Integrating human health, ecology and built environment design: A TDAR Gardens Intervention case study with an informal slum community in the Peruvian Amazon

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Abstract

Integrating human health, ecology and built environment design:
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This dissertation investigates the intertwined relationship between the built environment and human and ecological health. The project developed and implemented a collaborative action approach to explore the potential for transdisciplinary urban ecological design interventions to be creative, effective, resource efficient and sustainable strategies to relieve burdens of disease, improve degraded urban environments, and address social inequities. The research explored the context of slum communities – places having harsh human, environmental and ecological health conditions. Using an applied Transdisciplinary Action Research (TDAR) approach to investigation, the team conducted a design-build-research project that implemented household and community gardens with residents of the informal floating slum community of Claverito in Iquitos, Peru and measured changes in human and ecological health over one year. This project tested the incorporation of health research into design practice, community design interventions as part of health initiatives, and deep community engagement to maximize impact. This dissertation presents the research in three manuscripts in preparation for publication: **1)** Assessing social-ecological health conditions in a Latin American slum community, **2)** Human and ecological health outcomes of a Gardens Intervention in a Latin American slum community, **3)** Using Transdisciplinary Action Research (TDAR) and a Gardens Intervention project to target human and ecological health issues in an urban slum community.

Outcomes of this research include: **a)** the development of a Community Social-Ecological Assessment Framework for gathering human-species-environment data in slum communities, applied to Claverito; **b)** analysis of the modification of the TDAR framework to target human and ecological health issues in Claverito and include a participatory design approach; **c)** results of the human and ecological health assessment after the Gardens Intervention: positive trend in land pollution and biodiversity of plants (change in H' = 15.48 and 1-D = .73), birds (change in H' = 15.48 and 1-D = .07), and butterflies (change in H' = .51 and 1-D = .01), significant positive changes in community beautification (p <.001), social relationships (p <.001), injuries and falls (p <.001), access to medicine (p <.001), self grown medicinal plants (p <.001), food security (p <.001), and mental wellbeing (p =.02), with household beautification not statistically significant (p = .53) and a slight decline in biodiversity of amphibians (change in H' = .09 and 1-D = -.02); **d)** results of the Design Impact Assessment: residents perceived the Gardens Intervention to have meaningful positive change across all indicators of land pollution, environment, beautification, social wellbeing, medicine security, food security and mental wellbeing; and **e)** outcomes of the Design Sustainability Assessment: positive indication of project sustainability and stewardship in Claverito across indicators of financial investment, emotional investment, durability and use, ownership, economics and education.

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Contents

Chapter 1

Introduction

This research investigates the relationship of the built environment to human and ecological health. It combines methods, processes and theory in the human health, natural sciences and design fields and adopts new tools and techniques for understanding and improving human and ecological health in communities. Using an applied approach to investigation, this study implemented a design-build-research project with a transdisciplinary team, testing the integration of health research into design practice, community design interventions as part of health initiatives and a transdisciplinary action research approach with strong community engagement to understand and maximize impact. This chapter introduces the theory behind the topic of inquiry, methods, processes and study location used in the research, with key investigations highlighted in bold.

Topic of Inquiry: Health and the Built Environment

Accelerated urbanization, social inequity, environmental degradation, species extinction, climate change, disease exposure and water and food insecurity are inextricably linked, pressing issues of today. Life on this planet is intertwined (Whitmee, Haines, Beyrer, & et al., 2015) and the **health of humans, species and the environment are co-dependent** (King, et al., 2008). Biodiversity and ecosystem function affects human health and wellbeing through shared food, water and soil system, disease transmission, climate regulation, and pharmaceutical, energy or material innovations, among others (Grifo & Rosenthal, 1997; Morand & Lajaunie, 2018). Figure 1a shows a diagram of the relationship between the health of humans, the health of flora and fauna and how both are situated in and dependent upon the health of a shared environment. This research focused on the *built environment*, or the shared environment that has been altered by humans in which we live, work and recreate. Figure 1b shows one of the hypotheses explored in this research, postulating that improved conditions of the shared built environment will result in improved human and ecological health. Likewise, poor built environment conditions may contribute to poor human and ecological health.

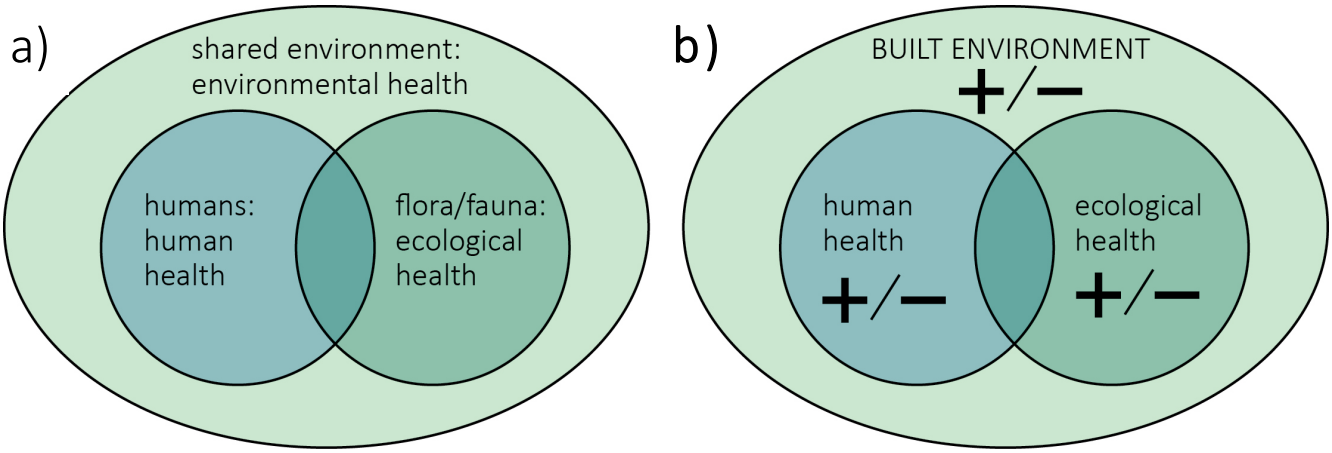

Figure 1: a) The health of humans, flora and fauna and their shared environment are all related. b) Therefore, positive improvements in the shared built environment conditions may contribute to improvements in human and ecological health, and likewise poor built environment conditions may contribute to poor human and ecological health [adapted from One Health theory **(King, et al., 2008)**]

A broad and growing body of literature supports the idea that **the built environment has a major and multi-faceted role in human and ecological health** and should be considered an integral part of public health systems. Because the study in this manuscript is led through the lens of a landscape architect, this work examined ***built environment landscapes*** (as

opposed to buildings) in particular. Built environment landscapes can be *indicators* of both human and ecological health. Because they are imprinted by cultural habits, socio-economic conditions, natural processes and the behavior of living organisms throughout history, they are both time capsules and barcodes suggesting layers of health and un-health (Andrews, 2013). Built environment landscapes are considered *social determinants of health*, creating circumstances and opportunities for healthy outcomes and are widely discussed as a critical component to improving *health equity* (Solar & Irwin, 2010; Williams, Costa, Odunlami, & Mohammed, 2008) and in *health promotion* and *disease prevention* (Dannenberg, Frumkin, & Jackson, 2011). Parallel research examining ecological health in our built environment landscapes connects environmental issues such as biodiversity loss and climate change to impacts on human health suggesting that built environment landscapes are *determinants of health for non-human species* as much as for humans (Seto, Solecki, & Griffith, 2016; Zari, 2014; Dean, Van Dooren, & Weinstein, 2011).

Public health and environmental scientists often refer to gardens, parks and green infrastructure within urban built environment landscapes as ***urban nature*** or ***nearby nature*** experiences. A large and growing body of scientific evidence indicates promising linkages between urban nature and positive and measurable physical, mental, social and economic health impacts (Wolf & Robbins, 2015; Pleasant, Scanlon, & Pereira-Leon, 2013; Seymour, 2016; James, Hart, Banay, & Laden, 2015). Urban nature may restore *ecosystem function*; this is important because humans also benefit from the health of ecosystems and their inhabitants through the *ecosystem services* they provide, and the loss of these services in dense urban areas contributes to poor human health and wellbeing (Millennium Ecosystem Assessment, 2005). Within urban nature, ***healing gardens*** may also create restorative spaces for target populations, playing a critical role in *palliative* or *rehabilitative care* by reducing the severity of symptoms and helping individuals cope with ill health such as injury, trauma or illness (Winterbottom & Wagenfeld, 2015). ***Defiant gardens*****,** or healing gardens created in extreme or difficult environmental, social, political, economic or cultural conditions such as slums, may have additional health supporting dimensions such as increased *resilience* and *empowerment* for the disenfranchised (Helphand, 2006).

Landscape architects, as professional designers of built environment landscapes, have long considered designing for human and ecological health, though not often as explicitly or critically quantified as the research presented herein. When the miasmatic theory, or the idea that "un-health" emerges from the landscape, was popular knowledge in the 19th century, Frederick Law Olmsted designed Central Park in New York City with the idea that the reverse was also possible - that built environment landscapes could be crafted to reduce miasma and therefore increase health (Szczygiel & Hewitt, 1974). The miasmatic theory faded with the discovery of the microorganism, however more recent specialties within the landscape profession such as designing healing gardens, memorials and therapeutic landscapes still focus on designing with human wellbeing as a broad goal however often for particular purposes. Trends in the design professions in the 1970's-90's shifted towards "fixing" damaged post-industrial landscapes that were causing environmental and human health issues and began layering in human and ecological health data into the design process (Amidon, 2010). This later evolved in the mid 2000's into designing preemptive multi-performative and generative ***green infrastructure*** landscapes. Because landscape architects have trained insight into this functional intentionality, can recognize the difference between what is wild occurring or designed green infrastructure, and are immersed in the scholarship of "nature", they tend to be sensitive to using the term urban nature to describe their designed work. In recent years, the term ***urban ecological design*** has been used to refer to designs that mimic ecological systems to improve ecosystem and social services, an approach that also adds further intentionality of human and ecological health to the design process (Amidon, 2010; Rottle & Yocom, 2011).

Yet, despite each of these evolutions, landscape architects and other designers of the built environment are not trained to understand and target health issues in communities, and rarely work on projects that quantify health outcomes to understand the impacts of their work and increase on-the-job professional knowledge (Andrews, 2013). Similarly contemporary health models often ignore the ecological dimensions of human health and disease and health and ecology professionals are not trained to engage with communities to understand how their living environments can be shaped to maximize health benefits (Steingraber & Hill, 2002). The urgency and immediacy of global environmental health issues and their health impacts should inspire changes in the focus of research and the practices of community action. Siloed disciplinary frameworks are no longer equipped to handle the complexity of issues we face today; we require consilience of ideas and evaluative methods (Wilson, 1998). While the body of literature on built environment landscapes, urban nature, and gardens and health is large and growing, because of these disciplinary silos in research and academia there is little comprehensive research that examines their multiple impacts across dimensions of human, ecological and environmental health and key questions remain unresolved (Guitart, Pickering, & Byrne, 2012; Frumkin H. , 2013; Frumkin, et al., 2017).

Complex human, ecological and environmental health challenges require integrated research and collaborative action strategies across the health, ecology and built environment design fields. Urgent calls for cross-disciplinary data collection and collaboration are coming from each of these fields to better understand and address the multiple dimensions and facets that contribute to the complex health issues that societies and communities face today (Frumkin H. , 2001, p. 238; Johnson & Hill, 2002, pp. 2,12; Alberti, 2009). Cross-disciplinary frameworks are emerging (Table 1).

Table 1: Summary of cross-disciplinary frameworks examining human and ecological health as related to the environment

Framework	Explanation	Reference
One Health Initiative	Hypothesizes that the key to addressing many of today's deadliest zoonotic and veterinary diseases lies in understanding human-species-environment interactions	(King, et al., 2008)
Planetary Health	Emphasizes the importance of protecting the environment to support human health	(Whitmee, Haines, Beyrer, & et al., 2015)
EcoHealth	Recognizes the role of biodiversity in health equity in that "health and wellbeing cannot be sustained in a resource depleted, polluted and socially unstable planet"	(Lerner & Berg, 2017)
Urban Ecological Design	Unites ecological theory with sustainable urban design approaches to enhance co-benefits to humans, species and ecosystems	(Rottle & Yocom, 2011)
Salutogenic Design	Health-promoting, preventative and ecological approach to urban design that addresses the origins of poor health	(Souter-Brown, 2014)
Social-Ecological Systems Framework	Supports ecological integrity inclusive of human wellbeing and societal needs	(Redman, Grove, & Kuby, 2004)
Ecosystem Services Paradigm	Examines human wellbeing benefits of ecosystems	(Diaz, et al., 2015; Millennium Ecosystem Assessment, 2005)
Ecosystem-Based Management	Resource management inclusive of both ecological integrity and human wellbeing and the relationships between each	(McLeod & Leslie, 2009)

These frameworks respond conceptually across spatial scales, disciplinary fields and systems. Yet, many of these frameworks are still in formative stages and more application to real-world communities is needed. Questions emerge around multi-inter-or-trans-disciplinary collaboration: How does one logistically collaborate across these fields? How can one weave scientific research with the creative design process and work with communities? The following section explains the theory behind these questions and presents the strategies used in this research.

Method and Process: Health Research Integrated with Community Design

Collaborating in research across disciplines can be complicated when the disciplines emerge from different knowledge claims. Creswell explains, "philosophically, researchers make claims about what is knowledge (ontology), how we know it (epistemology), what values go into it (axiology), how we write about it (rhetoric), and the processes for studying it (methodology)" (Creswell, 1994, p. 6). Disciplines in the human health sciences and natural sciences often approach research from a *postpositivist* knowledge claim, meaning that they tend to adopt the scientific method and start their research with a hypothesis, identify variables and controls, and then use validated instruments to collect empirical data (Polkinghorne, 1983). In contrast, designers and social scientists may employ more *exploratory* or *descriptive* research methods, in which they start with a question or issue instead of a hypothesis to be tested (Creswell, 1994, pp. 6-8, 19) and may be more familiar with applied research, which seeks knowledge for the purposes of being applied to address a specific need or problem (NSF 2015). This is complicated even further with design professionals who often work directly with communities and may be more familiar with knowledge claims of *advocacy* or *participatory action*, which take collaborative approaches to address specific sociopolitical issues and empower community members (Creswell, 1994, p. 8). Participatory design and community engagement methods are widely discussed as the most ethical way to design within communities, and especially vulnerable communities. These methods are transactive, a give-and-take between professional design teams and community members to mutually exchange critical information and resources and create responsive products and

outcomes (de la Pena, Jones Allen, Hester Jr, Hou, Lawson, & McNally, 2017). These different knowledge claims mean that each profession views knowledge, and sees the world very differently than the next.

This is complicated even further by the lack of consensus in the built environment fields, and in particular landscape architecture, on how research is described in the profession (Table 2). Design knowledge typically emerges from practice and experience associated with constructed projects, shared through mentoring and via case studies, with lessons learned rarely shared external to the design firm in formal or scholarly communications. The term research is widely used in the design professions in everyday conversation and can popularly refer to anything from scanning and compiling multiple technical resources to deep reflective thinking during the design process to the postpositivism scientific method stance (Riley, 1990). Not clearly defining research is one of the main reasons why the design professions are having such a hard time determining if the design process has a place in research. A recent dissertation that surveyed a random sample of practitioners who were members of the American Society of Landscape Architecture (adjusted response rate = 31%, n=239), found that knowledge created from design analysis and case studies were widely recognized as research and over half agreed that design generation or design related activities were considered research (Chen, 2013).

Table 2: Chart displaying a lack of consensus around the ways landscape design research is described in the literature

Research Framework	Description	Reference
Nine categories	Descriptive, modeling and correlation, experimentation, classification, interpretation, evaluation and diagnosis, engaged action, design projection and logical systems	(Swaffield & Deming, 2011)
Five categories, Three categories	Concept-test, analysis-synthesis, experiential, complex intellectual activity, and associationist – but after getting feedback from experts, reorganized in three categories: before, during and after design	(Milburn & Brown, 2003)
Three categories	Research for design (research informs design to improve quality), research on design (research carried out on finished products or the design process), research through design (the activity of designing as a research method in itself)	(Lenzholzer, Duchhart, & Koh, 2013)
Three categories	Design research/research on design (research into designers and their designs and core concepts), research for design (to help contribute to the design process) and research by design (either research is applied as a method while designing, or the design process itself would be explorative or experimental and becomes research in itself)	(van den Brink & Bruns, 2014)
Three cyclical activities, in the five stages of design	Imaging, presenting and testing; programming, preliminary design, final design, working drawings, construction supervision	(Zeisel, 1984)
Two categories	Action based knowledge/research (discovering ways and methods for how to do things that guide professional actions) and cognition based knowledge/research (discovery of truths and facts that offer explanations and justifications for these actions	(Chen, 2013)
Two categories	Tacit knowledge/research (personal knowledge generated to be shared internally) and explicit knowledge/research (knowledge generated to be accessible to others)	(Tress, Tress, & Fry, 2006)

The purpose of designing is to change the physical world to achieve identifiable goals. The design process is not linear, but rather cyclical, and the goals are established and negotiated by the entire design team (designer, client, users, regulatory agencies etc.) (Zeisel, 1984). The exploratory creative design process and market driven practice can sometimes be at odds with the traditional pre-determined hypothesis approach used in scientific research. However, in recent years, landscape architects have begun to learn to design to address larger societal and environmental issues alongside market trends by using pre-determined performance metrics (e.g. Sustainable SITES, LEED), some of which hold the designer responsible for the constructed outcome and not just the intended design goals (e.g. Living Building Challenge). Additionally, partnerships between academia and practice have produced a database of case studies on performance-based landscape projects with quantified environmental, economic and social benefits (Landscape Architecture Foundation, 2018). There is a growing

desire for the profession to engage in deep integrative scientific partnerships to influence policy, be seen as an active and valid contributor to the creation of scientific knowledge, tackle larger human and environmental health issues through built environment solutions, and capture the knowledge embedded in 'place' (van den Brink & Bruns, 2014; Tress, Tress, & Fry, 2006; Dannenberg, Frumkin, & Jackson, 2011; Preston, 2003). The success of evidence-based medicine (Guyatt, et al., 1992) has influenced discussion around need for *evidence-based landscape architecture* practice in order to mature the profession into research (Brown, 2011). Complementary movements in healthcare innovation and research have adopted *design thinking* and *user experience* approaches to stimulate new ideas through creative problem solving strategies that put the client at the forefront (Roberts, Fisher, Trowbridge, & Bent, 2016; Shin, Yi, & Lee, 2016). Similarly, contemporary citizen science and community-based-participatory research techniques show science as a remarkably creative and collaborative process (Dickinson & Bonney, 2012; Wallerstein & Duran, 2010).

This research tackled the challenge of integrating scientific human health and ecology methodology within a community participatory design approach to implement a built environment intervention that targeted and measured specific human and ecological health issues in a community. It embraced the art and science of this project and the additional embedded challenge of conducting action research.

