An innovative strategy to increase the resilience of flood-vulnerable communities while reducing risk of population displacement and psychological trauma

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Abstract

Protecting communities from the displacement and psychological trauma that may accompany severe flooding is challenging. Vulnerable communities are increasingly faced with climate change-induced crises, often having a limited, inadequate set of tools to cope with the intensity and urgency of post-crisis circumstances. The increasing frequency of natural hazardous events requires forward-looking strategies to limit the likelihood that hazards will evolve into disasters, leading to repetitive loss and rebuild. To date, standard flood mitigation strategies have ineffectively relied on systems that either attempt to control water or avoid it by moving away. Instead, how might we better embrace climate changes and adapt our infrastructure to accommodate flooding? One solution is the implementation of amphibious architecture, specifically, buoyant foundations. Buoyant foundations are a cost-effective, adaptive flood risk reduction strategy that works in synchrony with a region′s natural flood cycles. These are retrofits that modify the foundations of existing buildings, enabling them to rise and float on the surface of water upon flooding and then return to their original positions as the floodwater recedes. An amphibious retrofit is a low-cost, low-impact flood risk reduction option that drastically reduces the loss and displacement that may cause more trauma than the event itself. This paper discusses case studies of amphibious prototypes developed for flood-prone sites in Nicaragua and Vietnam.

Keywords: Amphibious Construction; Population Displacement; Disaster-Related Trauma; Malacatoya Nicaragua; Mekong Delta Vietnam; Flood Risk Reduction; Climate Change Adaptation.

1. Introduction

Flooding is one of the most common and destructive natural hazards, accounting for 47 percent of all weather-related disasters, and causing more damage worldwide than any other type of natural hazardous event (Alinovi, 2017). Climate change has led to an increase in the frequency of flooding, causing devastating effects on vulnerable communities. As sea levels rise and urbanization grows in flood-prone areas, the number of people exposed to flood inundation, storm surges and seasonal river floods increases. This is especially critical for indigenous communities, where water source proximity is critical for survival and traditional practices as communities rely on it for food, livestock and agricultural production as well as cultural traditions.

Severe flooding can have significant psychological impacts on a community. Flood disasters can pose issues during the initial event (primary stressor) but often result in problems that continue afterwards during the lengthy recovery period (secondary stressor) (Fussell & Lowe, 2014). Government-funded forced relocation programs are expensive, and ultimately prove to be unsuccessful, with populations frequently abandoning the resettlement location and returning to their places of origin. Relocations uproot communities from their identified homes, property and ultimately, memories. Recent studies of post-disaster displacement prove that post-trauma displacement exacerbates psychological damage, resulting in symptoms of depression, anxiety, and post-traumatic stress disorder for years after the disaster. Fussell and Lowe looked at four factors that determine the severity of stress associated with displacement: geographic distance, type of housing, number of times moved, and time spent in temporary housing. Statistically, individuals who relocate maintain higher stress levels than those who return home after a disaster. In addition, people who spent a significant amount of time moving or living in temporary housing had substantial increases in stress levels.

Displacement heavily disintegrates routine and community. Where people live, with whom they interact, and where they work are heavily impacted by displacement. Other stressor include disruptions to education and limited access to healthcare, exercise and contact with friends and family. Displacement increases risks of discrimination, physical danger, and isolation (Fussell & Lowe, 2014). While commonly seen as separate issues, emotional and monetary costs are important and interrelated aspects of recovery. Poor mental health makes managing and solving stressful situations particularly challenging during relocation. In addition, the ability to find and maintain employment is strongly tied to one's mental health (Harnois & Gabriel, 2000) and plays a crucial role in post-disaster financial recovery. Relocation impacts far more than simply a person's physical location—in the long term, it has proven not merely unsatisfactory but damaging for residents in flood-prone regions. Reports of psychological distress range from anxiety, headaches, and difficulty sleeping, to more serious symptoms such as post-traumatic stress disorder (PTSD) and depression (Alderman et al., 2013). Studies have shown that respondents still struggle years later with anxiety during rain and flooding events (Lamond et al., 2015). Apart from the environmental trauma of surviving a disastrous natural event, respondents have reported aftermath stress in dealing with government and insurance agencies, difficulties with clean-up, and difficulties in rebuilding and re-establishing one's life (Dixon et al., 2016).

