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Assessment of social perception on the contribution of hard-infrastructure for tsunami mitigation to coastal community resilience after the 2010 tsunami: Greater Concepcion area, Chile

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ABSTRACT

A GIS analysis on the urbanization spread (1725 to present) in the Greater Concepcion Region demonstrates that increasing the tsunami disaster resilience of coastal communities is a pressing issue in Chile, due to the continuous presence of human settlements in tsunami-prone areas. This research assesses the contribution of “hard-infrastructure” for increasing disaster resilience within five coastal towns (Dichato, Coliumo, Tumbes, Penco and Talcahuano). Structures were considered beneficial to resilience-building if they had multi-functional properties which aided in the social and/or economic recovery of the affected community. The assessment was carried out through in-depth interviews with local inhabitants until the point of data-saturation. Results reveal that all surveyed coastal towns had hard-infrastructure that was built after 2010, in the form of promenades and elevated housing. The former structures contributed positively to building economic resilience in Dichato, Talchuano and Penco, through the promotion of tourism and small-scale fishing activities. However, the physical design of the elevated houses was found to only facilitate recovery of community economic functions in Tumbes, while causing strain on the social fabric and possibly hindering tsunami evacuation in all other study sites. The mixed contribution of hard-infrastructure to coastal resilience highlights the need for the de-centralization of planning and reconstruction processes for a successful contextualization of the issue.

1. Introduction

Global awareness of tsunami disasters has been increasing, especially in the wake of the 2004 Indian Ocean Tsunami and the 2011 Tohoku tsunami. In addition, the 27 February 2010 tsunami, which impacted Chile's Maule region, cost the country an estimated USD 30 billion in damage [5] and represents South America's biggest tsunami disaster since 1979 [25]. In light of the devastating impact of tsunami disasters, increasing tsunami disaster resilience in coastal communities is necessary. Tsunami disaster resilience has been defined as preparations that minimize both the number of causalities and the damage to physical and institutional infrastructure [8,19].

Typical characteristics of tsunami-resilience in coastal communities include the existence of both soft and hard types of resilience. In general, soft resilience measures do not directly provide a physical (protective) barrier against the direct force of a tsunami, as compared to hard resilience measures [27,19]. Examples of these measures are summarized in Fig. 1.

Fig. 1 shows that hard artificial resilience measures include protection and accommodation infrastructure, which will be referred to in this paper as “hard-infrastructure”. Hard-infrastructures are able to contribute to building tsunami resilience mainly in three ways: (1) decreasing the direct damage from the next tsunami event; (2) performing multi-functional/secondary functions which facilitate the social/economic recovery of the affected areas and (3) strengthening soft resilience by serving as physical reminders that reinforce a culture of tsunami awareness. The latter two contributions highlight the versatility of

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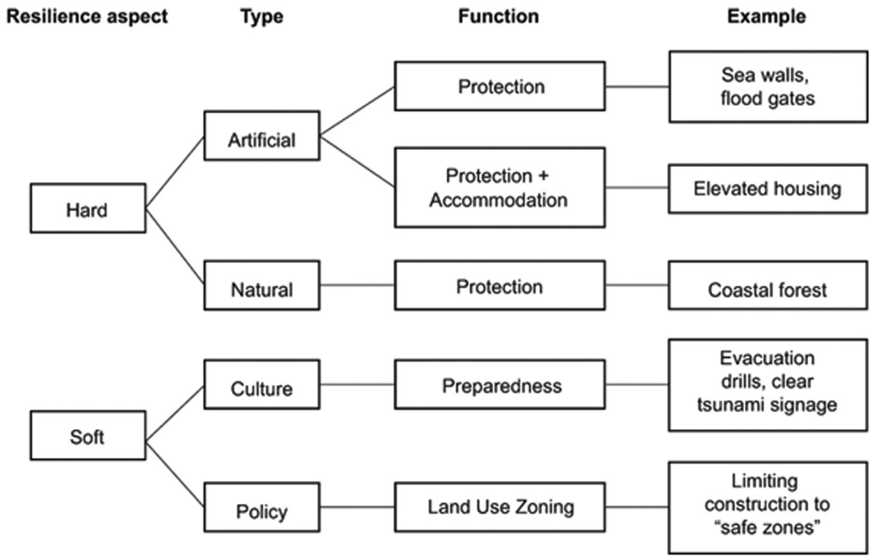

Fig. 1. Diagrammatic representation hard and soft tsunami disaster resilience in coastal cities and their functions. Adapted from: Intergovernmental Oceanographic Commission [27], Franco and Simbieda [19] and Esteban et al. [15].

hard-infrastructure in performing multi-functional roles, which provide positive feedback to building tsunami disaster resilience.