The framework that showed the most promise for integrating these values while best meeting the goals of this research was Transdisciplinary Action Research (TDAR). TDAR provides an accessible framework for deeply collaborative efforts that address complex societal and ecological issues across scales – from immediate community scale needs to broader societal goals of public health, social and environmental justice, and ecological sustainability (Stokols, 2011). TDAR examines the translation of research and diverse knowledge cultures into community problem-solving strategies using effective collaboration with a diversity of researchers, community members, and local experts and organizations (Stokols, 2006; Thering & Chanse, 2011). TDAR builds upon other collaborative action-research approaches such as *Community-Based Participatory Research* (Horowitz, Robinson, & Seifer, 2009; Wallerstein & Duran, 2010), *Participatory Action Research* (Baum, MacDougall, & Smith, 2006; Chevalier & Buckles, 2013) and *Community-Based Conservation* (Mulrennan, Mark, & Scott, 2012; Western & Wright, 1994). TDAR can include robust community engagement and co-creation strategies such as those at the core of *Participatory Design* and *Plural Design* practices (de la Pena, Jones Allen, Hester Jr, Hou, Lawson, & McNally, 2017; Bowns, 2011). Scholars in a Special Issue of *Landscape Journal* (Neckar & Pitt, 2011) emphasized the potential contributions of TDAR to landscape practices (Table 3). While the authors issued a call for more work in TDAR to compare common experience and transcend the limitations of localized case studies, few studies to date have been added to the literature (Thering & Chanse, 2011).

Table 3: Potential Contributions of TDAR to Landscape Architecture and Planning, adapted from (Neckar & Pitt, 2011)

1.	Maximizes the understanding and making of multi-functional landscapes
2.	Examines landscape performance across socio-cultural and biophysical systems
3.	Acknowledges that design has external consequences and responsibilities, making design a political act
4.	Coordinates local interests with broader societal concerns
5.	Uncovers social and environmental nuances that directly inspire form
6.	Integrates diverse world views to construct new knowledge that informs and creates innovative approaches to tough problems
7.	Supports mutual learning and empathy for the "other"
8.	Transcends communication barriers between disciplines and types of knowledge
9.	Increases effective translation of science to on-the-ground problem solving
10.	Nurtures long term relationships, policies and actions

This research adapted the TDAR framework to include a participatory design approach (Figure 2) that shaped both the research instruments and the built environment intervention targeting community-prioritized human and ecological health issues in a community, detailed in Chapter 4 of this manuscript. This research also added a Community Social-Ecological Assessment Framework to the TDAR model (Figure 3) for gathering human-species-environment data both through scientific and participatory methods, detailed in Chapter 2.

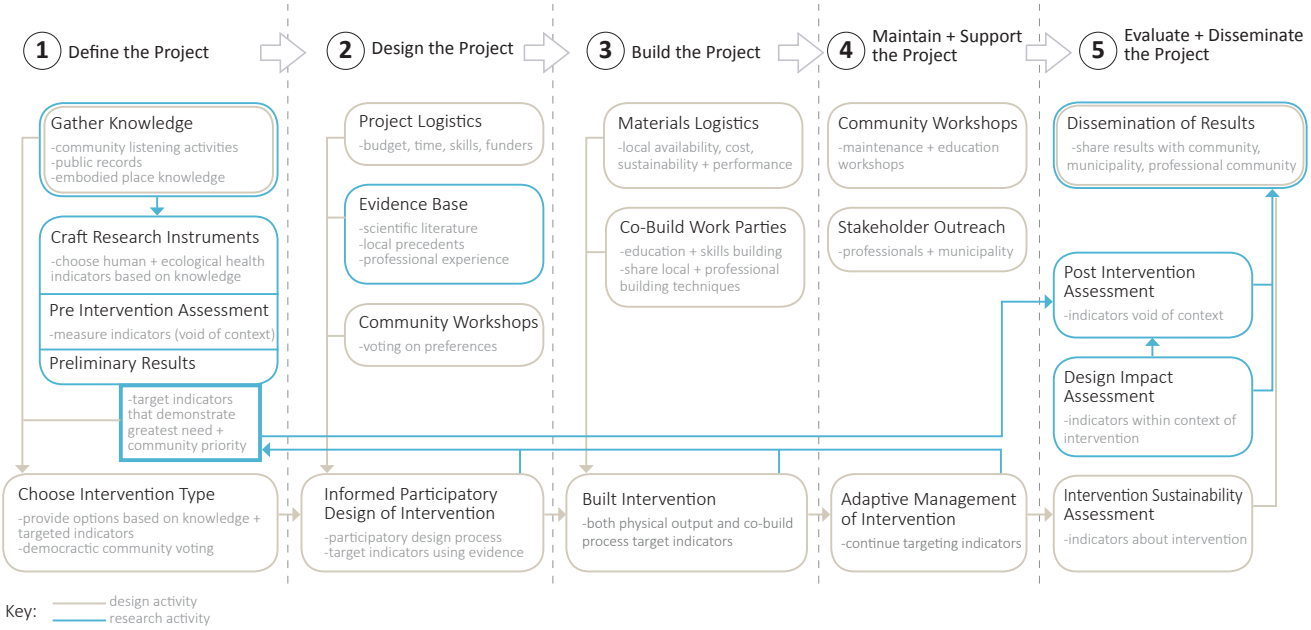

Figure 2: Schematic of the TDAR framework used in this research,, adapted to target specific human and ecological health issues in communities by integrating participatory and evidence-based design. See Chapter 4 for more details.

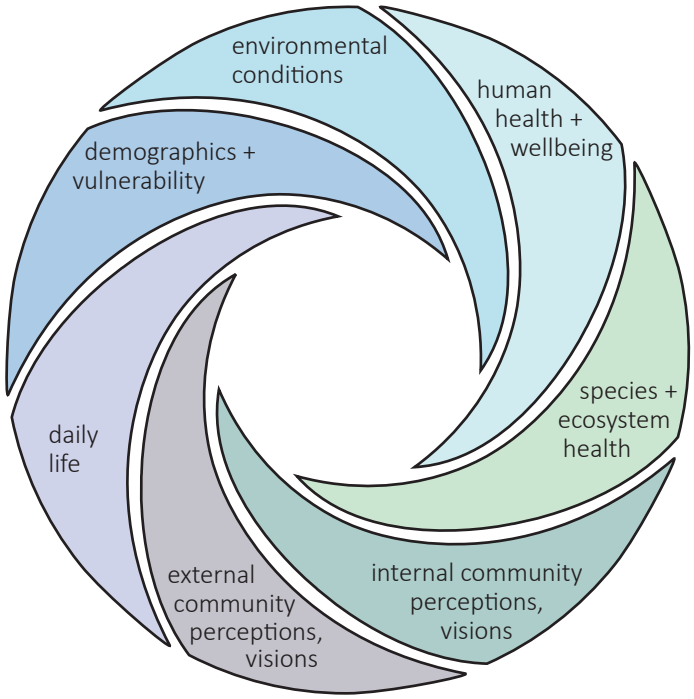

Figure3: Diagram of the Community Social-ecological Assessment Framework added to the TDAR framework to support both scientific and participatory data collection methods. See Chapter 2 for more details.

Testing: A demonstration in a slum community in the Peruvian Amazon

This research used an applied approach to investigating the topic of health and the built environment and demonstrating the method and process of integrating health research with community design. The site is the community of Claverito, an informal urban slum community in the Peruvian Amazon. This section explains the decision behind working with a slum community and describes the site context.

Background on slum communities

Approximately one billion, or one in eight, people in all regions of the world now live in urban slum conditions (United Nations, 2016), with these numbers continuing to rise as world-wide displacement reaches the highest levels ever and forced migration is projected to increase (UNHRC, 2015). In the past 15 years, the population living in slum conditions grew an average of 6 million a year, or 16,500 people a day (United Nations, 2016). Slum conditions are defined by a lack of access to improved water and sanitation, overcrowded living area, non-durable housing, and/or tenure insecurity (UN-Habitat, 2002). These conditions often go hand-in-hand with food and medicine insecurity as well as exposure to environmental contaminants, hazards and extreme weather events. Further, the intimately shared social and physical environments of slums make them particularly susceptible to high risks of infection, injury and illness with effects beyond those of poverty alone (Ezeh, et al., 2016). Improving slum conditions has become a top global priority (Millennium Development Goal 7 Target 7D; Sustainable Development Goal 11 Target 11.1 etc.) and is widely viewed as one of the most critical steps towards the sustainable development in the 21st century (UN-Habitat, 2016).

Despite this priority, little is known about disease burden or wellbeing in slum communities (Heitzinger, Montano, Hawes, Alarcón, & Zunt, 2014), or the impact the dense and often unsanitary conditions have on the flora, fauna and surrounding ecosystems that sustain lives, both locally and globally. The research documenting health, environmental conditions or daily life patterns within slum communities is especially underdeveloped in comparison to urban health, and poverty and health research (Ezeh, et al., 2016). The documentation of the burden on animals and plants within and near slum conditions is even more rare. Sums are often not included in national censuses or epidemiological or environmental studies because of accessibility, safety and other challenges (Heitzinger, Montano, Hawes, Alarcón, & Zunt, 2014). Additionally, while there is a recent interest in architecture and urban planning to work in slum communities (Lepik, 2010; Smith, 2011; Architecture for Humanity, 2012) there are very few models to guide landscape architects and public space designers in this context (Waller, 2017) and no known projects that have measured the impacts built environment design has on health in slum communities.

While the topic of inquiry, methods and process in this research could be applied in any community with health needs, this research acknowledges the extreme need, conditions and lack of information in slum communities which makes them ideal locations to study integrated solutions for improving intertwined human, environmental and ecological health and built environment conditions. This research supports calls by UN-Habitat for "participatory, robust, standardized and computerized data collection processes" to support results-based management and improvement of conditions in slum communities (UN-Habitat, 2016, p. 18).

Iquitos: The urbanized Peruvian Amazon

Because of its extreme urban ecological context, Iquitos, Peru is a demonstrative location to study relationships between human, ecological and environmental health. Iquitos is the largest city in the Peruvian Amazon Rainforest and the fifth largest city in Peru, with over a half million documented residents (INEI, 2015). Rapid rural to urban migration and expansion of informal urban 'slum' communities in Iquitos has contributed to almost 70% of the population living in poverty (in comparison Peru is 34.8% (INEI, 2009)). Displaced from highly lush and intact ecosystems of their 'home' landscapes in the jungle, migrants are forced to create new homes in the dense city,

Figure 4: Context map showing Iquitos, Peru

often building over the water in *asentamientos humanos flotantes*, or floating slum communities, to maintain a similar lifestyle connected to the environment and the river. Impoverished circumstances and poor environmental conditions in such neglected communities in Iquitos often result in highly prevalent chronic conditions (e.g. 49.5% of children 6-59 months suffer from anemia (UNICEF, 2013)), vector borne diseases (e.g. 2,134 cases of dengue/100,000 residents (MINSA, 2011)), diarrheal disease (37% of children under 5 have acute diarrhea (MINSA, 2011)), and poor mental health and wellbeing due to the lack of safe water (for 48% of population (INEI, 2007)), inadequate sanitation (for 57% of population (INEI, 2007)), poor access to nutritious food (i.e. 32% of children under 5 suffer from chronic malnutrition (UNICEF, 2013)) or public greenspaces, disrupted social and ecological systems, precarious structures and exposure to severe storms and flooding, all exacerbated by changing climatic conditions.

Figure 5: Iquitos is a city of 0.5 million in the Amazon Rainforest. Claverito is a floating slum community in the heart of the city [GoogleMaps]

The informal floating slum community of Claverito

Claverito is one such floating slum community in Iquitos. This neighborhood of approximately 50 houses, 270 residents, 240 domesticated animals, and hundreds of species of animals and plants is located in the heart of Iquitos just two blocks to the north of the downtown public waterfront. Nestled on the edges of the city and the Amazon jungle, Claverito is strongly influenced by and vulnerable to both urban and ecological systems. Residents of this informal floating community have livelihoods closely tied to the resources of both the city and jungle (fishermen, floodplain agriculture, animal husbandry, selling in markets etc.) and their health is directly related to the health of the animals, plants and environmental conditions. Most residents are recent migrants from the jungle and all are either first or second generation indigenous migrants from villages in the rainforest. They are emotionally and culturally connected to plants, animals and the environment (for example, one resident observed that he was actually “feeling pain when others destroy the plants”). Although residents

have lived here anywhere from 1-45 years, Claverito is not recognized by the local government and residents do not have formal access to urban services (i.e., water, sewer, etc.), resulting in stressful and degraded living conditions.

Not only is Claverito a highly neglected community, but also it is severely misunderstood. The people living in the formal/upper parts of the city hold many stereotypes, misperceptions, poor attitudes and resentment towards people living in the *asentamientos humanos flotantes*, resulting in continued degradation of environmental conditions in and surrounding the communities (i.e. frequent dumping, spitting, urinating and defecating, graffiti, crime, drugs and drinking, vandalism etc.) and impacts upon human and ecological health. For example, the hillside riverbank above Claverito had over one meter of garbage spilling down onto the community, negatively impacting water quality of the wells below, creating a safety hazard for children playing on the hillside, reducing biodiversity, restricting animal and plant life, creating mosquito reservoirs, degrading human spirits and fueling feelings of disempowerment, all of which result in poor physical and mental health. There is much potential in Claverito to understand the intertwined connection between humans, non-human species and their shared environment, and provide a socio-ecological design intervention to address these interconnected issues.

Figure 6: The floating informal slum community of Claverito, view from the Itaya River in the high river season

Figure 7: Aerial plan of Claverito. The community is situated between two public plazas and organized in three floating streets.

Figure 8: Houses in Claverito float on large logs during the high river season and rest on the ground during the low river season.

A demonstration project in Claverito

The study team first met the community of Claverito in July 2015. Over the following year the team established a long-term partnership with residents to conduct yearly design and research projects and participate in a longitudinal study in which the team would follow the progress of the community over time. The research outlined in this manuscript is the first in a series of projects working with Claverito. Between July 2016 and December 2017, the team established a baseline of human, ecological and health conditions (Chapter 2), conducted a transdisciplinary design-build-research project of community and household gardens with residents (Chapter 3) and analyzed changes in human and ecological health over one year (Chapter 4). This manuscript outlines the process, product, agents and outcome in this research.

Figure 9: Preview of the intervention in Claverito showing the Community Entrance Garden (left) and a Household Floating Garden (right)

Dissertation Structure

This dissertation presents the research in three manuscripts in preparation for publication: Chapters 2, 3 and 4 in this document. Table 4 describes the research questions, goals, target audience and terminology considerations for each of these manuscripts. While referring to the same work, because of the interdisciplinary nature of this research, different terminology was considered for each paper to speak the language sof the target audience of the potential future publication. For example, the second manuscript with an audience of public, community or global health professionals describes the intervention as *urban nature* and *gardens* in order to cite literature familiar to this audience; however the third manuscript with the intended audience of landscape architects and community designers describes the intervention as *urban ecological design* and *defiant gardens*, terminology that better captures the complex systems and performance design thinking in the project that designers may be interested in. The final chapter (Chapter 5) reflects upon the topic of inquiry, methods, process and outcomes of this research, and proposes challenges and opportunities for future studies.

Table 4: Summary of each of the three manuscripts included in this dissertation

Chapter	Title	Research Questions	Goals and Objectives	Target Audience	Terminology Considerations
2	Assessing social-ecological health conditions in a Latin American slum community	How can we assess human, ecological and environmental health conditions in slum communities? What human-species-environment relationships are found in Claverito?	Develops a pilot Community Social-Ecological Assessment Framework, a methodology for data capture to understand human-species-environment health relationships including both science and participatory methods of data collection. Applies to Claverito and discusses unexpected socio-political beneficial outcomes of this data collection.	Researchers in global health and those who work with slum planning, research and census gathering	Describes intervention as *community-scale built environment intervention* and *gardens*
3	Human and ecological health outcomes of a Gardens Intervention in a Latin American slum community	What changes in human and ecological health indicators occur after implementing a Gardens Intervention in Claverito?	Discusses the measured human and ecological health impacts of a Gardens Intervention project in Claverito. Applies a pre-and-post-test Health Assessment with human and ecological health indicators documenting change within a longitudinal study context, and a Design Impact Assessment that repeats these same indicators but as a post-test of the Gardens Intervention project.	Public, community or global health workers; environmental psychologists; designers interested in health research	Describes intervention as *urban nature* and *gardens*
4	Using Transdisciplinary Action Research (TDAR) and a Gardens Intervention project to target human and ecological health issues in an urban slum community	How can a TDAR approach target specific health issues in communities? How does TDAR impact the intervention design and outcome? What are the challenges and opportunities with using this approach?	Describes the Transdisciplinary Action Research framework adapted to target health issues in Claverito using a highly collaborative team and deep community engagement process. Details the physical Gardens Intervention outcome and the outcome of the Design Sustainability Assessment examining signs of stewardship and sustainability of the project.	Landscape architects or community designers interested in health research or TDAR	Describes intervention as *urban ecological design* and *defiant gardens*

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Chapter 2

Title

Assessing social-ecological health conditions in a Latin American slum community

Abstract

Despite one in eight people living in slums around the world (United Nations, 2016), there are very few studies documenting the disease burden and wellbeing of slum residents, or the impact slum conditions have on surrounding ecosystems. This research gap offers much potential. The extreme environmental conditions in slums makes them unique locations to study the ways the built environment is an interrelated determinant of health for humans, flora and fauna, and to use this information to ground contemporary interdisciplinary human-species-environment frameworks such as One Health and Planetary Health through informed actions. This manuscript presents the Community Social-Ecological Assessment Framework, a methodology for gathering social-ecological data in slum communities that includes both traditional science and participatory methods of data collection. To ground this discussion, this manuscript analyzes a case study with a slum community in the urbanized Peruvian Amazon, and examines the data gathered in each of the seven Framework categories, as well as the human-species-environment relationships discovered. Additional potential outcomes of performing the assessment include reducing public stigmas burdening slum communities, laying the foundation for efficient evidence-based planning and informed community interventions, and strengthening relationships between slum communities and authorities.

Keywords

Built environment, slum, Peru, global health, social-ecological, assessment

1. Background

Accelerated urban migration, social inequity, environmental degradation, species extinction, climate change, disease exposure, and water and food insecurity are inextricably linked, pressing issues of our era. These issues far exceed governmental response capacities, and many migrants displaced by these matters are forced to live in self-constructed urban 'slum' settlements. Approximately one billion, or one in eight, people in all parts of the world now live in slum conditions (United Nations, 2016), with these numbers continuing to rise as world-wide displacement reaches the highest levels ever and forced migration is projected to increase (UNHRC, 2015). In the past 15 years, the population living in slum conditions grew an average of 6 million a year, or 16,500 people a day (United Nations, 2016). Slum conditions are defined by a lack of access to improved water and sanitation, overcrowded living area, non-durable housing, and/or tenure insecurity (UN-Habitat, 2002). These conditions often go hand-in-hand with food insecurity, high risks of infection and injury, and exposure to environmental contaminants, hazards and extreme weather events (Ezeh, et al., 2016).