Current flood mitigation strategies that attempt to control or alter the environment are proving to be ineffective over time. Erecting barriers may provide temporary protection from flooding, but consequences are magnified when the system ultimately fails. Instead of trying to fight sea level rise, this paper proposes amphibious foundation retrofits as an effective strategy for minimizing the traumatic repercussions of disastrous flooding and displacement. It is imperative that we reconsider the traditional relationship of water and human habitation to focus on flood resilience through accommodation rather than flood defense. Similar concepts of achieving flood resilience through adaptation rather than control, by adopting the approach of "flood tolerance", are explored by Liao et al. (2016).

The amphibious foundation strategy is not an unprecedented system. There are examples of its use in Old River Landing, Louisiana, where residents have for forty years been outfitting their homes with expanded polystyrene flotation blocks and steel guidance posts as protective measures against seasonal flood damages (English, 2009). Additional projects include individual houses in the US, the UK and Thailand, and several amphibious housing complexes in the Netherlands (English et al., 2016). Although flood resilience strategies are being explored internationally, most of these are new construction in developed countries and serve to protect the property of the fairly well-off. The strategies described in this paper for amphibious retrofits to existing houses in low-income communities are relatively inexpensive to implement and easy to install. They offer resilience against damage, loss and trauma and can mitigate the threat of forced displacement for those communities that are vulnerable, under-resourced, and living in rural and under-served parts of the world (English et al., 2016).

The amphibious retrofit concept assembles three basic components: a buoyancy system that displaces water and provides flotation during the flood, a vertical guidance system to prevent any horizontal movement of the house as it rises and falls, and a structural subframe that connects these new components to the existing house. A buoyant foundation can accommodate varying levels of water, and is less susceptible to hurricane and wind damage compared to statically elevated homes (English et al., 2017) (Figure 1). Buoyant foundations are ideal for houses that are already elevated enough to have a crawl space and are in locations that do not have fast-flowing floodwater or large waves. The simplicity of the design allows for easy customization. The use of local materials and local construction practices are encouraged when implementing the system, allowing location-specific site issues to be addressed and accommodated. Buoyant foundation technology is easily adaptable and replicable by local tradespeople, thus both supporting the local economy and promoting community resilience and independence. Amphibious architecture offers an innovative, economical, and culturally sensitive option for flood-vulnerable communities. The following analysis provides both theoretical and built case studies of amphibious retrofits.

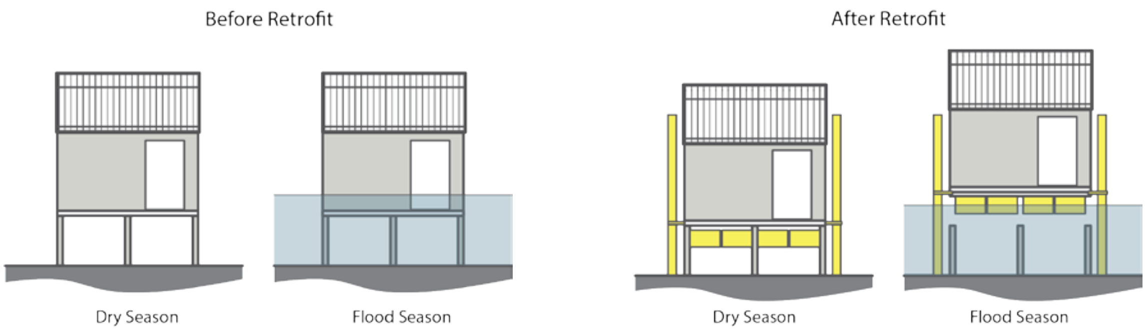

Figure 1: Diagrams showing how a regular elevated house compares to an amphibious retrofit during flooding (BFP/Teresa Tran)

2. Casa Anfibia, Malacatoya, Nicaragua

Nicaragua is experiencing social, economic and environmental crises that threaten vulnerable and low-income communities located in flood-prone areas. These communities have difficulty adapting to rising sea levels as they often do not have the resources to build flood protection or relocate to a safer place of their own choosing. The Nicaraguan government resettlement programs have been largely unsuccessful, with people frequently abandoning the government-provided housing in distant locations to return to their devastated former homes with no hope of any further government assistance. These populations rely heavily on the local water and food supplies in their home regions and resist adapting to the unfamiliar and unfavourable conditions of the new resettlement locations. Our proposal Casa Anfibia would allow local people to retain their original place of residence and be able to withstand flooding, encouraging an end to the damaging process of forced relocation (English et al., 2016).