1.1. *Multi-functionality in resilience thinking*

The concept of multi-functionality was first introduced in ecology [26] and is positively correlated with system resilience. The more multi-functional a system is, the more it is able to absorb disturbances without sustaining significant change to its original function [10].

The classic illustration of multi-functionality utilizes an ecological food web where an increase in multi-functionality can be demonstrated through increasing the number of flows (connections between species) per node (any given species) [14]. A low level of multi-functionality, and accordingly, low resilience, can be represented in a simple one predator, one prey food chain model [14]. A food web system represents an increase in multi-functionality and resilience due to the increased number of flows from a single node at a higher tropic level to nodes at a lower tropic level. In this classic case, increasing multi-functionality could be thought of as being synonymous with increasing redundancy due to the similar functional property of each individual flow.

However, multi-functionality and redundancy have distinct characteristics upon application of the ecological food chain/food web model to the contribution of hard-infrastructure to building tsunami-disaster resilience in coastal communities. In terms of increasing resilience through redundancy, more resilient communities would have a higher number of hard-infrastructure which performs the same protective function. In terms of contributing to resilience building through multi-functionality, hard-infrastructure may have physical characteristics which provide economic and/or social benefit (on top of the basic benefit of physical protection). For example, a sea-wall/promenade can both function to reduce direct damage from a tsunami but, if properly designed, can also facilitate beachfront access for tourism purposes.

For the purpose of this study, the focus remains on resilience as a multi-functional property (instead of redundancy) for resilience-building. This is because an increase in the number of hard-infrastructure with similar characteristics does not necessarily result in a proportional increase in resilience in terms of potential physical protection. The same hard-infrastructure may have variable effectiveness in different communities, given the unique geographic context of each coastal community. Therefore, on top of the basic physical protection requirement it is important that the number of positive qualities inherent to any given hard-infrastructure outweighs negative qualities, if the structure is to maximize its contribution to coastal community resilience [22,48]. An example of a negative quality associated with constructing seawalls of more than three meters above sea level is the wall's tendency to obstruct scenic views of the ocean [6].

Studies by Paton and Johnston [35] and Almuna et al. [1] suggest that both positive and negative functions inherent to hard-infrastructure can be elucidated from community perception of livelihood and communal improvements which result directly from multi-functional characteristics of such infrastructure. Notably, quantifying post-tsunami changes which were found to result in an improvement in livelihood (and the resultant economics of the region), as well as increase a sense of community, are considered to contribute positively to resilience building against future tsunami disasters [1,35]. These tangible positive multi-functional effects further drive risk perception and consequently supports the building of soft resilience (culture of preparedness) and lends support towards other mitigation initiatives [35].

Despite the potential of hard-infrastructure to contribute to tsunami disaster resilience, there have only been limited studies which assess this potential from the perspective of multi-functionality in resilience theory. Previous studies on tsunami-disaster resilience in coastal cities has been examined through a macro-level, multi-sectoral analysis on short-term disaster response. These studies have focused on broadly defining how well current social, economic and/or political factors in coastal cities (mainly in the United States and Chile) fit into the current concept of tsunami-disaster resilience; and if not, explaining what factors are lacking [7,8,19]. Broad, macro-level analyses of resilience often does great justice in expanding the resilience concept but sometimes has limitations in providing clear step-wise guidance on how to promote resilience practices due to the blending of descriptive and normative aspects [10].

As such, this paper aims to first demonstrate the need for artificial hard-resilience infrastructure in coastal towns in the Greater Concepcion Region, by justifying that the towns are located in areas regularly hit by tsunamis. This paper then aims to utilize multi-functionality as a lens to examine the contribution of hard-infrastructure constructed in these towns after 2010 to