In all communities the built environment is a health determinant that may have a major role in quality of life (Dannenberg, Frumkin, & Jackson, 2011; Solar & Irwin, 2010), and human health is closely linked to the health of non-human species and their shared environment, (King, et al., 2008). Because of this, improving slum conditions has become a top international priority (Millennium Development Goal 7 Target 7D; Sustainable Development Goal 11 Target 11.1) and is widely viewed as one of the most critical steps towards achieving the sustainable development of humankind (UN-Habitat, 2016).

Yet, little is known about the disease burden or wellbeing in slum communities (Heitzinger, Montano, Hawes, Alarcón, & Zunt, 2014), or the impact the dense and often unsanitary community conditions have on flora, fauna and surrounding ecosystems that sustain our lives. The research documenting health, environmental conditions or daily life within slum communities is especially underdeveloped in comparison to urban health, and poverty and health research (Ezeh, et al., 2016). The documentation of the burden on animals and plants within and near slum conditions is even more rare. Also slum populations are often not included in national censuses or epidemiological or environmental studies. It is difficult to gather reliable data because informal communities lack an address, are constantly changing, or may be dangerous to access due to crime or unstable infrastructure (Heitzinger, Montano, Hawes, Alarcón, & Zunt, 2014). Standard city census data alone is typically not a reliable way to understand the physical, mental and social health in slums, as it often combines data of informal and formal residents. Slum communities face additional challenges and stressors from their physical and social environments that formalized communities do not endure, and data gathered in slum communities may be limited or skewed from political distrust, embarrassment or land tenure uncertainties (Riofrio, 2003; Lilford, et al., 2016; Feld, 2014).

Including slum communities within censuses and surveys, and with slum specific tracts, is necessary for generating comparable data, however pairing this with participatory on-the-ground methods is key to breaking barriers of mistrust that result in inaccurate data (de la Pena, Jones Allen, Hester Jr, Hou, Lawson, & McNally, 2017). Participatory methods include community workshops, citizen science data collection, and environmental mapping and photography, among other techniques that gather information on local perspectives and daily life. These techniques reveal residents' needs and priorities, potentially transferring power to slum residents to engage in decision-making and governance of their own lives (Spencer, Bolton, & Alarcón, The Informal Urban Communities Initiative, 2015; UN-Habitat, 2016; Gouverneur, 2015).

There is a renewed need to acknowledge and gather data in slums, and to understand how residents' lives are embedded in social-ecological systems and connected to the health of plants, animals and ecosystems. This manuscript outlines a methodology for gathering social-ecological data to understand human-species-environment relationships in slum communities and pilots a Community Social-Ecological Assessment Framework that includes both traditional science and participatory methods of data collection. To ground this discussion, this manuscript presents and analyzes a case study working with a slum community in the urbanized Peruvian Amazon, and examines the data gathered as well as unexpected outcomes of this thorough assessment of human, ecological and environmental health conditions in this community.

2. Concepts and Literature

Urgent calls for cross-disciplinary data collection and collaboration across the health, ecology, and urban design and planning disciplines seek to better understand and address the multiple dimensions and facets that contribute to complex health issues (Frumkin H. , 2001; Johnson & Hill, 2002; Alberti, 2009). Several cross-disciplinary health frameworks are already in place; the One Health Initiative hypothesizes that the key to addressing many of the most prevalent zoonotic and veterinary diseases is in understanding human-species-environment interactions (King, et al., 2008); Planetary Health

emphasizes the importance of protecting the environment to support human health (Whitmee, Haines, Beyrer, & et al., 2015); Urban Ecological Design unites ecological theory with sustainable urban design approaches to enhance co-benefits to humans, species and ecosystems (Rottle & Yocom, 2011); and Social-Ecological Systems supports ecological integrity inclusive of human wellbeing and societal needs (Redman, Grove, & Kuby, 2004). These interdisciplinary frameworks emphasize how biodiversity and ecosystem function affect human health and wellbeing through shared food, water and soil systems, disease transmission, climate regulation and pharmaceutical, energy or material innovations, among others (Grifo & Rosenthal, 1997; Morand & Lajaunie, 2018). However, to date there are very few human-species-environment empirical studies with communities assessing health outcomes and no known studies of these relationships in the context of slums. Studies of the extreme environmental conditions in slum communities are ideal for examining the aspects of the built environment that are health determinants for humans and species. Using data-driven community scale studies and interventions, results could be used to better ground One Health, Planetary Health, Urban Ecological Design and other frameworks. At this time, little is known beyond speculation about the ways humans, animals and the environment are linked in the most vulnerable communities in the world.

Integrated human and environmental health data has important implications for those living in slum conditions. Slum dwellers often closely interact with the land and therefore may be more impacted by plant and animal illnesses, degraded ecosystems, and changing weather conditions. Such interactions may occur through employment (e.g. meat markets, urban agriculture, fishing etc.), daily life tasks (e.g. free range livestock and pets, harvesting materials for housing and firewood, gathering water etc.), recreation (e.g. playing in bare feet, swimming etc.) or spiritual or cultural practices (e.g. medicinal plant use, forest bathing etc.). One of the UN-Habitat Keys for Successful Slum Upgrading and Prevention is developing and coordinating broader frameworks for integration of people within larger systems, to “ensure a more complex understanding of the communities living in slums” (UN-Habitat, 2016, p. 18). Without assessment of human and environmental health in slums, officials may make under-informed decisions that could have unintended consequences on larger socio-ecological systems. For example, eradicating a slum community working in informal floodplain agriculture could cause economic disruption to local vegetable markets, stream erosion and degradation, and species loss.

3. Methods

3.1 Case Study Setting

Claverito is a floating slum community situated in a floodplain tributary of the Amazon River on the edge of the city of Iquitos, Peru (Figure 1). Located between a city of 0.5 million residents and the Amazon Rainforest with its tens of thousands of different plant and animal species, Claverito is strongly influenced by and vulnerable to both urban and ecological systems. Claverito consists of about 50 homes that float on large logs during the high river season (~January-June), and rest on the ground during the low river season (~July-December). Although the community was established several decades ago, Claverito is informal, in that it is not recognized by local or federal government, so residents do not have formal access to services (e.g. water, sewer, etc.) and do not appear on city maps (Maynas, 2011). Residents report they have never been documented in the national census, are rarely patrolled by police and have never been included in city health programs such as mosquito control (Claverito community leaders, 2018, March 30, personal interviews.)

Figure 1: View of Claverito in the high river season, with the city of Iquitos to the right and the Amazon Rainforest to the left

3.2 Methodology, study design and procedures

The overall objective of this case study project was to prepare a comprehensive baseline dataset in Claverito to inform a future series of community interventions that would address specific health needs and priorities in the community, and monitor health change over time. A pilot assessment framework, named the Community Social-Ecological Assessment Framework (Figure 2), guided collection of data: 1) demographics and vulnerability; 2) daily life; 3) environmental conditions; 4) human health and wellbeing; and 5) species and ecosystem health, and included reflections on both internal and external insights through gathering information on 6) internal community perceptions and visions; and 7) external perceptions and visions of the community. Each data category required a different data capture instrument, methods and expert team members. Therefore the study utilized a mixed methods approach based on the Transdisciplinary Action Research (TDAR) concept (Stokols, 2006), and involved a team of 17 different disciplines as well as the municipality and the residents of Claverito (summarized in Table 1). Details of this TDAR process and how it informed a community intervention to improve human and ecological health is outlined in Chapter 4 of this dissertation. The study combined a household Global Assessment of Zoonotic and Environmental Risks (GAZER) survey, field measurements (environmental assessment, physical human health and biodiversity), and participatory workshop activities conducted in community meetings. Data collection occurred in the low river season over two weeks, with the exception of field measurements that seasonally changed (e.g. species counts, river water quality etc.) of which occurred again over two weeks during the high river season. Physical health measurements also occurred in the high river season. Species counts were conducted at different times of day per species' needs (eight-hour observations ensuring sunrise and sunset captures for birds, eight-hour observations at mornings and nights for amphibians, four-hour traps for butterflies). External community perceptions and visions data were not shared in this manuscript. The study area was defined by the limits of the Community of Claverito including both the urban area where residents live and the adjacent Camu-Camu Bosque, trees planted and managed by a Claverito family.

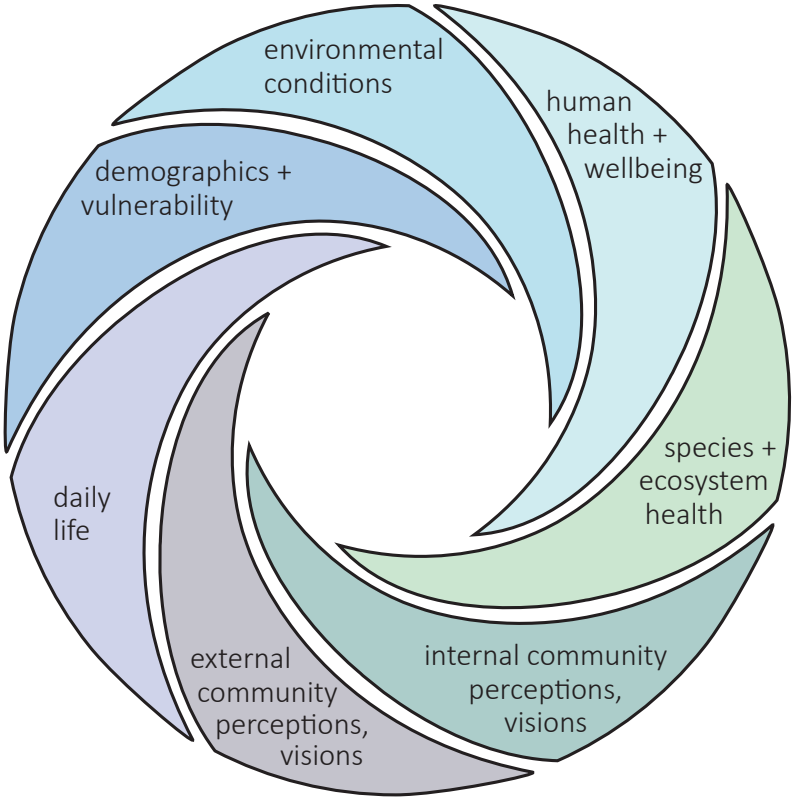

Figure 2: Diagram of the Community Social-Ecological Assessment Framework used to understand slum communities, showing seven data gathering categories. This framework was piloted on the Claverito study, however was designed for its potential replicability and further development.

Table 1: Summary of study design across each of the seven data categories in the Community Social-Ecological Assessment Framework. Replication lies in the framework structure; exact measurements may be edited based on context.

Data Category	Data Capture Instrument	Expert Team	Information Categories Gathered	Details
Demographics and Vulnerability	GAZER Household Survey	Local professional surveyors with environmental or health sciences background	Gender	Adult who knows the most about the household answers for each family member
			Age	
			Education Level	
			Household Size	
			Domestic Animals, Pets	
			Occupation	
			Economic Status	
			Migration Status	
			Indigenous Status	
			Land Tenure Status	
Daily Life	GAZER Household Survey	Local professional surveyors	Contact with nature	Contact with animals, plants, water, outdoor activities and jobs
			Traditional practices	Medicinal plant and animal use, religion/spiritual identity
			Everyday tasks	Meals (24 hour recall), chores, employment
Environmental Conditions	Field Measurements (Environmental Assessment)	Built environment professionals (landscape architects, architects, environmental engineers)	Landscape and architectural quality	Inspection of houses, public stairs, paths, greenspace, community center
			Water quality (river, spring)	3M Petrifilm *E.coli* /coliform count plates, LaMotte field kit
			Land quality (hillside)	Trash counts as per U.S. NOAA Guidelines for Marine Debris
			Access to public services	sanitation, water, electricity, solid waste disposal
Human Health and Wellbeing	Field Measurements (Physical Health)	Local medical professionals (nurses, doctors)	Anthropometrics	BMI, child growth, arm and waste circumference
			Chronic disease risk	Blood pressure, glucose
			Nutritional / Immunological Measurements	Hemoglobin, fecal samples for parasite analysis, diarrhea
	GAZER Household Survey	Local professional surveyors	Food Insecurity	Household Food Insecurity Access Scale (HFIAS), Food Frequency Questionnaire (FFQ)
			Mental Wellbeing	PHQ-9 Depression Scale
			Environmental Hazards	Injuries, poisoning
			General Health Screening	Self reported health conditions, medications, hygiene, substance use
Species and Ecosystem Health	Field Measurements (Biodiversity)	Local biologists (ornithologists, herpetologists, entomologists, botanists)	Birds	Census by transects
			Amphibians, Reptiles	Visual Encounter Survey (VES) with active search in sampling stations
			Butterflies, Dung Beetles	Entomological nets, Van Someron-Rydon, pit traps in sampling stations
			Plants	Census by quadrats
			Vectors (Mosquitos)	Mouth aspirator, per house
Internal Community Perceptions and Visions	Participatory Workshop Activities	Built environment, public policy, anthropology professionals, with community members	Preferences, ideas	Photo journalism, community visioning drawings
			Needs, desires, priorities	Cognitive mapping, democratic voting and prioritization
			Emotional sources	Identify things that make you happy or sad, could make life better
	GAZER Household Survey	Local professional surveyors	Sense of Belonging	Safety and security, feeling home, social comfort
			Sense of Place	Community pride, perception of beauty, environmental satisfaction
			Health Awareness	Perception of plant, animal, ecosystem, personal health status
External Community Perceptions and Visions	Semi-structured Interviews	Team leaders	Opinions, stories on slums living here; visions of city development	Anonymous, individual, with local formal urbanites; to understand stereotypes, stigmas, perceptions*

*not included as part of this paper

3.3 Study Participants

The study interacted with human subjects through the household GAZER survey, physical health measurements and a participatory workshop. Table 2 displays demographics within each research instrument. The household GAZER survey (n=44) was a full capture, documenting 44 households of the 50 intact houses in Claverito. Nonparticipating households did not meet informed consent requirements (adults consistently intoxicated, underage, or did not speak Spanish) or were seasonally absent (three attempts). Physical measurements (n=108) were gathered at a community Health Fair open to all Claverito residents two years or older, with approximately 46% of the community participating. The Participatory Workshop (n=38) included 2.5 hours of activities and open to all adults and teenagers in Claverito. While 56 adults and 17 teenagers were at the workshop (approximately 51% of the adults and teenagers in Claverito), many family members worked together to formulate responses due to low comprehension levels (more than half did not graduate from primary school).

Table 2: Study participants

Type	Criteria	How administered	Participant demographics	Value	SD
Household GAZER Survey (n=44)	adult over 16 that knows the most about the household	orally administered house-by-house	% female	89%	
			mean age	37.8	13.4
			mean years of school	6.1	2.8
			% married or cohabitating	77%	
Physical Health Measurements (n=108)	open to all residents >=2 years old	at a Health Fair	% female	57%	
			% children <18	55%	
			mean age	21.9	18.6
Participatory Workshop (n=38)	open to all residents >13 years old	at a community meeting	% female	74%	
			mean age	37.1	13.5

4. Results

The study documented 44 households and recorded information on 239 people, 240 domestic animals and thousands of wild animals living in the community of Claverito. Information is presented in the Community Socio-Ecological Assessment Framework data gathering categories below. National (Peru) and city (Iquitos) comparisons are included when data was available. Both national and city data included a mixture of people living in slum conditions and those who did not. It is likely that many informal and slum communities were not included in these data.

4.1 Demographics and Vulnerability

Kasperson et al (1995) describe vulnerability as "the propensity of social or ecological systems to suffer harm from external stresses and perturbations" (Kasperson, Kasperson, & Turner, 1995). Slum populations suffer disproportionately from health, crime, human rights and severe weather issues, and certain sub populations within slums are even more vulnerable to external events. Indicators of vulnerability in slum communities include: low gender status, children and elderly, illiteracy and low education levels, unstable and insufficient incomes especially with large household sizes, rural to urban migrants and those with low urban literacy such as indigenous peoples, and those lacking governmental recognition or tenure (Mohapatra, 2012). Indicators of vulnerability within Claverito are reported in Table 3. Compared to Peru, Claverito has a higher percentage of children and lower percentage of elderly. Compared to Peru and Iquitos, residents have lower education levels; 39% of adults never reached high school and 82% did not graduate high school. Household sizes vary from 1-10 people, with 25% having 8 or more people living in the same 66 m^2 (710 ft^2) house, much more than found in Peru and Iquitos data. Three out of four adults do not have stable employment, with most in the informal market (e.g. fishing, foraging, selling goods). Intermittent employment combined with large household sizes results in 89% of families living below the Peru poverty line and two-thirds in extreme poverty, substantially greater poverty than found in Peru and Iquitos data. More than half of residents are first generation indigenous, born in a village in the jungle, and the rest have indigenous roots. All but one household (participating in a governmental agriculture program) did not have land tenure and could be asked to leave at any moment, despite residents reporting living in Claverito for up to 45 years.

Table 3: Demographics and Community Vulnerability (n=239)

Characteristic	Measurement in Claverito	Value	Peru Comparison	Iquitos Comparison
Gender	% female	49	49.9 [1]	47.8 [6]
Age	% children < 15 years	40	30 [1]	36.1 [6]
	% elderly > 65 years	4	6.3 [1]	3.6 [6]
Highest Education Level Obtained (adults > 15 only)	% no school (0 years)	8	5.4 [10]	3.4 [6]
	% primary school (1-5 years)	31	26.4 [10]	34.3 [6]
	% secondary school (6-11 years)	56	38.0 [10]	45.1 [6]
	% post secondary (>11 years)	5	30.13 [10]	17.3 [6]
	mean years of education	6.7	DNA	DNA
Household Size	% households with >4 people	68	30.9 [1]	49.8 [9]
	% households with >=8 people	25	4.0 [1]	DNA
Occupation	% of adults with unsteady work (seasonal and informal workers, housewives, unemployed)	74 [4]	DNA	DNA
Economic Status	% households in poverty or extreme poverty [2]	89 [3]	25.8 [7]	50 [6]
	% households in extreme poverty [2]	66 [3]	6.0 [7]	14 [6]
Migration Status	% migrated <= 2 years ago	14	DNA	DNA
	% migrated >= 20 years ago	25	DNA	DNA
Indigenous Status	% 1st generation indigenous migrants	57	10.48 [5]	32 [8]
Land Tenure	% of families that do not have land tenure	98	22 [6]	DNA

1. (INEI) Instituto Nacional de Estadistica e Informatica, *Encuesta Demográfica y de Salud Famiiar, 2012*
2. INEI, *Evolución de la pobreza monetaria 2007-2017,* grafico 2.4 "Peru: Linea de Pobreza Extrema, Segun Dominios 2016-2017. For the urban jungle region in Peru, extreme poverty line is <175 soles ($53 USD) and poverty line is <305 soles ($93 USD) per person per month.
3. We anticipate poverty levels are significantly underreported, and incomes are being sent to other relatives living in the jungle
4. 74% confirmed, however more likely 100% (e.g. respondent answered "food worker" but likely referring to selling food in the streets)
5. Percentage is those who identify as indigenous as per the National Census 2017 (INEI)
6. INEI, *Fuente Censo Nacional*, 2011.
7 INEI, *Evolución de la Pobreza Monetaria 2007-2017,* 2012 data.
8. Presupuesto Institucional 2018, Gobierno Regiona de Loreto
9. INEI, *Censos Nacionales de Población y Vivienda*, 1993-2007, "Numero de personas por hogar", 2008
10. INEI, *Encuesta Nacional de Hogares*, 2016

4.2. Daily Life

Claverito residents' lives are closely tied to natural resources of the jungle and river, and the health and wellbeing of residents relied upon the health and quality of local animals, plants and environmental conditions. Although situated in a highly urbanized area only four blocks away from the central city square, Plaza de Armas, Claverito residents participated in daily activities more similar to those in rural communities in the jungle, such as fishing, floodplain agriculture, animal husbandry, boat transportation, crafts and sewing. This may be because of their location in the river floodplain on floating houses, or that residents were either recent migrants from the Amazon or had close indigenous roots. The study revealed that residents were deeply and culturally connected to plants, animals, the river and the surrounding environment. For example, over 40% of households reported using traditional medicines with plant and animal parts and 73% of households reported eating fish caught in the river 5-7 times per week. Residents had a particularly strong connection to the river; every survey respondent reported daily participation in at least one river-related activity such as fishing, swimming, boating, drinking, bathing or doing laundry in the river. Claverito residents have a productive environmental ethic; they see the Amazon as a source of food, building materials, transportation route, and entertainment.