Nicaragua is home to one of the largest tropical forests in the western hemisphere, though increasingly, the forest is threatened by the timber and agricultural industries. Deforestation is a national concern, contributing to temperature increase and making the region increasingly susceptible to the impacts of climate change. Today, there are only three million hectares remaining of the eight million hectares of forest that existed in 1950. Forests act as a natural shield against extreme weather such as storms and hurricanes and help to regulate rainfall. Without the protection of forests to mitigate destructive forces, communities are increasingly susceptible to disasters, such as Hurricanes Mitch and Felix. Biologist and geographer Jaimie Incer Barguero reports that, "Rain causes greater damage to land stripped of its trees than to forested areas" (Silva, 2007). Officials credit trees for weakening the intensity of storms during Hurricane Felix.

When the water level of the river is high, the Malacatoya community becomes accessible only by boat, and flooding encroaches on homes along the banks of the river. The government solution to this dangerous situation is to evacuate and relocate the affected families. According to local pastor Roger Caray, 92 percent of people forcibly relocated by the government leave the place of resettlement to return to debilitated conditions (Laffay, 2012) (Figure 2). Many residents have lived along the river for their entire lives and are unwilling to live elsewhere. They are aware of the risks associated with living near the river; however, they find there is more for them there than in the new locations. While dangerous, the river provides the community with their means of survival. Residents depend on the fertile soil for raising food, and the river provides access to a virtually unlimited supply of water for daily living, agriculture, and livestock. Relocation disrupts established social networks and access to their main sources of sustenance and income, namely agriculture and fishing. The prevailing sentiment of the community as voiced by a resident is "life wouldn't be the same somewhere else" (Laffay, 2012).

The site chosen for the development of amphibious foundations is along the Malacatoya River between Lake Managua and Lake Nicaragua. This region is prone to natural hazards such as earthquakes, hurricanes, and seasonal flooding. Communities in the area suffer from chronic flooding and other major issues such as poverty, legal vulnerability, and the threat of displacement. Amphibious foundations are proposed by the Buoyant Foundation Project (BFP) as an affordable solution for flood resilient housing that would allow Malacatoya residents to remain in their homes during flooding and minimize unnecessary trauma caused by damage, displacement and loss. Casa Anfibia (Figure 2) is designed with recycled and renewable materials, and the

Figure 2: View of the Malacatoya River (left); houses reoccupied by residents post-displacement (right) (CO2Bambu)

technology is easily transferable and adaptable to a range of locations and scenarios. Recycled plastic barrels are suggested for the buoyancy elements due to their low cost and local availability. The frame is designed of bamboo for its low weight, reducing the cost of the buoyancy system. Bamboo is renewable and can be regrown quickly, in light of local issues of deforestation (Hammond, 2008). Nicaraguans employed in forest harvesting operations are often very poor and have no other sources of income. The implementation of amphibious foundations offers a means to grow the local economy. These simple new amphibious houses for Malacatoya provide low cost, flood protected living quarters, including a surrounding deck to accommodate the homeowner's pigs and chickens, and support residents in their desire to maintain their traditional way of life in their place of origin (Figure 3).

Figure 3: Casa Anfibia, the design proposal for the Malacatoya community (BFP / Zak Fish)

3. Mekong Delta, Vietnam

The Buoyant Foundation has recently completed the construction of four amphibious foundation retrofits to homes in the Mekong Delta. This project, funded by the Global Resilience Partnership Water Window Challenge and the Z Zurich Foundation, resulted in a two-year international collaboration among Canadian and Vietnamese universities, government agencies and non-profit organizations to develop amphibious retrofits for Vietnamese rice farmers' houses. The Buoyant Foundation Project is evaluating the performance of these amphibious prototypes for use in developing a replicable model for easy, low-cost implementation throughout the region. Once established, the system can be expanded and reproduced throughout the country.

In Vietnam, water is a part of everyday life. A complex system of rivers and canals weaves through the region. These waterways are used for transportation, floating markets and community activities. Vietnam is facing major climate change challenges, with much of the population living in coastal and deltaic zones. This makes disaster management, particularly flood and storm control, a top priority for the government.

The Mekong Delta is a low-lying plain, located less than three metres above sea level, and is highly susceptible to floods caused by rising sea levels and climate change (Figure 4). Flooding is an annual event in the region and it provides important benefits to local agricultural and aquacultural production. The Mekong Delta region provides a majority of the staple food and fish for the rest of the country and is considered Vietnam's rice basket. It is a densely populated area, home to over 17 million people. With climate change and upriver dam-building, there is an increased risk of potentially disastrous floods. Annual runoff from the upper basin of the Mekong Delta is estimated to increase by 21 percent by 2030, with annual precipitation expected to increase by 200mm each year (Eastham et al., 2008). Climate specialists have estimated that sea level will rise by 0.8 meters by 2100, resulting in 40 percent of the Mekong Delta being submerged. If nothing is done, nearly one third of the local population will be affected and many will be forced to relocate.

