organizations. In the island of Taboga, there is an answer of 100% in the denial of ever received conferences or workshops about prevention of disasters including tsunamis, of any contingency plans of natural disasters including tsunamis or even about any realized studies by the local municipality in respect of the given vulnerability of people and their settlements towards tsunamis.

The low participation in tsunami drills is somehow not surprising. Panama participated with 31 other countries in a regional event called “Caribe Wave 2018” on March 15 2018, where it was supposed to simulate an 8.1 event on the Richter Scale with incoming waves of up to three meters. This event being promoted by the UNESCO and SINAPROC had the intention to understand the degree of the public’s preparation and being simultaneously also awareness raising (Fig. 5). It helped certainly as community training and capacity building, but unfortunately, the participation was very low. As long as there is a way to long time gap between the last (national) tsunami impact and recent days, the interest of participation and preparation will remain low.

Fig. 5: Tsunami drill of the March 15 2018 event in Panama. Credit Critica.com.pa

In this respect it is a challenge for the corresponding authorities to raise creatively and intelligently awareness of the existing tsunami hazards and especially in the known vulnerable coastal communities on both side of the country. Such communities need to be prepared to react correctly and respond timely when a tsunami alerts will be given. They will need also to know how to remain close to the affected areas prior the arrival of national and international aid agencies and institutions. The DIPECHO program teaches the local government and its organizations exactly the most effective life-saving efforts, which are usually conducted by the affected populations themselves, during and after a tsunami impact.

These activities may be accompanied by the installations of local but far reaching early warning systems and signs and corresponding emergency plans (Fig. 6). It is imperative to rethink the land use of vulnerable areas, to elaborate new coastal vulnerability maps based on a variety of potential scenarios, to apply potential relocations of entire villages and also where possible to apply a reinforcement of buildings and other strategic infrastructure, which is on reaching distance of tsunami hazards, as demonstrated in other countries of the region (Chunga and Toulkeridis, 2014; Matheus Medina et al., 2016; Toulkeridis, 2016; Rodríguez Espinosa et al., 2016; 2017; Chunga et al., 2017; Toulkeridis et al., 2017a; 2017b; 2018; Navas et al., 2018).

Once the local population may be prepared to a certain degree, than the regional authorities may use existing of how to prepare visitors and tourists towards tsunami hazards, as Tourism is especially vulnerable to disasters and, being fragmented, often its response is difficult to initiate and coordinate (Ritchie, B. W. (2004; Mistilis & Sheldon, 2006; Pforr & Hosie, 2008; Matheus-Medina et al., 2018).

Fig. 6: Installation of Tsunami evacuation signs in Panama. Credit Critica.com.pa

6. CONCLUSIONS

Panama has been historically impacted multiple times by a variety of tsunamis from the Atlantic as well as Pacific oceanic sides.

The Panamanian population, although they know what is a tsunami and its hazards, more than 35%, does not see or realize that Panama is a vulnerable country towards tsunamis or marine quakes. This is largely due to a lack of historical memory of events that occurred in the past.

Lack of awareness of this oceanic hazards and the lack of implementation of concrete plans and actions at the local, regional and national levels leave the population to be much more vulnerable to the possibility of a disaster caused by tsunamis and associated hazards.

It is necessary to include training and drill activities for the population in the topics of risk assessment within formal and non-formal education, as established by the national policy for comprehensive risk management for tsunami hazards and risks.

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