4.3 Environmental Conditions

Slum dwellers often face additional risk exposures and stressors beyond poverty alone (UN-Habitat, 2002; Lilford, et al., 2016). Field measurements in Claverito revealed inadequate environmental, social and infrastructure conditions in all categories (Table 4): housing, public stairs and paths, community greenspace, a place to hold community gathering, river and spring water, land pollution, and access to improved sanitation, water, electricity and solid waste disposal.

Table 4: Environmental Conditions

Characteristic	Measurement in Claverito	n	Value
Landscape and Architectural Quality	% of households with adequate housing[1]	44	0%
	% of safe public stairs or paths[2]	16	0%
	Designated community greenspace / gathering space[5] (low river season)		8 sq m per person[4]
	Designated community greenspace / gathering space[5] (high river season)		0 sq m per person[4]
Water Quality	Mean # of *E.coli* and total coliforms, community spring water (low river season)	3	3 *E.coli*/ml [6] 50 col/ml
	Mean # of *E.coli* and total coliforms, river water within community (high river season)	46	64 *E.coli*/ml [6] 127 col/ml
Land Quality	Counted trash on hillside (by removal)		622 bags, 5,443 kg [7]
	Projected pounds of trash in community Projected trash in community in tons		86 lbs/ cu.m 73 tons[8]
Access to public services	% of households with improved sanitation[3]	44	0%
	% of households with improved water[3]		4%
	% of households with improved electricity		0%
	% of households with improved solid waste disposal		0%

1. As defined in Fact Sheet #21: The Right to Adequate Housing (UN-Habitat, 2014)
2. As defined by Peru Safety Standards. Reglamento Nacional de Construcciones. 2006, Decreto Supremo No. 011 – 2006, Ministerio de Vivienda, Construcción y Saneamiento (Peru).
3. As defined in the Slum Almanac 2015 2016 (UN-Habitat, 2016)
4. The World Health Organization recommends 9 square meters per person (WHO, 2012)
5. Claverito does not have any community gathering spaces protected from the elements (e.g. with a roof)
6. US and Canadian standards are 0 for *E.coli* and total coliforms as drinking water standards
7. Weighing random selection of filled trash bags using calibrated scale (Travelon, 12775 MüV®)
8. Using US Environmental Protection Agency, Standard Volume to Weight Conversion Factors for Solid Waste (U.S. EPA, 2016)

4.4 Human Health and Wellbeing

Concerning health and wellbeing measurements (Table 5) health issues included food insecurity, overweight adults, parasitic infection, diarrhea, risk for cardiovascular disease and diabetes, depression, and injuries. Positive health aspects included no children under five at risk for severe malnutrition, very few underweight adults, and low hypertension and anemia rates. This suggests everyday diet, environmental and social conditions are contributing factors to both health and disease in Claverito. Another possibility could be frequent physical activity (not measured) from outside activities documented in 4.2. A 24-hour dietary recall revealed the main diet of residents was fish, plantains and rice, with the addition of fresh fruit juices mixed with sugar when in season. The high caloric, high sugar, but low micronutrient diet may be a contributing factor to obesity, elevated glucose, and cardiovascular disease risk; conversely the fish in their diet may be a contributing factor to low hypertension and anemia rates. Food insecurity may be due to the low variety in food options, and a fishing lifestyle on a low income (families may skip meals or have smaller portions if no fish were caught that day). Additionally, poor access to recreation, greenspace and social gathering spots as well as large household sizes in small housing footprints, surrounded by water in the high river season, may contribute to overweight status and chronic disease issues as well as poor social relationships. Land and water pollution may be a contributing factor in parasitic disease and diarrhea, and precarious stairs and pathways were associated with the high number of reported injuries.

Access to healthcare services is complex in Claverito. Residents have the opportunity for free or reduced healthcare through the national Seguro Integral de Salud (SIS) program, however a lack of program awareness, long wait times, inconsistent government funding, lack of formal addresses, or a preference for indigenous treatment were barriers for residents to participate in this program. Of the 303 health conditions self-reported by a family member, 38% went to a medical doctor to be treated, 80% reported taking medicine, herbs or vitamins in the last 6 months, and 89% had at least one vaccination. No adult reported having received all recommended vaccinations. Self-reported personal hygienic practices and substance use are likely underreported (Lavrakas, 2008), however just less than half reported not consistently washing hands before cooking, or after using the bathroom or touching animals, which may contribute to infections from contaminated environment, food and water. Substance use may be confounded by two nonparticipating households because the adults were consistently intoxicated and could not give consent.

Table 5: Select Human Health and Wellbeing Measurements

Type	Measurement in Claverito	Value	n	National Average	Iquitos Average
Anthropometrics	% adults underweight	2%	43	2.6% [6]	DNA
	% adults overweight	49%		35.5% [1]	DNA
	% adults obese	19%		19% [1]	DNA
	% children <5 at risk for severe malnutrition	0%	14	17.7% [6]	DNA
Chronic Disease Risk	% adults with hypertension	9%	44	14.6% [1]	DNA
	% adults with high glucose levels	62%	50	DNA	DNA
	% adults with severely high glucose levels	2%		DNA	DNA
Nutritional and Immunological Measurements	% adult women age 15-49 and children <5 with anemia	6%	48	28.6% [7]	44.5% [7]
	% adults and children with parasitic infection	82%	87	DNA	DNA
	% adults and children with soft stool or diarrhea	42%		12.3% [3]	DNA
Food Insecurity	% of households severely food insecure	57%	44	DNA	DNA
	% of households moderately to severely food insecure	89%		23% [2]	DNA
Mental Wellbeing	% of adults that may have depression (moderate to severe)	25%	44	4.8% [4]	DNA
	% of adults showing depressive symptoms (mild)	45%		DNA	DNA
	% of participants with suicidal ideation	11%		DNA	DNA
Environmental Hazards	% report falls or injuries on community stairs in last 6 months	42%	71	DNA	DNA
	# reported injuries or falls from stairs in 6 months	82		DNA	DNA
General Health Screening[5]	% of self reported health conditions that report going to a medical doctor for treatment	38%	44	DNA	DNA
	% report taking medicine, herbs or vitamins in the last 6 months	80%		DNA	DNA
	% report receiving at least one vaccination	89%		DNA	DNA
	% report "always" washing their hands after using the bathroom	56%		DNA	DNA
	% report "always" washing their hands before cooking	60%		DNA	DNA
	% report "always" washing their hands after touching an animal	27%		DNA	DNA
	% report a household member who smokes at least 5-7x a week	9%		DNA	DNA
	% report a household member who drinks at least 5-7x a week	5%		DNA	DNA

1. (INEI) Instituto Nacional de Estadistica y Informatica, Reporte Peruano *Enfermedades No Transmisibles y Transmisibles,* (INEI, 2014)
2. Young Lives Study (Niños del Milenio), 2010. (Young Lives, 2010)
3. USAID Stat Compiler, DHS Program, Peru (USAID, 2012)
4. World Health Organization, Report World Health Day (2015)
5. Too numerous to report all findings of self reported health conditions for each family member in this paper
6. Informe técnico, Estado nutricional en el Perú por etapas de vida, Ministerio de Salud, Peru, (2013)
7. INEI, Encuesta Demográfica y de Salud Familiar- ENDES, Peru (2014)

DNA = Data Not Available

4.5 Species and Ecosystem Health

Table 6 shows species abundance, richness and evenness for each biological indicator group. Species abundance is the number of individuals counted in that category (e.g. birds) in the study area in the two week study period. Species richness is the number of different species within that category. Biodiversity indices show species richness and evenness. The Shannon-Weiner Index (H') assesses the predictability that an unknown individual animal will or will not be of a particular species. The Simpson Index of Diversity (1-D) assesses the predictability that two individuals will be of the same species. Crossing multiple biodiversity indices such as H' and 1-D provides a strong indication of ecosystem health for a given area (Morris, et al., 2014). Reported species diversity and evenness data is only representative of the sites in or adjacent to the Claverito community. Regional comparisons of diversity were not consulted due to the complexity and distinct structure of site conditions.

Biodiversity indices were high for birds, amphibians and reptiles, including sightings of several notable bird species (12 migratory, 18 CITES protected and 2 regionally rare species), however biologists reported these rates were not as high as regional averages in similar ecosystems in the Amazon. Bird diversity and abundance were surprisingly high for an urban area with limited greenspace. Biologists noted that certain human activities in Claverito supported bird habitat, including floodplain agroforestry, tall poles to stabilize houses doubled as bird perches, and community infrastructure retained aquatic vegetation and created floating vegetated islands ideal for nesting in high river season. Shoreline birds, however, were surprisingly lacking in this floodplain area, likely from high levels of trash covering potential nesting areas. Amphibians and reptiles, arguably the most sensitive to urbanization and dynamic floodplain conditions, were not nearly as diverse, and butterflies reduced significantly in both richness and abundance in the high river season, likely due to a significant reduction in available land area. Claverito had approximately 70% plant coverage of open areas in the low river season, and plant biodiversity appeared at a moderate level, and 30% plant coverage in the high water season (with aquatic floating vegetation) at a high level of biodiversity. This shows much promise for thinking about the value of aquatic vegetation to provide supportive habitat in floating slum communities. A significant amount of *Aedes aegypti* mosquitos were found in houses suggesting a high potential for transmission of vector-borne infections. Possibly due to a lack of mosquito prevention, eradication and education initiatives, it also may indicate a lack of mosquito-eating animals in the community.

Table 6: Biodiversity Measures

Beneficial Species Measure	**Low River Season**				**High River Season**				**All Seasons**
	Abundance	**Species Richness**	**H'**	**1-D**	**Abundance**	**Species Richness**	**H'**	**1-D**	**Species Richness**
Birds	9995	77	16.06	0.85	6374	83	20.60	0.92	100
Amphibians and Reptiles	445	14	7.57	0.84	303	14	9.20	0.87	18
Butterflies	667	11	1.70	0.26	22	6	4.53*	0.77*	12
Plants	3389	116	1.43	0.18	332	43	32.17	0.97	144
Vector Species Measure	**Low River Season**				**High River Season**				**All Seasons**
	Abundance n=43 houses	**Species Richness**	**% houses with *A. aegypti***		**Abundance** n=46 houses	**Species Richness**	**% houses with *A. aegypti***		**Species Richness**
Mosquitos	41	4	12%		57	7	31%		7

*species abundance too low to be accurate reflection

4.6 Internal Community Perceptions and Visions

Residents should have a say in management and development of their community, and communities have unique and valuable local knowledge. Outside professionals can provide expert guidance that complements community needs and perceptions. We used several participatory techniques administered by professional experts to gain insight into community perception of life challenges and opportunities, and resident's needs, desires, priorities, preferences, and vision of the future for their community:

1) A Photo Journalism project called "Claverito Bonito" had residents photograph what they considered beautiful in their community, giving team members insider perspectives on a clientele the team knew very little about at project initiation. Photos revealed residents' perception of beauty centered around family, food, a clean house, children doing homework, homemade art, and natural elements including the river, sunrise, and flowering plants.

2) A Cognitive Mapping activity revealed areas of concern within Claverito, with the hillside above (leading into) the community emerging as a major stressor. Wealthy teenagers and adults not residing in Claverito were regularly performing illicit activities including drug use, theft, gang activity, sex and urination/defecation in the public spaces and hillside immediately above the community, and police rarely patrolled the area. Claverito residents were afraid to walk outside their community in the evening, or take action against offenders who might threaten their tenure prospects. In addition, maps revealed that uphill urbanites were regularly dumping trash on the hillside. Claverito residents were frustrated with garbage build up and revealed they organize a "minga", or community work party, every other week to clean the area though with their limited resources there is still a large amount trash accumulation.

3) A workshop activity asked residents to write five things that made them sad or stressed in their daily life, and five that made them happy or relaxed, emphasizing community strengths and frustrations (Table 7). This exercise revealed that the community president had been submitting Claverito's application to become a formally recognized human settlement every month since 2011, but the city had not yet discussed the application, a significant source of despair and frustration for residents. Residents were also asked for their ideas of what five things could make daily life better, and to produce drawings of what they imagined the future of Claverito could be, helpful insights for potential future slum upgrading strategies.

Questions on the Household GAZER Survey also provided insight into residents' sense of belonging, sense of place and sense of health. Residents were aware of their challenging conditions and struggled with community pride and seeing their community as beautiful. Despite these challenges, and the varying amount of time households had lived in Claverito (see 4.1), 98% of respondents answered "yes" to "does Claverito feel like home?" suggesting that Claverito was not a transition spot for these residents, but rather a chosen destination with significant emotional and social investment (Table 8).

Table 7: Community Needs, Desires, Priorities (n=38)

Top 5 things that make me sad or stressed in my daily life		**Top 5 things that make me happy or relaxed in my daily life**		**Top 5 things that I think would make my daily life better**	
Responses	**%**	**Responses**	**%**	**Responses**	**%**
Bad relationships with neighbors, family, friends, couple	76%	The family	89%	Stable work	63%
Not having water	61%	Sports, exercise, walking	84%	Better housing	47%
Housing conditions	47%	Working	53%	Help from authorities	37%
Outsiders throwing trash, degraded environment	45%	Good relationships with neighbors, family, friends or couple	42%	Better floating paths	37%
Not having work	42%	Cooking, food, eating every day	42%	Having water	34%
Poor personal and family health	39%	A clean organized house	32%	A community center	32%
Not having money	34%	Good personal and family health	26%	Light / electricity	29%
Not having light / electricity	29%	Leisure activities (reading, dancing, market, TV, bingo)	26%	Better relationships with neighbors, family, friends, couple	26%
No help from authorities	29%	The environment, river, trees and birds in Claverito	18%	Better stairs	24%
Unstable and ugly stairs and paths	26%	Pride of the Amazon traditions, festivals, community activities	16%	More trees, gardens, food plants	24%
Not having sewer	18%	Community work, cleaning trash	13%	More money	18%
Crime, drugs, illegal activity in the public spaces above	11%	Education	13%	Educational opportunities, skills training	16%

Table 8: Community Perceptions (n=44)

Category	Characteristic	Measurement in Claverito	Value
Sense of Belonging	Safety/security	% are happy about level of safety and security in Claverito	27%
	Feeling Home	% think Claverito feels like home	98%
	Social Comfort	% feel they fit in socially in Claverito	75%
Sense of Place	Community Pride	% are proud of Claverito	27%
	Perception of Beauty	% think the environment in Claverito is beautiful	27%
		% are proud of the physical appearance of their house/property	39%
	Environmental Satisfaction	% are satisfied with ___ in Claverito?	
		Air quality	50%
		Water quality (river)	41%
		Land or soil quality (trash)	34%
		Level of noise	23%
		Environmental odors	27%
		Available parks and gardens	27%
		Play and recreation spaces	32%
		Plants and nature	20%
		Community meeting spaces	70%
Sense of Health	Meeting Basic Needs	% think they have adequate access to_____	
		Food	71%
		Medicine	32%
		Clean drinking water	75%
		Adequate sanitation	21%
		Electricity	75%
		% think their family has "just enough" or "more than enough" money for their needs	5%
	Healthy Environment	% think their environment is healthy	30%
		% have seen sick animals in Claverito	12%
		% have seen sick plants in Claverito	30%
		% are aware of things in their environment that could harm or make them sick	89%
	Personal Health	% rate their health "good" or "excellent"	62%

5. Discussion

The data collection and assessment activities, guided by seven data gathering categories in a piloted Community Social-Ecological Assessment Framework, document the complex challenges and benefits of living in this slum community. A large population of children and indigenous migrants, large household sizes, low education levels, unstable employment, high poverty levels, and lack of tenure contribute to the vulnerability of Claverito. Significant challenges included inadequate housing; lack of public stairs, paths, or community greenspace; no access to clean water, poor land quality or access to public services; injuries, food insecurity, overweight adults, parasitic disease, diarrhea, diabetes and cardiovascular disease risk, poor social relationships and mental wellbeing including depression; Positive aspects of human health include no malnutrition for children under five, few underweight adults and low hypertension and anemia rates. Positive ecological benefits include overall high biodiversity for an urban area and presence of sensitive species for birds, however biodiversity and species evenness has the potential to be improved, especially for plants, shoreline birds, amphibians, reptiles and butterflies. It was also discovered that residents thought of Claverito as their home, have lived there for as much as 45 years, and have a way of life very much tied to this landscape and place, suggesting Claverito is a chosen destination with significant emotional and social investment. The Claverito data varied substantially from the available Peru and Iquitos data in almost all categories, and especially demographics, diarrhea, food insecurity and mental wellbeing, supporting the initial assumption that national censes and epidemiological studies should have slum specific tracts.

This transdisciplinary assessment revealed several human-species-environment relationships that demonstrate interconnected social-ecological systems in Claverito, providing insight into how these systems may impact the health of slum communities and the environment in which they live. Figure 3 gives an interpretive example of one of these connections, examining how trash likely disposed of by non-Claverito residents may have contributed to human health

issues in Claverito such as vector-borne diseases or depression, and species health issues such as decreased habitat quality for shoreline birds or less quantity and diversity of amphibians and reptiles. The study revealed that impoverished slum residents might be disproportionally affected by land pollution because of aspects of their daily life unique to these communities that closely interact with the landscape. For example, a desire to improve community image to obtain governmental recognition pressures residents to participate in regular trash cleanup, and without affording protective clothing and shoes, residents are regularly exposed to harmful contaminants and vectors in their environment. Another pathway to contaminants may be through consumption of chickens and fish that consume trash or have parasites. While there are likely also other pathways that contribute to poor health, this study strengthens the dialogue on how the built environment is a determinant of health, and that human-species-environment relationships as described in One Health, Planetary Health and Urban Ecological Design frameworks are especially important to understand in slum communities.