Figure 4: Houses in the Mekong Delta, during flood season (BFP / Elizabeth English)

Previous government flood mitigation strategies include dike and canal construction to control water flow, and providing loans to homeowners for relocation. These methods have limited long-term effectiveness and fail to meet the needs of local people. The dikes significantly interfere with the natural ecosystem, making food production difficult for low-income agricultural and aquacultural farmers (Chapman, 2018). Relocation and resettlement programs provide limited success. Relocated residents report a decrease in income and an inability to repay their debts after relocation (Chun, 2015). Some residents develop their own solutions for flood mitigation, including statically elevating their houses, however static elevation cannot accommodate gradually increasing flood levels without repeated, expensive renovations.

In mid-2018, the Buoyant Foundation Project worked in Vietnam to retrofit four houses in the Mekong Delta, two of them in An Giang Province and two in Long An Province.

The project's first client is Nguyen Van Nao, a rice farmer in Tri Ton District in An Giang Province. Nao's home is situated in a recurrently flooding rice field. The buoyancy for Nao's house is provided by recycled jugs bundled together and tied up with rope to the structure under the house. Skirt boards surround the jugs to protect them from the force of flowing water. A simple sleeve detail is used: a thick rope looped around each of the guidance posts, keeping the house in place laterally as it rises and falls with the level of flooding (Figure 5).

Figure 5: Nguyen Van Nao's house, a new built house (left) and the sleeve detail used (right) (BFP / Elizabeth English)

The second prototype in An Giang belongs to Nao's younger brother Nguyen Van Lac, also a rice farmer. His house was mandated for displacement several meters away from its existing position on the edge of the elevated road, into the rice field behind it (Figure 6). Our project both moved his house and retrofitted it with an amphibious foundation. The design for this retrofit was modified from that for Nao's house, with a different method of arranging and attaching the jugs, a different design for the centering devices, and a more complex sleeve detail comprised of wood wrapped with rope to frame each guidance post.

Figure 6: Nguyen Van Lac's house, which was moved back from the road (BFP / Teresa Tran; Elizabeth English)

Two prototypes were also constructed in Long An Province, both of them retrofits to existing houses as was the case in An Giang. The retrofits for Dang Van Nang's home replaced wooden posts with stone columns for better structural support.

The buoyancy elements in this case were recycled plastic barrels. The guidance posts had rope-wrapped wooden sleeves, similar to those of Lac's house in An Giang (Figure 7). The fourth retrofit, to a house belonging to Nang's sister-in-law Nguyen Thi Dung, was similar to Nao's, using recycled jugs and a simple rope sleeve.

Figure 7: Dang Van Nang's house (left) and the more complex sleeve detail (right) (BFP / Elizabeth English)

Each retrofit is slightly different to allow comparisons of their behaviour during flooding. There was visible improvement in the construction of the details as the crew gained experience with each project. As of July 2018, all four retrofits were completed and ready to be monitored in the upcoming monsoon season to gather data on each system's performance and community satisfaction. During the fall 2018 monsoons that followed, all four houses floated successfully to the great satisfaction of the owners and envy of their neighbours (Figure 8).

In future scale-up phases, additional houses in the Mekong Delta will be retrofitted with amphibious foundations and improved with the gathered data. Training manuals will be compiled as guides for amphibious construction and as a basic cost estimation tool. These guidelines will help reduce upfront engineering costs for the systems when they are later implemented in other vulnerable areas.

Figure 8: Amphibiated homes in An Giang Province floating on the 2018 monsoon flood (Pham Duy Tien)

4. Conclusions

Due to changes in the global climate and rapid urbanization, the threat of flooding is at the forefront of global issues. Cities are continually faced with flooding with increased severity and frequency. As population steadily grows, people around the world experience greater social and economic damage with each flood. Floods can disrupt lives, create trauma, trigger displacement and introduce costs that low-income families cannot afford. The stresses of dealing with disastrous flooding and consequent displacement can have grave negative impacts on wellbeing and mental health. It is imperative to rethink the current strategies that work against nature, and instead strive to implement approaches that accommodate the natural course of water. Amphibious foundations are a way of working in harmony with nature, providing low-income communities with flood protection that is culturally and environmentally sensitive, and helping to preserve traditional ways of life. Amphibious retrofit construction can be applied to individual buildings or entire neighbourhoods and provides numerous potential benefits in comparison to alternative strategies. An amphibious approach allows homeowners to keep their houses safe without the devastation of repetitive damage or the trauma of forced removal from their homes and communities.

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