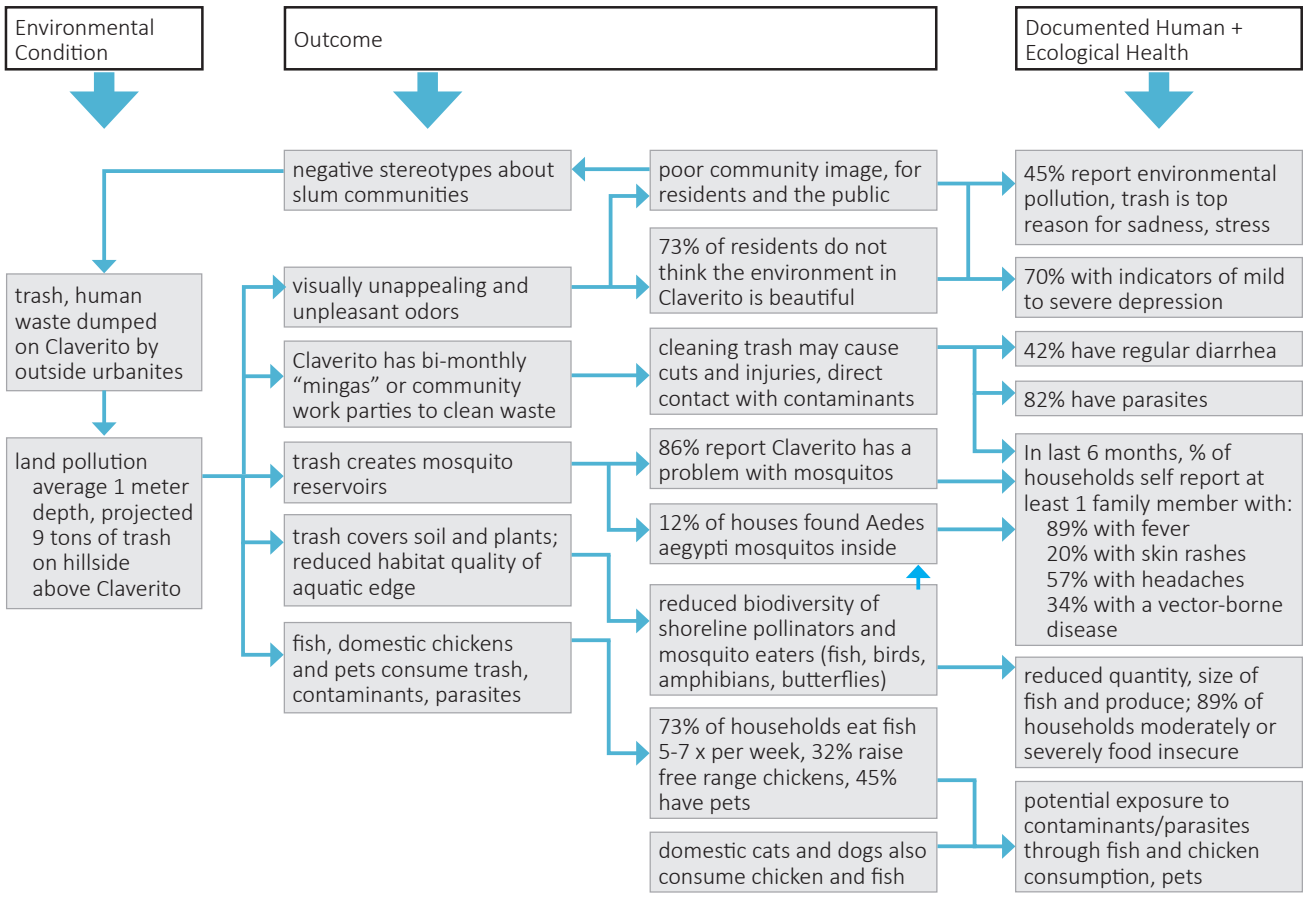

Figure 3: One example of reflections on human-species-environment relationships in Claverito

The data collected as part of this study is currently being shared with the local government and research institutions and it has already been shared with the residents of the community of Claverito. Disseminating the data will not only provide information about Claverito to decision-makers, but may also provide insight into living conditions for the 30,000 other people living in floating slums in Iquitos.

The process of gathering, analyzing and disseminating the data has the potential to influence in several ways beyond collecting the data itself. These include reducing stigmas of slum communities, laying the groundwork for evidence-based planning and informed interventions to improve human and ecological health in Claverito and similar communities, and strengthened relationships with city and federal authorities, each described in the following sections.

5.1 Reducing stigmas of slum communities

In cities with slum conditions, the lack of information about informal communities can cause tensions between residents of informal and formal settlements. Formal residents may assume those living in slum conditions have different, less desirable cultural values and behavior patterns resulting in violence, drugs, and unhygienic living conditions; slum dwellers are judged to be the source of environmental degradation and poor health (Gouverneur, 2015). This biased perception may be because formal residents are rarely exposed to the ways of life inside informal areas, and governmental reports and the media lack the facts needed to expose these stereotypes and stigmas. Additionally, wealthier and more educated urban residents may value Euclidean planning and zoning efforts practiced by former colonial rulers or modern Western cities, which is very different than construction patterns of informal areas settled by recent migrants influenced by more indigenous forms of land ownership and culture (Gouverneur, 2015). The incremental development of slum communities is often misread as a lack of care or helplessness instead of a unique vitality and adaptability in a challenging situation (Spencer, Bolton, & Alarcón, 2015).

With tensions high, individual formal urban residents may make personal decisions that ignore or degrade their powerless neighbors, such as constructing high walls around their property, tossing their garbage in slums, or not hiring a known slum dweller. The engrained discrimination, stigma and negative stereotypes often prevail in city governance when there is a lack of information or leadership to represent slum community interests or to expose these misperceptions. Government officials may selectively respond to formal urbanite taxpaying constituents resulting in decisions that further marginalize or eradicate slum communities (UN-Habitat, 2016). Further marginalization and displacement contributes to ever declining health outcomes, damaged environments, and deep cycles of disempowerment and poverty.

Like many slum communities, Claverito is often viewed as blight to the city by formal urban residents and therefore has not been invited to take part in city programs. Through informal conversations with formal Iquitos residents, team members discovered several negative stereotypes and stigmas about Claverito and observed the negative impact these misperceptions may have on the community. With dissemination of the assessment findings in this study to local authorities and popular media, the facts that emerge from the assessment in this study may be a small step towards reducing harmful stigmas, not only for Claverito, but for other similar slum communities as well. See Table 9.

Table 9: Common Stereotypes Compared to Study Findings

Stereotype	Potential Negative Health Impact	Findings from the Pilot Study
1) People are only temporarily living in Claverito until they find a better place, and are not invested in their community	Residents in Claverito report not being included in public health initiatives, rarely patrolled by police, and Claverito does not appear on city or national maps	Residents have reported living in Claverito for up to 45 years and 98% say it feels like home.
	The city has not invested in public services for Claverito; inadequate access to water, sanitation, electricity, medicine and physical infrastructure may be contributing to high rates of injuries and exposure to contaminated soil and water	Claverito created a neighborhood organization with a President and task committees, have self-constructed community infrastructure complete with named roads, addresses, and shops and meet regularly to discuss the future of the community. This shows significant emotional, social and physical investment.
2) Claverito lives on the river even though it is an unsustainable way of life because there is no place else to live	The community submits their application to become a formally recognized human settlement every month since 2011, but the city has not yet reviewed the application; may be contributing to poor mental wellbeing and disempowerment	Residents have strong cultural, economic and social ties to the river. Residents chose to live in Claverito above other locations because of the close proximity to both city and river resources, and strong social ties from family and friends already living in the community.
	The city plans to relocate all floating slums miles from the river because they believe the river is an unsustainable place to live; if this happens may damage cultural, economic and social systems in the community	Well constructed floating houses are actually more sustainable in flood conditions than fixed structures because they rise with the river; (there are many examples of sustainable floating communities all around the world*)
3) Claverito is destroying the environment and Claverito residents do not care	Non Claverito urbanites have been seen dumping their trash and human waste onto the community; may be contributing to poor mental wellbeing, poor community image, disempowerment, contaminated soil and water, and increased mosquito reservoirs in Claverito.	Claverito has "mingas", or community work parties, to clean trash every other Sunday. Residents have a very low environmental footprint, build with discarded materials, and are not the main trash polluters. Almost half of residents report a polluted environment and trash as a top reason for being sad or stressed.
	Placing sole blame on floating slums may hold the city back from implementing initiatives to improve environmental conditions	Certain human activities in Claverito may actually be increasing water cleaning shoreline and floating vegetation, and supporting bird, reptile and amphibian habitat; these actions benefit the entire city

* *Relevant to mention, but not a part of the study*

5.2 Evidence-based planning and informed interventions

Data collection and synthesis helps local governments and slum communities to make informed actions to improve residents' lives. When information is non-existent or unreliable, there is no clear guidance for slum management, and responses are incomplete and inaccurate (UN-Habitat, 2016). This may result either in slum communities being left out of city management strategies entirely, or decisions on slum management end up being speculation-based (as opposed to evidence-based) resulting in relocation or eradication programs that move the problems around to benefit more vocal formal urban residents, and potentially making human and environmental health situations even worse.

Because perceptions may cloud facts, successful slum management requires informed decisions based on evidence rather than speculation. This can be demonstrated by examining another slum community, Belen, about a mile upstream of Claverito. Belen started out similarly to Claverito, with floating raft houses on the river. There is an evident progression of house construction and community formality in Belen, in which the older and more developed houses are closer to the shore and built on high stilts, and the newer and more precarious structures are floating on logs. According to locals, building your house on stilts requires less maintenance each year, but they also claim that in order to be considered as a legal (not informal) resident of Belen, their house is required to touch the ground, and so they are pressured to build their houses on stilts. However, stilted houses are much less resilient to the dynamic Amazon floodplain, especially with increased intensity of climate change, and in 2012 floods surpassed the height of the houses, endangering residents (Gobierno Regional de Loreto , 2013). Noting these unsafe conditions and the health burden on the city, and believing that

communities that live on the water are unsustainable due to this flood event, the government then implemented a plan to relocate residents of Belen into new modular houses safely away from floodwaters, and in 2015 they began relocation efforts (Campuzano, 2015). However, while residents accepted the free houses initially, many residents ended up moving back to Belen despite the unsafe conditions (Arrue, 2015), and those who stayed may possess a whole new set of health issues (Dominguez, 2014). We know from our documentation in Claverito, that these communities are living in the floodplain intentionally because they have strong cultural, economic and social ties to the river and its resources. The relocation program moves residents over four miles away from their community along a highway and a one-hour walk to the nearest river. The residents' entire lifestyle would have to change, which is difficult for an indigenous migrant community with rural skills and limited education. One might speculate that residents may have returned to Belen because of these close ties to the river. We also know that floating communities have been designed in safe ways all around the world, and that it was likely the stilted houses pressured by recognition efforts that contributed to unsafe conditions, not the rising river. A social-ecological assessment to understand the way of life and pathways to health outcomes in Belen may have led to a more informed plan of action to improve the lives of slum dwellers. Additionally, if all of Belen is to be relocated in the future, it may significantly impact larger systems including the Belen Market, one of the largest economic hubs and tourism attractions in the city managed almost entirely by Belen slum residents.

The fate of Claverito may very well shadow that of Belen. Claverito has submitted documents to become a recognized community every month since 2011 in order to gain access to public services and improve their environmental conditions that may be contributing to poor health for them and the other species they share their community with. These efforts have been unsuccessful thus far. The pressure to rebuild their floating houses to rest on stilts is high. Additionally, residents were not invited to participate in recent city planning conversations that zoned the area they live in as recreation, despite residents in the community living there for up to four decades. If they were given the opportunity to take part in governmental conversations there may be ways to meet the desires of the city as well as the needs of Claverito. For example, given the rich biodiversity discovered in Claverito as well as the documented way residents of Claverito are improving the water quality and habitat through their daily activities, with additional resources Claverito could actually become a demonstration community for eco-tourism or citizen science programs in the city. With a more robust dissemination plan, the data collected as part of this study may support evidence-based planning, and open conversations with decision-makers about the potential future of the community.

In the mean time, understanding the human-species-environment conditions in Claverito from data gathered as part of the Community Social-Ecological Assessment Framework, including identifying needs, priorities and visions through participatory methods, has allowed the study team to work with residents to define small community-scale interventions that target the specific health needs of residents and non-human species (e.g. designing productive gardens with plants that attract butterflies). This study has provided a baseline for which to measure the impact of the interventions over time. More information on interventions and their documented impacts on human and ecological health in Claverito can be found in Chapters 3 and 4 of this dissertation.

5.3 Strengthened relationships with city and federal authorities.

Lastly, the assessment of human, ecological and environmental health conditions in this community opened doors for conversations with city authorities and members of the formalized public, whereas previously Claverito was essentially invisible. This was likely a result from both the collected data and the visible presence of the research team in the community. After hearing about the amount of biodiversity found in the community, the municipality volunteered fourteen staff on a Saturday to work alongside the residents of Claverito to remove 622 bags of garbage in the community. Tourists, artists and urbanites not living in Claverito began taking photographs and drawings of the improved community, and on-going dumping in this beautified area has decreased over time- indicators that public stereotypes are beginning to change. With this increased attention, the police began soliciting residents from Claverito to join the neighborhood watch program. In September 2017, Claverito was included for the first time in city-wide mosquito eradication efforts. In February 2018, the Ministry of Health approached Claverito residents to invite them to participate in a mobile clinic program. On October 22, 2017, just a year after the initial study assessment, the Community of Claverito was included in the National Census for the very first time in the 45 years since the first resident moved there. While Claverito is still not an officially recognized community, their statistics are now included in the larger conversation for national and city management.

5.4 Study challenges and limitations

While the use of the piloted Community Social-Ecological Assessment Framework and data outcomes in Claverito were fairly straightforward, it was not without challenges. The team included professionals that crossed disciplines, which was challenging to manage for both personnel and data. This also became complicated in cross-analysis of data to formulate social-ecological connections. A limited budget and timeline was a barrier to performing complex statistical analyses to critically analyze relationships and causality between data points. Assumptions based on team observations and experiences working in the community were necessary to draw conclusions, without of which it would be difficult to understand connections.

There may be limitations to replication of the Framework. Participatory methods used in the Daily Life and Internal Community Perceptions data gathering categories require intimate researcher to resident ratios. The team estimates a limit of 30 households per team leader, so if a larger slum community is being studied, it is recommended to divide it into smaller tracts or neighborhoods of 60-90 households with 2-3 study leaders each. Additionally, the challenges of accessing slum communities, and in particular, floating slum communities, for house-by-house assessments, require careful attention and worker health and safety protocols. Ideally community leaders would assist in slum navigation and would need to be properly compensated for their involvement. Lastly, the Framework was piloted in Claverito, with a very particular socio-political-environmental context. For application to other slum communities in Iquitos, Latin America and other parts of the world the Framework would require cultural and environmental adaptability to meet the particular context of the community in focus.

6. Conclusion

A human, environmental and ecological health assessment of slum communities such as Claverito grounds cross-disciplinary frameworks such as One Health, Planetary Health and Urban Ecological Design into practical application and helps us better understand how the built environment is a determinant of health. The assessment of Claverito using the seven categories of data gathering in the Community Social-Ecological Assessment Framework proposed in this manuscript gives us insights into slum communities through the professional lens of multiple disciplines across the human health, ecology and built environment fields, as well as internal perspectives of residents in Claverito.

There is a renewed need to acknowledge slums, to understand interconnected human-species-environment systems, and to use that information to reveal public misperceptions resulting in stigmas and discrimination as well as to make informed actions towards improving the lives of slum dwellers and strengthen relationships with authorities. Accurate data results in smarter more inclusive decisions in slum management and overall city planning that work with the way of life in slum communities instead of against it. It also creates a basis for defining community scale interventions to address specific needs and priorities of an individual slum community and surrounding environment. UN-Habitat boldly calls for a *data revolution* to support results-based management of slum communities by taking strong baseline and follow-up measurements to guide intervention efforts and monitor achievement over time. Much more discussion and action is needed to jumpstart the "participatory, robust, standardized and computerized" *data revolution* that UN-Habitat says is necessary for successful management of slum communities (UN-Habitat, 2016, p. 18). However, the pilot study of Claverito and the Community Social-Ecological Assessment Framework may provide a preliminary model for how to work with other slums and undocumented communities and improve health, environmental richness and quality of life around the world.

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Chapter 3

Title

Human and Ecological Health Outcomes of a Gardens Intervention in a Latin American Slum Community

Abstract

A shortage of healthcare resources around the world demands creative, collaborative, affordable and preventative solutions for addressing the global burden of disease. This case study describes a Gardens Intervention (GI) project in an informal slum community in the urbanized Peruvian Amazon developed through a Transdisciplinary Action Research (TDAR) approach with community participatory design techniques, and explored the complexity of health benefits that urban gardens have to offer to slum communities and their environment. The case study applies a pre and post test Health Assessment with human and ecological health indicators documenting change within a longitudinal study context, paired with a Design Impact Assessment that repeats these same indicators but as a post-test of the GI project. One year after garden construction, the Health Assessment showed a positive trend in land pollution and biodiversity of plants (change in H' = 15.48 and 1-D = .73), birds (change in H' = 15.48 and 1-D = .07), and butterflies (change in H' = .51 and 1-D = .01), significant positive changes in community beautification (p <.001), social relationships (p <.001), injuries and falls (p <.001), access to medicine (p <.001), self grown medicinal plants (p <.001), food security (p <.001), and mental wellbeing (p =.02), with household beautification not statistically significant (p = .53) and a slight decline in biodiversity of amphibians (Δ H' = .09, 1-D = -.02). Results of the Design Impact Assessment showed residents perceived the GI to have meaningful positive change across all indicators of land pollution, environment, beautification, social wellbeing, medicine security, food security and mental wellbeing. In conclusion, the built environment, urban nature, gardens and the TDAR approach can have a major and multi-faceted role in improving human and ecological health and should be considered an integral part of public health systems.

Keywords

Built environment, landscape architecture, slum, social-ecological systems, action research, global health

1. Introduction

A shortage of healthcare resources worldwide demands creative, collaborative, affordable and preventive solutions to address the global burden of disease (Darzi & Evans, 2016). Built and natural environments, including the spaces in which we live, work, learn and play, have major and multi-faceted roles in human health and wellbeing and should be considered an integral part of national to local public health systems. Collectively, various physical and social conditions are social determinants of health, creating circumstances and opportunities for healthy outcomes, and are widely discussed as a critical component to improving health equity (Solar & Irwin, 2010) and in health promotion and disease prevention (Dannenberg, Frumkin, & Jackson, 2011). The built environment can also be designed to create healing spaces for target populations, playing a critical role in palliative or rehabilitative care by reducing the severity of symptoms and helping individuals cope with ill health such as injury, trauma or illness. (Winterbottom & Wagenfeld, 2015; Cooper Marcus & Sachs, 2014)

People who live in slum conditions are a target population characterized by inadequate built environment conditions (UN-Habitat, 2002). Their intimately shared social and physical environments make them particularly susceptible to high risks of infection, injury and illness with effects beyond those of poverty alone (Ezeh, et al., 2016). Community interventions, such as those in the built environment, may have an especially high rate of benefit in slums because outcomes are shared across dense and integrated populations through an intimate "neighborhood effect" (Lilford, et al., 2016) and mitigation of a harsh environment and human and ecological health challenges offers the potential for detectable and multi-faceted change.

Urban nature in the built environment, including gardens, parks and small-scale landscapes in the urban context, may be particularly beneficial to health. A large and growing body of scientific evidence indicates promising linkages between urban nature and positive and measurable physical, mental, social and economic health impacts (Wolf & Robbins, 2015; Pleasant, Scanlon, & Pereira-Leon, 2013; Seymour, 2016; James, Hart, Banay, & Laden, 2015). Built environments and urban nature can also influence the health of animal and plant associations and ecosystems, which in turn influences human health (Elmqvisst, et al., 2013; Seto, Solecki, & Griffith, 2016; Zari, 2014). Humans derive numerous benefits from healthy ecosystems and their inhabitants through the ecosystem services they provide, and the loss of these services contributes to poor human health and wellbeing (Millennium Ecosystem Assessment, 2005). Biodiversity and ecosystem function are common indicators of ecological health and affect human wellbeing through shared food, water and soil systems, disease transmission, climate regulation and pharmaceutical, energy or material innovations, among others (Grifo & Rosenthal, 1997; Morand & Lajaunie, 2018). Health frameworks such as Planetary Health, One Health and EcoHealth emphasize the importance of protecting, restoring and navigating our shared environments and interactions with animals within to simultaneously support human health and the health of non-human species (Whitmee, Haines, Beyrer, & et al., 2015; King, et al., 2008; Lerner & Berg, 2017). Supportive ecological frameworks such as Social-Ecological Systems (SES) and Ecosystem-Based Management (EBM) approach natural resource management by supporting ecological integrity inclusive of human wellbeing and societal needs (Ostrom, 2009; Breslow, et al., 2017) and the Urban Ecological Design framework guides designers to create high-functioning urban nature with co-benefits to humans, species and ecosystems (Rottle & Yocom, 2011).

Within urban nature, urban gardens (the noun) and urban gardening (the verb) have been studied for their positive impact on underserved, impoverished and marginalized human populations as well as vulnerable urban species such as pollinators. For example, strategically designed gardens have the potential to provide health supporting products such as increased access to fresh food (Alaimo, Packnett, Miles, & Kruger, 2008), medicinal plants (Maroyi & Mosina, 2014), and community and habitat greenspace (Okvat & Zautra, 2011; Luke, Taylor, Kaplan, & Munro-Stasiuk, 2013). Urban gardens and gardening can also provide services supporting ecological, community or individual or family health. The ecological health services that gardens can provide include increased food and shelter options for a variety of species (Strauss, 2009; Paker, Yom-Tov, Alon-Mozes, & Barnea, 2014), improved biodiversity (Gaston & Gaston, 2011), and gardening can revitalize polluted, vacant or neglected urban spaces with improved ecosystem function (Yadav, Duckworth, & Grewal, 2012; Gittleman, Farmer, Kremer, & McPhearson, 2017). Personal gardens and gardening can provide the opportunity for individual or family health services including increased food security (Letts, 2013) and improved mental health (Korn A. , Bolton, Spencer, Alarcon, Andrews, & Voss, 2018). Gardens and gardening can also provide community health services benefiting individuals and the community as a whole including strengthened social cohesion and relationships (Teig, Amulya, Bardwell, Buchenau, Marshall, & Litt, 2009) and community beautification (Perkins, Adam-Bradford, & Tomkins, 2017). Utilizing community participatory processes for garden implementation in slum communities may support social empowerment and enhance

benefits of gardens (Spencer, Bolton, & Alarcon, 2015; Korn A. , Bolton, Spencer, Alarcon, Andrews, & Voss, 2018). Landscape architect Kenneth Helphand explains that gardens created in extreme or difficult environmental, social, political, economic or cultural conditions such as slums may also have additional health supporting dimensions such as providing a voice for the voiceless, and a place of hope, escape, cultural pride and home (Helphand, 2006). Termed "defiant gardens", they are sites of assertion and affirmation created by defiant gardeners who boldly confront their circumstances and celebrate the dignity of life for human and non-human species within dehumanized and stagnant environments (pp. 212).

The frameworks and body of evidence regarding built environment, urban nature and gardens and health is large and growing. Yet with disciplinary silos in research and academia, very few studies have looked at the multiple impacts of urban nature and gardens across dimensions of human, ecological and environmental health. Key questions remain unresolved (Guitart, Pickering, & Byrne, 2012; Frumkin H. , 2013; Frumkin, et al., 2017). In addition despite the aforementioned health, ecology and design frameworks that connect humans, species and the environment, very little research exists on the application of these frameworks to on-the-ground interventions, particularly in partnership with communities. Additionally, while many studies have been conducted on garden projects in poor neighborhoods in high-income countries, very little research has been done in low-and-middle-income countries or in slum communities (Guitart, Pickering, & Byrne, 2012; Frumkin, et al., 2017).

This case study of a Gardens Intervention (GI)[1] project in a slum community in the urbanized Peruvian Amazon assessed measures of change for ecological, community, and family and individual health conditions during a one year time frame. The GI was implemented using a Transdisciplinary Action Research (TDAR) approach (Stokols, 2006) with community participatory techniques. Measurements were twofold: a pre-and-post Health Assessment with human and ecological health indicators documenting change within a longitudinal study context, and a Design Impact Assessment that repeats these same indicators but as a post-test of the GI project. The research was guided by four objectives:

1. To examine changes in ecological health using indicators of land pollution, plant biodiversity, and animal biodiversity.
2. To examine changes in community health using indicators of beautification and social wellbeing.
3. To assess individual and family health using measures of injuries and medicine security and validated scales of food security and mental wellbeing.
4. To compare results of aforementioned ecological, community and individual and family health measures to a design impact assessment that asks residents how the GI specifically impacts each indicator

2. Materials and Methods

2.1 Study setting

Claverito is a floating slum community situated in a floodplain tributary of the Amazon River on the edge of the city of Iquitos, Peru (See Figure 1). Located in between a city of 0.5 million residents and the Amazon Rainforest, Claverito is strongly influenced by and vulnerable to both urban and ecological health systems. Claverito has about 50 houses that float on large logs during the high river season (approximately January-June), and rest on the ground during the low river season (approximately July-December). Although the community was established several decades ago, Claverito is informal, as it is not recognized by the local or federal government, so residents do not have access to municipal services (e.g. water, sewer, electricity etc.) and their community does not appear on city maps (Maynas, 2011). Baseline human, environmental and ecological health conditions are documented in detail in Chapter 2 of this dissertation.

[1] The term Gardens Intervention was used for simplicity, however the intervention in actuality was a complex design utilizing urban ecological design principles to target specific human and ecological health indicators

Figure 1: Bird's eye view of the floating slum community of Claverito in the high river season, with the city of Iquitos to the right and the Amazon Rainforest to the left

2.2 Study Design

The overall design and research project employed a Transdisciplinary Action Research (TDAR) approach, utilizing a highly collaborative and inter/transdisciplinarily diverse team in applied research aimed at community problem-solving strategies that also address broader societal goals of public health, social and environmental justice and ecological sustainability (Stokols, 2011; Thering & Chanse, 2011). The professional team consisted of researchers from universities in the U.S. and Iquitos as well as professional consultants who are experts in their field, and represent seventeen disciplines across the human health, natural sciences and built environment design fields. The project team also included Claverito residents and local experts. As part of this TDAR process, the GI utilized a participatory design approach in which the intervention and research indicators were defined through community-driven priorities and the intervention was designed, constructed and maintained by community members. Participatory techniques are commonly used to democratize design processes and enhance community ownership, empowerment and sustainability of built environment designs (de la Pena, Jones Allen, Hester Jr, Hou, Lawson, & McNally, 2017). The TDAR process including the participatory approach is detailed in Chapter 4.

This project is part of a larger longitudinal study in which local surveyors are administering a household Global Assessment of Zoonotic and Environmental Risks (GAZER) survey, and local nurses are administering physical health measurements yearly to follow Claverito over a proposed ten years. This study includes the quantitative and qualitative measures taken as part of this GI project. This project, nested within the larger longitudinal study, used a single arm pre-post intervention study design (Thiese, 2014). The study examined measurements at baseline before intervention design and construction (low river season 2016) and at one year after intervention construction (low river season 2017). In addition, a Design Impact Assessment was applied one month after the post intervention measurements (also low river season 2017).

2.3 Gardens Intervention

To reduce community fatigue, the GI was conducted in two phases: A Community Entrance Garden and Household Floating Gardens (see Figure 2 for location map) designed and constructed over two six-week periods with two months in between. Details of the intervention design components and participatory design strategy are described in detail in Chapter 4. Figure 3 shows an overview of the 150 m^2 (1,600 ft^2) Community Entrance Garden. Design features included a concrete staircase with handrails, wood retaining walls with water infiltration infrastructure, and replacement of one meter's depth of trash with plants for beautification, food, medicine and habitat, all open for community use. Figure 4 shows three examples of the 28 Household Floating Gardens. Residents individually designed their floating gardens, including customized plantings, painting, art and poetry. In total, the GI added 151 food-producing plants, 493 medicinal plants, 92 both food and medicine producing plants, and 805 non-productive plants with flowers or aesthetic appeal, totaling over 1,500 new plants in the community, and a total of 193 m^3 of greenspace available for residents and doubling as multi-species habitat year round in both the low and high river seasons.

Figure 2: Location of Gardens Intervention in Claverito

Figure 3: Phase 1, The Community Entrance Garden

Figure 4: Examples of Phase 2, Household Floating Gardens

2.4 Measurements, Instruments, and Statistical Analysis

The team measured project outcomes by conducting assessments examining targeted human and ecological health indicators and evaluating the intervention design (Figure 5). This manuscript focuses specifically on the assessments in blue: 1) comparing objective indicator measures (pre and post GI) using a Health Assessment as part of a larger longitudinal study following Claverito, and 2) a Design Impact Assessment analyzing indicator measures (post GI only), which directly asked residents about the impact of the GI. The Design Sustainability Assessment is detailed separately in Chapter 4.

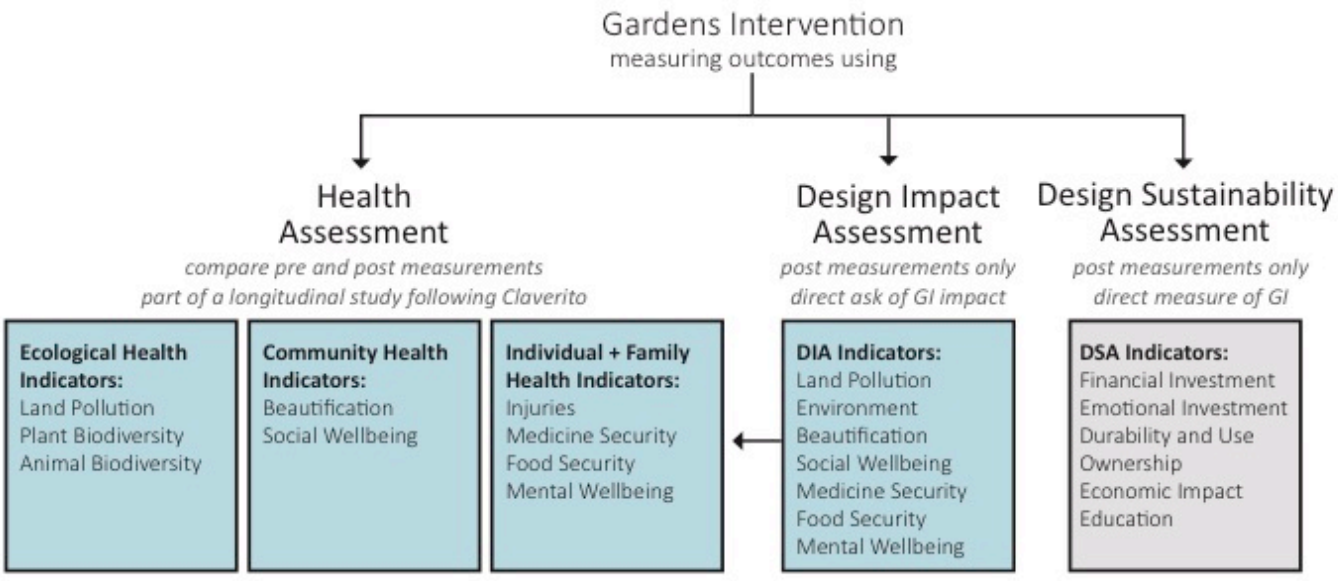

Figure 5: Project outcomes were measured in three assessments. This manuscript discusses those in blue: a Health Assessment of objective measures in and around the community measured pre and post intervention, and a Design Impact Assessment in which residents were asked how the GI project specifically impacted these same measures.

Health outcomes were measured along dimensions of ecological health, community health and individual and family health. Specific indicators within each dimension were chosen based on outcomes of a community participatory workshop in which residents identified their needs, desires, priorities and collective vision of how they wanted their community to develop, before the GI was defined or designed. The Injuries measure was added later after the design process identified a staircase as a community priority. Outcomes of the community workshop activity were used to understand Social Wellbeing. Due to the cross-disciplinary team of researchers, instruments were chosen based on the best methods used by contributing investigators. Statistical analysis was the following: If same residents pre/post, means, then used a two-tailed paired *t*-test; if same residents pre/post, dichotomous values, then used a McNemar test; if different residents pre/post then used a Generalized Estimating Equation (GEE). Table 1 shows a summary of all study measures.

Ecological Health: All measurements of ecological health were site based, using a professional team of private and university affiliated botanists, ornithologists, herpetologists, entomologists and taxonomists trained in Iquitos Amazonian flora and fauna, with the exception of land pollution measures which were conducted by the community and municipal workers, but guided by resource management professionals.

Land Pollution was measured by counting filled 64-gallon trash bags before and immediately after the Community Entrance Garden intervention. Trash monitoring continued every two months over a six month period. Trash was defined as plastic, metal, glass or other inorganic materials, but did not include construction rubble (brick, concrete remnants) as these materials were recycled and used in the garden installation. Only Macro trash (>2.5 cm, as defined by the 2013 U.S. National Oceanic and Atmospheric Administration guidelines for Marine Debris Monitoring and Assessment) was documented. Baseline and ongoing trash quantities were estimated assuming the average 64 gallon trash bag was filled to 50 gallons and weighed 8.75 kg (20 lbs), verified with random selection using a calibrated scale (Travelon, 12775 MüV®).

Plant Biodiversity measured plant density (number of individuals per area) and species richness (number of different species) by counting plants and identifying species within the GI limits both before and after the intervention. Because of

the relatively small size of the sample area (193 m^2, 43 m^2 of which was covered by water), relatively homogenous and short plants in baseline conditions, known quantities and types of plants that were installed as part of the intervention, and steep slope of study area making vegetation easy to view, a full census could be captured. Study area was divided into 2m x 2m quadrats using the stairs as an alignment reference. Botanists recorded all plants with living tissue and rhizomatous plants (e.g. grama lote grasses) were estimated by counting culm groups (clumped stems) per quadrat. Taxonomic classification was performed using records of the Amazonian Herbarium at the National University of the Peruvian Amazon.

Animal Biodiversity measures included abundance (number of individuals recorded), species richness (number of different species), and notable species (IUCN Red List of threatened species (IUCN, 2016), CITES protected (CITES, 2016) and migratory (Plenge, List of the Birds of Peru, 2016)) each for birds, amphibians and butterflies as key indicator taxa across a two week period. Birds, amphibians and butterflies were chosen as biological indicators because of their mobility differences, sensitivity to human activity, services to humans (pollinators, mosquito eaters etc.), and cultural symbolism of beauty and prosperity. Sampling methods used were appropriate for each organism. Bird sampling used a census by transects approach (Bibby, Burgess, & Hill, 1992) using 1 km long transects, registering bird species by direct observation (Vortex binocular of 8x42) or by identifying songs and calls (Sony digital recorder Model VN-5200PC). Identification referenced "Birds of Peru" (Schulenberg, Stotz, Lane, O'Neill, & Parker, 2010) and taxonomic classification, sequence and nomenclature used "Lists of Birds of Peru" (Plenge, 2017). Amphibian sampling used the Visual Encounter Survey (VES) with active search technique (Crump & Scott, 2014) across 0.5 km long sampling stations. Active search involved checking under fallen logs, between litter, within puddles etc., photographing, measuring and releasing. Identification and nomenclature used "Amphibian Species of the World" (Frost, 2016). Butterfly sampling used a dual methods across sampling stations, utilizing both active direct search with an entomological net and passive Van Someren-Rydon traps with decomposed fruit bait at 1.5m-1.8m above soil (DeVries, 1987). Identification referenced butterfly diversity literature from the nearby Tambopata National Reserve and encompassing region of Loreto (Grados, Figueora, & Alvarado, 2010; Lamas, Robbins, & Harvey, 1996) and taxonomic classification was performed at the Fauna Laboratory of the National University of the Peruvian Amazon as per (Borror & DeLong, 1964). Times of day for sampling were also adjusted to address appropriate times for taxa activity (eight hour observations ensuring sunrise and sunset captures for birds, eight hour observations at both mornings and nights for amphibians, four hour direct capture and daily traps for butterflies). The study area was the limits of the Community of Claverito including both the urban area where residents live (2.53 hectares) and the adjacent Camu Camu Bosque composed of trees planted and managed by a family in Claverito (7.12 hectares).

The Shannon-Weiner Index (H'), assessing predictability that an unknown individual will or will not be of a particular species, and Simpson's Index of Diversity (1-D), assessing predictability that two individuals will be of the same species, were used in statistical analysis for both plant and animal biodiversity (Magurran & McGill, 2011).

Community Health: Two questions in the household survey examined perceptions of *Beautification*:1) 'Do you think the environment in Claverito is beautiful, yes or no?' and 2) 'How proud are you of the physical appearance of your house and property?' on a scale from 1-5, where 1 is not proud at all and 5 is very proud. Statistical analysis compared percent "yes" for the first question and used the McNemar test, and means for the second question and used a two-tailed paired t-test.

For *Social Wellbeing* residents wrote open-ended responses to the questions 1) 'What are five things that make you sad or stressed in your daily life?' and 2) 'What are five things that could make your daily life better?' Responses were coded using a content analysis process. Categories were then collapsed (using inter-rater interpretation) and statistically compared using a GEE. This Social Wellbeing category examines responses coded as "relationships with my neighbors, family, friends and/or couple".

Individual and Family Health: For *Injuries* residents were asked: 'Have you fallen down or been injured on the stairs leading to the community within the prior six months, yes or no?' Statistical analysis compared percent "yes" and used a GEE for statistical analysis.

Medicine Insecurity questions in the household survey were: 1) 'Do you think you have adequate access to medicine, yes or no?' and 2) 'Where do you get your traditional or medicinal plants or herbs?' with options of market, grown in the community, grown at home, the jungle, or other. McNemar tests were used for dichotomous yes/no responses and whether medicinal plants were "grown within the community" or "grown at home".

Food Insecurity was recorded using the validated Household Food Insecurity Access Scale (HFIAS) (Coates, Swindale, & Bilinsky, 2007) asking nine questions about anxiety over food, and insufficient quantity and quality of food. Statistical analysis was conducted using a two-tailed paired t-test on means and descriptive statistics on food insecurity categorization.

Mental Wellbeing was examined by identifying depressive symptoms using the Patient Health Questionnaire (PHQ-9, 1999) asking nine questions about mood, energy levels, daily activities and negative thoughts, and analyzed using a two-tailed paired t-test on means and descriptive statistics on wellbeing categorization.

Perceived Design Impact: The above ecological, community and individual and family health measures were asked about the community at large, not the Gardens Intervention specifically. A complementary Design Impact Assessment asked residents to specifically evaluate how the gardens impacted their life by way of these same indicator categories. Questions were phrased as such: "The Gardens Project made [insert indicator] and used a 1 to 5 Likert scale indicating level of change. To explain the difference between the Health Assessment and Design Impact Assessment:

> *Health Assessment question:* 'In the past 4 weeks did you or any other household member go to sleep at night hungry because there was not enough food?' 0 (never), 1 (rarely), 2 (sometimes) or 3 (often)
>
> *Design Impact Assessment question:* 'I feel like the Gardens Project has made my access to food…' 1 (much worse than before), 2 (worse than before), 3 (the same as before), 4 (better than before), or 5 (much better than before)

The categories "plant biodiversity" and "animal biodiversity" were collapsed as residents did not readily understand the terms, and "the environment in Claverito" was substituted. The Design Impact Assessment was administered once, one month after all other aspects of the project were completed.

Table 1: Measures, Instruments and Statistical Analysis used in the Health Assessment and Design Impact Assessment

Measured	Dimension	Indicator Category	Instrument	Instrument Specificity	Statistical Analysis
Health Assessment (pre and post measures)	Ecological Health	Land Pollution	Field Measures	Initial and ongoing trash counts: U.S. NOAA guidelines for marine debris monitoring and assessment	Descriptive statistics
		Plant Biodiversity	Field Measures	Species counts: Census by quadrats	Shannon-Weiner + Simpson Index of Diversity
		Animal Biodiversity	Field Measures	Species counts: Census by transects; Visual Encounter Survey with active search by sampling stations; Active direct search, Van Someren-Rydon traps by sampling stations	Shannon-Weiner + Simpson Index of Diversity
	Community Health	Beautification	Survey	GAZER Household Survey questions: community and household beautification	2 tailed paired *t*-test McNemar test
		Social Wellbeing	Workshop Activity	Participatory activity: open ended questions about daily life coded using content analysis	Generalized Estimating Equation
	Individual + Family Health	Injuries	Survey	Injuries Survey question: reported fell or injured on stairs	Generalized Estimating Equation
		Medicine Security	Survey	GAZER Household Survey questions: access to medicine and growing medicinal plants	McNemar test
		Food Security	Survey	GAZER Household Survey questions: Household Food Insecurity Access Scale (HFIAS), validated in Spanish	2 tailed paired *t*-test
		Mental Wellbeing	Survey	GAZER Household Survey questions: PHQ-9 Depression Scale, validated in Spanish	2 tailed paired *t*-test
Design Impact Assessment (post measures)	Perceived Design Impact	Land Pollution Environment Beautification Social Wellbeing Medicine Security Food Security Mental Wellbeing	Survey	Design Impact Assessment questions: how gardens project impacted each indicator	Descriptive statistics

2.5 Ethics and Sampling Constraints

This project is part of a longer longitudinal study regarding the health of Claverito residents by a partnership between Peruvian and US research centers. This project was approved by the Institutional Review Boards of both the U.S. and Peruvian universities involved, and community members also approved the study.

The Project Team began their relationship with the Community of Claverito in 2015. A series of participatory workshops and activities since then helped facilitate trust and support between residents and the team. Projects were developed based on community-driven priorities. A control community was deemed both impractical and unethical. First, the Claverito community is unique in its human and ecological composition, in addition to the social relationships of the team and community members, so no comparable place was in close proximity. Second, given the vulnerability and limited resources of slum communities and considering the research literature on the benefits of gardens, withholding a potentially beneficial intervention while burdening the community members with data collection was determined to be unethical (Levine, 1986).

2.6 Demographic Context

Table 2 shows the demographics of the residents of Claverito, as reported through the GAZER household survey. Household sizes are large (25% with more than eight people), and children make up 40% of the entire population. Adults have low education levels (93% did not graduate high school), and most work in the seasonal and informal sector. Reported poverty levels are high (89% in poverty or extreme poverty). More than a quarter of families have lived in Claverito for 20 years or more, more than half are first generation migrants from the jungle, and all but one household do not have land tenure and could be evicted by the government at any moment.

Table 2: Demographics of Claverito

Characteristic	**Measurement in Claverito** (n=239)	**Percent**
Gender	% female	49
Age	% children < 15 years	40
	% elderly > 65 years	4
Education Level (adults > 15 only)	% with 0 years of school	8
	% did not reach secondary/high school (<6 years)	39
	% did not graduate secondary/high school (<11 years)	93
Household Size	% households with >4 people	68
	% households with >=8 people	25
Occupation	% of adults with unsteady work (seasonal and informal workers, housewives, unemployed)	74 [1]
Economic Status	% households in poverty or extreme poverty [3]	89 [2]
	% households in extreme poverty [3]	66 [2]
Migration Status	% migrated <= 2 years ago	14
	% migrated >= 20 years ago	25
Indigenous Status	% 1st generation indigenous migrants	57
Land Tenure	% of families that do not have land tenure	98

1. More likely 100% (e.g. respondent answered "food worker" but likely referring to selling food in the streets)
2. Poverty levels are likely underreported, and incomes are being sent to other relatives living in the jungle
3. INEI, *Evolución de la pobreza monetaria 2007-2017,* grafico 2.4 "Peru: Linea de Pobreza Extrema, Segun Dominios 2016-2017. For the urban jungle region in Peru, extreme poverty line is <175 soles ($53 USD) and poverty line is <305 soles ($93 USD) per person per month.

2.5 Study Participants

Multiple methods were used for data collection from residents in two different formats: 1) a Household Survey conducted with the same respondents pre and post, and 2) activities conducted in community meetings in which attendance changed from pre to post; activities included a Participatory Workshop, Injuries Survey and Design Impact Assessment. Table 3 displays information about the study participants for each of these instruments. The household survey engaged 44 households of the 50 intact houses in the community and was conducted verbally in house-by-house visits. Those households not participating did not meet informed consent protocols (e.g. head of household was either consistently intoxicated, underage or did not speak Spanish) or were seasonally absent and the house was empty each of three visits. We estimated a community population of 143 residents over 13 years old. The Participatory Workshop (n=38), Injuries

Survey (n=71), and Design Impact Assessment (n=25), were open to all adults and teenagers in the community and conducted during community meetings. Across all data collection formats, the mean age was consistently within 1.6 years, though gender composition varied by 23%. All households were invited to participate in the GI projects and research, and all residents from children to elderly were invited to participate in the design and construction process.

Table 3: Study Participants

Format	Type	Criteria	Baseline n	Participant demographics	Value	SD
Systematic Survey: Conducted house by house to same respondents	Household Survey	Adult >16 that knows the most about the household	44	% female	89%	
				mean age	37.8	13.4
				mean years of school	6.1	2.8
				% married or cohabitating	77%	
Community Meeting Activity: Invited entire community, attendance changed from pre to post	Participatory Workshop	Household representative, open to all residents > 13 years old	38	% female	74%	
				mean age	37.1	13.5
	Injuries Survey		71	% female	66%	
				mean age	36.2	14.6
	Design Impact Assessment		25	% female	80%	
				mean age	37.1	14.3

3. Results

Health outcomes are reported within dimensions of ecological health, community health and individual and family health, and compared to the residents' perceived impact that the GI project had on each of these dimensions. The results are detailed below. An alpha level of .05 was used as a significance criterion for all statistical tests.

3.1 Ecological Health

Land Pollution: As Table 4.1 displays, the installation of the Community Entrance Garden required the removal of one meter's depth of trash on the hillside (622 bags, 5,433 kg). Results show a downward trend in ongoing trash accumulation from 2 months after construction (0.25 bags, 5.5 kg) to 6 months after construction (0.06 bags, 2.2 kg).

Plant Biodiversity: The GI project increased species richness in the community from 18 species to 64 species (Table 4.2). Baseline conditions show a large density (70.60 plants per quadrat), dominated by grass-like species, and with small plants (< 30 cm tall). At 1-Year, the density decreased (32.10 plants per quadrat) with the installation of larger plants (30-125 cm tall). The GI project added over 1,500 plants, 93% native to the low rainforest ecosystem (several non-native edible plants such as carrots were requested by residents). Species richness and evenness increased significantly from baseline (H' = 1.43, 1-D = 0.18) to 1-year (H' = 16.91, 1-D = 0.91). To provide a reference of significance, the higher the H' Index, the higher the biodiversity, and the closer the 1-D index is to "1", the greater the species richness and evenness.

Animal Biodiversity: Measures of animal biodiversity suggest an overall positive trend (Table 4.3). Species richness increased for both birds (13 species) and butterflies (11 species) and there was an increase in sightings of notable species of birds from baseline (19 species) to 1-year (27 species) with no changes for amphibians or butterflies. The Shannon Diversity Index (H') showed an increase in species richness and evenness for birds, amphibians and butterflies, increasing by 96%, 2% and 30% respectively, and the Simpson Index of Diversity (1-D) showed slight increase for birds and butterflies, increasing by 8% and 4% respectively however a reduction for amphibians by 2%.

Table 4: Ecological Health Dimensions

4.1 Changes in Land Pollution (Trash) Measures on Hillside in Claverito Over One Year

Land Pollution Measure	Baseline	After Construction (Nov 2016)	Ongoing (Jan 2017)	Ongoing (March 2017)	Ongoing (May 2017)
# bags of trash (50 gal)	622	0	0.25	0.25	0.06
Estimated weight (kg)	5,443	0	5.5	4.7	2.2

4.2 Changes in Habitat Measures in Gardens Intervention Locations in Claverito Over One Year

Greenspace Measure	Baseline				1-Year			
	Density	Species Richness	H'	1-D	Density	Species Richness	H'	1-D
Plants Species	70.60	18	1.43	0.18	32.10	64	16.91	0.91

4.3 Changes in Biodiversity Measures in Claverito Over One Year

Species Measure	Baseline					1-Year				
	Abundance	Species Richness	Notable Species	H'	1-D	Abundance	Species Richness	Notable Species	H'	1-D
Birds	9995	77	19	16.06	0.85	6244	83	27	31.54	0.92
Amphibians	433	11	0	4.70	0.84	269	10	0	4.79	0.82
Butterflies	667	11	0	1.70	0.26	447	22	0	2.21	0.27

3.2 Community Health:

Beautification: Residents reported positive change in beautification measures for both the overall environment in Claverito and beautification of their houses (Table 5.1). Perceived community beautification significantly increased (McNemar(41) = 13.47, p <.001) from baseline (27%) to 1-year (68%), a positive change of 152% . Perceived household beautification increased by 7%, but was not found to be statistically significant ($t(41) = 0.33$, $p = .53$).

Social Wellbeing: Baseline measures revealed that relationships with neighbors, family, friends and/or couples were a substantial cause of sadness or stress in residents' lives (76% of residents had "bad relationship" as a response) but decreased substantially one year later (28% of residents) and was found to be statistically significant (GEE, p <.001) (Table 5.2). Additionally, residents reported that better social relationships was a key influence for better daily life (26% of residents had "better relationships" as a response) and seemed to find their social relationships better one year later (0 residents had this as a response). Because of the lack of 1-year responses, statistical testing was unable to be performed.

Table 5: Community Health Dimensions

5.1 Changes in Beautification Measures in Claverito Over One Year

Beautification Indicator	Measurement	Baseline		1-Year		McNemar Test / Paired *t*-test	
		n	Value	n	Value	*p*-value	95% CI
Beautification of Environment	Do you think the environment in Claverito is beautiful? *% who answered "yes"*	44	27%	41	68%	<.001	[2.84, 749.96]
Beautification of Houses	How proud are you of the physical appearance of your house and property? (1-5) *mean score*	44	3.18	41	3.29	.53	[-0.53, 0.38]

5.2 Changes in Social Wellbeing Measures in Claverito Over One Year

What are 5 things that make you sad or stressed in your daily life? (open ended question)
Respondents who answered "bad relationships with my neighbors, family, friends and/or couple"

	n	Percent "bad relationships"	Rank	95% CI	Percent female	Mean age	Generalized Estimating Equation	
							p-value	95% CI
Baseline	38	76	#1 of 13 categories	[0.61, 0.87]	74	37.1	<.001	[-0.69, -0.25]
1 Year	25	28	#4 of 11 categories	[0.14, 0.48]	80	37.1		

What are 5 things that could make your daily life better? (open ended question)
Respondents who answered "better relationships with my neighbors, family, friends and/or couple"

	n	Percent "better relationships"	Rank	95% CI	Percent female	Mean age
Baseline	38	26	#7 of 15	[0.15, 0.42]	74	37.1
1 Year	25	0	Not a response	[0.00, 0.12]	80	37.1

3.3 Individual and Family Health:

Injuries: Baseline shows a substantial number of residents reported falls or injuries on the wood and mud stairs in the six months prior to the GI project (42%, a total of 82 falls or injuries) (Table 6.1). One year later, after the concrete stairs with a multi-tiered handrail were built as part of the Community Entrance Garden, injuries on the stairs in the prior six months reduced substantially (4%, or one resident reporting two falls), and found to be statistically significant (GEE, p <.001).

Medicine Security: Medicine insecurity decreased significantly (McNemar(41) = 14.45, p <.001) with 44% less households reporting that they do not have adequate access to medicine from baseline (68%) to 1-year (24%), and 39% more households reporting offsetting their medicine needs with medicinal plants or herbs from grown in Claverito from baseline (9%) to 1-year (48%), also found as statistically significant (McNemar (41) = 11.13, p <.001) (Table 6.2).

Food Security: Household food insecurity reduced nearly fifty percent over the year (Table 6.3), with a statistically significant decrease in HFIAS scores (t(41) = 5.44, p <.001) from baseline (M = 12.3, SD = 6.88) to 1-year (M = 6.9, SD = 6.4). Severe food insecurity reduced by 30%, moderate food insecurity reduced by 3%, mild food insecurity increased by 10% and households that are food secure increased by 22%.

Mental Wellbeing: A substantial number of residents showed baseline PHQ-9 scores suggestive of depression (25%) with an additional 45% of residents showing mild depressive symptoms. PHQ-9 depression scores at baseline (M = 7.0, SD = 4.80) to 1-year (M = 5.1, SD = 4.33) significantly decreased (t(41) = 2.51, p = .02). Residents showing PHQ-9 scores suggestive of depression reduced by 10% and those with mild depressive symptoms reduced by 16%. Residents that report minimal to no depressive symptoms, and therefore likely do not have depression increased by 26%.

Table 6: Individual and Family Health Dimensions

6.1 Changes in Falls and Injuries Measures in Claverito Over One Year

Have you fallen or had an injury on the stairs in the prior six months? *(yes or no)*

	n	Percent "yes"	95% CI	Percent female	Mean age	Generalized Estimating Equation	
						p-value	95% CI
Baseline	71	42	[0.31, 0.54]	66	36.2	< .001	[-0.68, -0.40]
1 Year	25	4	[<.001, 0.21]	80	37.1		

6.2 Changes in Medicine Security Measures in Claverito Over One Year

Safety Indicator	Measurement	Baseline		1-Year		McNemar Test	
		n	Value	n	Value	*p*-value	95% CI
Access to Medicine	% of respondents that report "no" they do not have adequate access to medicine	44	68%	41	24%	< .001	[3.02, 789.46]
Growing Medicinal Plants	% of respondents that report getting their medicinal plants or herbs grown inside Claverito	44	9%	41	48%	< .001	[1.98, 35.03]

6.3 Changes in Food Security Measures in Claverito Over One Year

Food Security Indicator	Measurement	Baseline			1-Year			paired *t*-test	
		n	Value	SD	n	Value	SD	*p*-value	95% CI
Household Food Insecurity Access Scale (HFIAS)	Mean score *(0 to 27, high is more insecure)*	44	12.3	6.88	41	6.9	6.36	<.001	[3.48, 7.59]
	% of households severely food insecure	44	57%		41	27%			
	% of households moderately insecure	44	32%		41	29%			
	% of households mildly food insecure	44	7%		41	17%			
	% of households food secure	44	5%		41	27%			

6.4 Changes in Mental Wellbeing Measures in Claverito Over One Year

Service	Measurement	Baseline			1-Year			paired *t-test* / McNemar Test	
		n	Value	SD	n	Value	SD	*p*-value	95% CI
PHQ-9 Depressive Symptoms Scale	Mean score *(0 to 27, high is more depressed)*	44	7.0	4.80	41	5.1	4.33	.02	[0.40, 3.70]
	% of respondents that may have depression (moderate to severe)	44	25%		41	15%			
	% of respondents showing depressive symptoms (mild)	44	45%		41	29%			
	% of respondents that likely do not have depression (minimal to none)	44	30%		41	56%			

Figure 6 graphically displays the indicators from 3.1 to 3.3 showing statistically significant results across the Gardens Intervention time frame. Those indicators with the greatest change are plant biodiversity, butterfly biodiversity, injuries and medicine insecurity. Bird biodiversity, food insecurity and depression had the smallest amount of change. Amphibian biodiversity is the only indicator with negative change from baseline to one year.

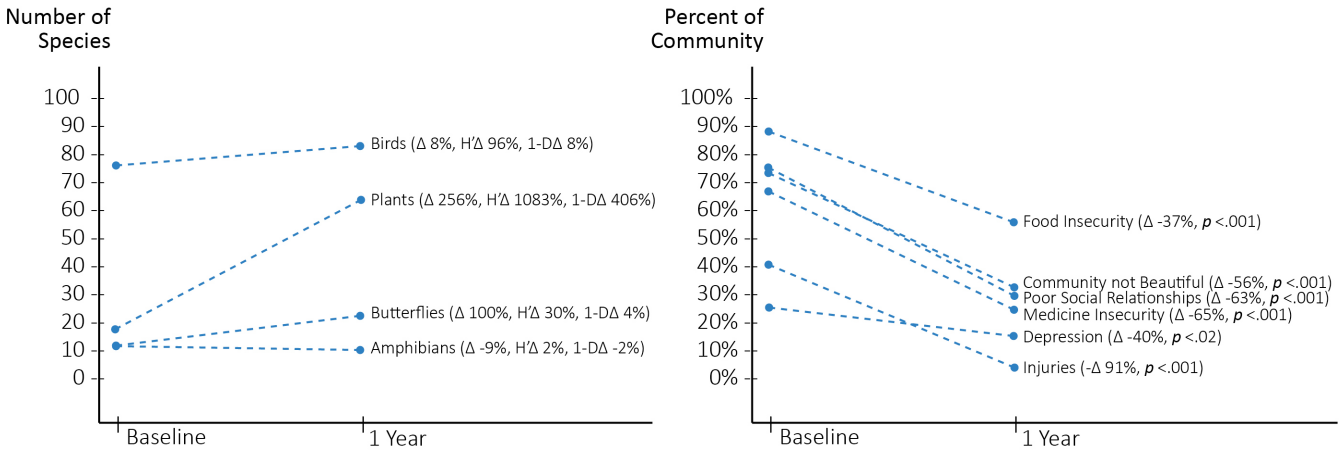

Figure 6: Percent Change in Indicators Over One Year

3.4 Project Impact:

Residents viewed the Gardens Intervention as having a positive impact on each indicator across ecological, community and individual and family health dimensions, with mean responses to community beautification and mental wellbeing rated somewhat higher (Figure 7). Slightly smaller improvements were indicated for social wellbeing.

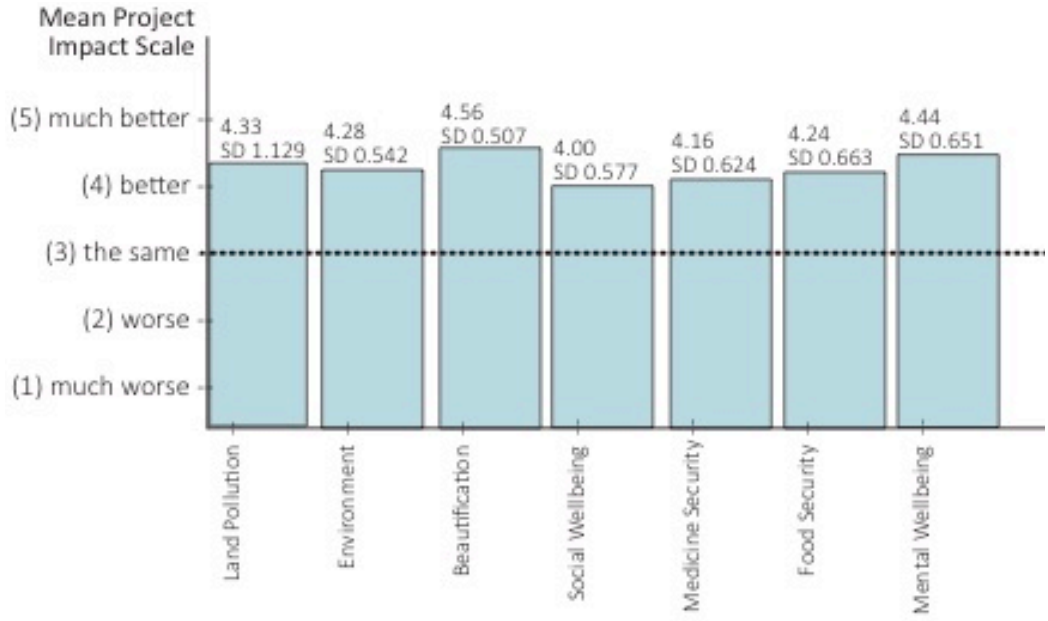

Figure 7: Perceived Impacts of the Gardens Intervention Project by Community Members (n=25, means and standard deviations)

4. Discussion

4.1 Discussion of Results

Land Pollution: A positive trend in trash reduction might be attributed to the "broken window theory", whereby the beautification of this space and removal of negative social cues (e.g. trash, neglect), people outside the community choose not to throw trash on the garden (Wilson & Kelling, 1982; Grodzinski, 2011). It may also be that Claverito residents are removing the trash in the garden area with increased stewardship of their community. The significance of trash removal

reaches across human and ecological health. While not directly measured, trash has a significant negative effect on aquatic and terrestrial species that consume or get entangled in inorganic materials. It also promotes mosquito breeding (and vector-borne diseases) and communicates neglect and carelessness towards the environment and its human and animal inhabitants.

Plant and Animal Biodiversity: The increase in plant biodiversity and positive trend towards increased animal biodiversity, especially among sensitive species, suggests that the Gardens Intervention is providing multi-seasonal improved habitat opportunities for a diversity of animals. While species counts require continued monitoring, these numbers suggest an overall positive trend towards increased biological diversity. Team biologists suspect that the reduction of trash, increased shoreline habitat opportunities, and increased diversity of plants, especially flowering and fruiting plants, may be attracting sensitive and more diverse species. The Ministry of Health conducted a city-wide mosquito spraying in response to high rates of zika virus and dengue fever in Iquitos two weeks before the one year data collection. For the first time in residents' memory, Claverito was included in these efforts. While this has potential positive impacts on residents' health, an observed reduction in amphibians may be related to the spraying by impacting food sources and/or chemical sensitivity.

Beautification: The improvement in community beautification was likely due to the construction of the Community Entrance Garden and the collective Household Floating Gardens acting as public/private greenspace in the community. The participatory design process assured the aesthetic and plant choices came from the community. The smaller increase in household beautification and lack of statistical significance may be because a smaller number of respondents participated in the Household Floating Gardens part of the project (59%).

Social Wellbeing: At baseline, social relationships appear to be a dominant cause of stress and sadness among three-fourths of residents, while 1-year later other life aspects became more prominent. Both the process of building the Gardens Intervention (with neighbors and families working together in the community participatory process) as well as the product of community greenspace and sharing of food and medicinal plants may be contributing positively to social wellbeing.

Injuries: The installation of stable concrete stairs with a multi-tiered handrail in the main pathway to the community as part of the Community Entrance Garden was likely the reason for the significant reduction in injuries. Regular heavy rains and poor quality construction materials were causing the baseline mud and wood stairs to be a hazard.

Medicine and Food Security: Positive improvements in medicine and food security was likely due to the over 1,500 medicinal and food bearing plants installed as part of the GI project. When asked how residents were using their plants, 84% report using them for food, 80% for medicine, 64% for aesthetics, 12% for selling, and 36% for spiritual or traditional use. Additionally, residents report sharing or bartering their produce or medicinal plants with other residents, thus increasing access to other foods and medicines beyond their household gardens. An overall trend for food security involved residents shifting down a category, with the greatest shift from those with severe food insecurity. The increase in mild food insecurity and food secure households was likely due to this shift.

Mental Wellbeing: The positive improvements in mental wellbeing align with body of literature showing trends that increased access to urban nature has a positive impact in stress reduction, improved mental health, reduced depression, reduced anxiety, greater happiness, well-being and life satisfaction, summarized in (Frumkin, et al., 2017). The smaller decrease in scores suggestive of depression in comparison to those with mild symptoms may suggest that those with clinical depression may require professional clinical attention, while the GI project may have lessened depressive symptoms for those with less severe conditions.

Examining both the objective Health Assessment measures and the Design Impact Assessment measures increased confidence in findings in an attempt to tie the indicators more specifically to the GI project and not an outside factor. Aside from household beautification and amphibian biodiversity, the post garden installations changes were all statistically significant, showing strong intervention effects. This corroborated with the results of the Design Impact Assessment of which all the indicators were on average "better than before". We expect this may be due to several factors: 1) As part of the TDAR framework, the indicator measures were chosen within a participatory process in which the community provided input into what factors mattered most in their daily life. This may have eliminated indicators that had less consequence for the community. Likewise, the Gardens Intervention was strategically crafted to target the key issues addressed by the indicators; 2) The TDAR process embraces outside agents and processes as part of change. This framework and process

cannot be separated from the garden product itself, as it may equally be as important in improving health outcomes. Thus the participatory design process and community interactions with the Team probably influenced self-reports of individual and community health improvements. However some indicators would not likely have been affected by the mere presence of outsiders (e.g. food and medicine security); 3) Women were the majority of respondents, and they typically spend the most time in the community and at their homes, so Gardens Interventions changes would have direct influences on their lives; 4) The "neighborhood effect" (Lilford, et al., 2016) and "defiant gardens" (Helphand, 2006) concepts support the idea that community interventions such as gardens may have an especially high rate of benefit in slum communities.

4.2 Potential Application

This project was a case study of the slum community of Claverito, having specific cultural, political and ecological contexts. An important implication is the potential application of TDAR design principles to introduce urban nature in other low-resource, poor health communities that have a need for rapid assessment of community change. At this time, the process and protocol may be more replicable than the physical intervention or specific health effects. More case studies and formal evaluations are needed to improve upon this urban nature intervention methodology within slum communities to better understand effects and make better informed recommendations. Further application in other communities could help refine data collection approaches and generate efficiencies across multiple study sites. After refinement, an assessment protocol could become standardized as a tool kit or set of guidelines for improving and measuring human and ecological health in slum or low-resource communities.

Another outcome of this process is the potential for self-initiation of project techniques among residents in other communities. Because residents were central actors in the intervention design, construction and maintenance, they may be able to utilize the construction techniques and organizational skills learned in this process to apply rational processes to other community issues in the built environment. Results were returned to community members after project closeout, providing the opportunity to understand the impact of the intervention on the health of their families and neighbors as well as the nearby environment and biota. In fact, aspects of this replication are already being seen within the community six months after project closeout, with expansion of gardens, additional stairs building, and community maintenance parties.

Iquitos has an estimated 30,000 people living in floating slum communities. This work begins to legitimize the presence of informal communities in the city and their role in public health and environmental remediation, and build stronger connections to local government and research institutions. This research, combined with future case studies, may be presented as 'best available science' to guide policy and program development in the city. This in turn may attract more sustained attention to the underserved communities, and provide examples to decision-makers that relatively small investments can increase quality of life in floating slum communities while also improving the environment.

4.3 Study Limitations

1. While referred to in the vernacular term "gardens" this moniker was used for the multi-cultural and multi-disciplinary accessibility of the word and does not reflect the professional expertise, systems thinking and performative designing that the Team layered into the project. The grassroots and community-driven component was complemented by expert input from professionally trained landscape architects, ecologists, horticulturalists, anthropologists, nutritionists, nurses and eleven other disciplines. It is not known whether a garden in the conventional sense would produce similar health outcomes in this community.

2. Methods limitations were possible based on the relatively small population size of the community. Small sample sizes impact statistical power and repeated measures concerns are associated both within group and across the pre-post testing period. Nonetheless, little prior research has addressed urban nature and health in slum communities. Future research in smaller communities should explore the opportunities of mixed methods qualitative and quantitative data.

3. Our study goals were achieved, to examine: 1) multiple human and ecological health impacts of urban nature and gardens, 2) within low-and-middle-income countries and slum communities, and 3) feasibility of an on-the-ground community intervention using the TDAR process. The health measures assessed outcomes; we were not able to determine causal mechanisms, a need for future interventions and their evaluation.

4. Project costs were reasonable - $13,000 construction budget, plus $83,000 for design services, data collection, and project management (USD, 2017) and project timeline was compressed over 18 months from participatory design to data analysis. Efforts to control costs and time and develop a community-based project that was affordable and appropriate for an informal and under-resourced settlement mandated decisions that may have affected the robustness of data.

5. Conclusion

This one year, single arm pre-post intervention study of a Gardens Intervention project in a slum community in the urbanized Peruvian Amazon explored the complexity of health benefits that urban gardens have to offer by examining nine indicator categories across dimensions of ecological, community and individual and family health. Based on a Transdisciplinary Action Research (TDAR) framework, the research included an extensive community participatory design approach that defined both the resulting Gardens Intervention and the measured health indicators. This study suggests a positive direction of change in land pollution and biodiversity of plants, birds and butterflies, and found statistically significant positive changes in beautification of environment (p <.001), social relationships as a dominant source of stress (p <.001), injuries and falls (p <.001), access to medicine (p <.001), access to medicinal plants grown in the community (p <.001), food security (p <.001), and mental wellbeing (p =.02). Household beautification had a slight positive change that was not statistically significant (p = .53), and there was a slight decline (1 species) in biodiversity of amphibians. Residents view the Gardens Intervention as having a positive impact on each of these indicator categories, with the greatest improvements to community beautification and mental wellbeing, and a slightly smaller improvement to social wellbeing. Large amounts of positive change may be due to using the TDAR process, having a large percentage of female survey respondents, and the dense social networks and harsh conditions within slums enhancing beneficial outcomes. Limitations include small sample sizes, the term "garden" may misleadingly assume an entirely grassroots effort, the breadth of indicators limits understanding causal mechanisms, and a limited project budget and timeline. Aside from positive health outcomes within this context, other potential outcomes include self-replication of project techniques within communities and providing "best available science" guidelines that could be applied to the other 30,000 people living in floating slum communities within Iquitos. With future replication and protocol refinement, the TDAR process may have the potential to evolve into a tool kit or guidelines for improving and measuring human and ecological health in slum or low-resource communities through built environment interventions.

The built environment, urban nature, and gardens may have a major and multi-faceted role in improving human and ecological health and wellbeing and should be considered an integral part of our health system. Gardens Intervention projects using a TDAR and participatory design process show promise in improving multiple dimensions of human, ecological and environmental health in slum communities. With over one billion people in the world living in slum conditions (United Nations, 2016), a shortage of healthcare resources worldwide, a desire to collaborate across disciplines to address the complex human and ecological health problems we face today, and a lack of research in urban nature and health projects in low-and-middle-income countries and in slum conditions, this research with replication and refinement has the potential to fill a significant gap.

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Chapter 4

Title

Using Transdisciplinary Action Research (TDAR) and a Gardens Intervention Project to Target Human and Ecological Health Issues in an Urban Slum Community

Abstract

With increasingly complex human and ecological health burdens all around the world that affect all but disproportionally impact the most vulnerable, the services of designers of the built environment are needed to address these issues through both preventive and restorative approaches. However, landscape architects and community designers are not trained to understand and target specific health issues in communities or lead research teams within the human and environmental health fields to understand the direct health impacts of their work. This manuscript proposes and tests a new approach to designing with communities to strategically target and measure their specific human and ecological health issues through the lens of a Transdisciplinary Action Research (TDAR) framework using participatory design techniques. This manuscript describes such an approach using a case study project with a highly integrated team of designers, researchers and academics across seventeen disciplines in built environment, health and ecology fields collaborating with a municipality and a floating slum community of indigenous migrants in the urbanized Peruvian Amazon. It uses the seven dimensions of TDAR to model the process and to add to the body of TDAR literature. It details the physical outcome, characterized as a Gardens Intervention, evaluates the sustainability of the design and summarizes health outcomes. Lastly, this manuscript provides insights into benefits and challenges discovered through the project process. We suggest that the highly integrated and diverse team produces a uniquely rich exchange of knowledge, respect, ideas and ethics resulting in durable, sustainable and multi-functional built environment actions with measured positive improvements to human and ecological health in the community.

Keywords

transdisciplinary action research, landscape architecture, health, garden, slum, community participatory design

1. Introduction

Global climatic and societal urgencies of our time are causing human and ecological health issues that exceed response capacities of local governments and health and ecology professionals all around the world (Darzi & Evans, 2016; Larson, Lauber, Kay, & Cutts, 2017). Examining the built environment as a societal and environmental determinant of health has emerged in recent years as a creative preventive and restorative strategy to address these complex issues and relieve the burden of poor health outcomes that affect all, but disproportionally affect the marginalized (Dannenberg, Frumkin, & Jackson, 2011; Solar & Irwin, 2010). In particular, urban ecological design in the built environment, including gardens, parks and green infrastructure, may support health promotion, disease prevention, health equity, and palliative or rehabilitative care; yet more research and application is needed (Winterbottom & Wagenfeld, 2015; Frumkin & Fox, 2011; Wolf & Robbins, 2015; Frumkin, et al., 2017). Landscape architects and community designers as direct shapers of the built environment are not traditionally trained to understand and target health issues in communities or lead multidisciplinary research teams with human and environmental health professionals to understand the impacts of their work (Andrews, 2013). Likewise, contemporary health models often ignore ecological dimensions of human health and disease, and health and ecology professionals are not trained to engage with communities to understand how living environments can be shaped to maximize health benefits (Steingraber & Hill, 2002). Professionals across the built environment, health sciences and ecology fields are recognizing their limitations and are calling for deeply collaborative and cooperative approaches that integrate knowledge, skills and research from a diversity of disciplines and stakeholders (Johnson & Hill, 2002; Jackson, 2011; Alberti, 2009; Frumkin, et al., 2017; Tress, Tress, & Fry, 2006; Rios, 2011). They also recognize that beyond combining disciplinary forces, civic engagement with local experts and communities is also required for effective, sustainable, equitable and embraced solutions (Thering, 2017; Smith, Verissimo, Leader-Williams, Cowling, & Knight, 2009; Cucari-Stone, Wallerstein, Garcia, & Minkler, 2014).

Transdisciplinary Action Research (TDAR) provides an accessible framework for such deeply collaborative efforts aimed at addressing complex societal and ecological issues across scales – from immediate community scale needs to broader societal goals of public health, social and environmental justice, and ecological sustainability (Stokols, 2011). TDAR examines the translation of research and diverse knowledge cultures into community problem-solving strategies using effective collaboration with a diversity of researchers, community members, and local experts and organizations (Stokols, 2006; Thering & Chanse, 2011). TDAR builds upon other collaborative action-research approaches such as Community-Based Participatory Research (Horowitz, Robinson, & Seifer, 2009; Wallerstein & Duran, 2010), Participatory Action Research (Baum, MacDougall, & Smith, 2006; Chevalier & Buckles, 2013) and Community-Based Conservation (Mulrennan, Mark, & Scott, 2012; Western & Wright, 1994). It can include robust community engagement and co-creation strategies such as those at the core of Participatory Design and Plural Design practices (de la Pena, Jones Allen, Hester Jr, Hou, Lawson, & McNally, 2017; Bowns, 2011). Scholars in a Special Issue of *Landscape Journal* (Neckar & Pitt, 2011) emphasize the potential contributions of TDAR to landscape practices (Table 1). These same scholars performed a meta-analysis of TDAR case studies and identified seven dimensions of TDAR (Table 2) as avenues of inquiry for advancing the scholarship of TDAR (Thering & Chanse, 2011). While they issue a call for more work in TDAR to compare common experience and transcend the limitations of localized case studies, few studies to date have been added to the literature.

Table 1: Potential Contributions of TDAR to Landscape Architecture and Planning, adapted from (Neckar & Pitt, 2011)

1.	Maximizes the understanding and making of multi-functional landscapes
2.	Examines landscape performance across socio-cultural and biophysical systems
3.	Acknowledges that design has external consequences and responsibilities, making design a political act
4.	Coordinates local interests with broader societal concerns
5.	Uncovers social and environmental nuances that directly inspire form
6.	Integrates diverse world views to construct new knowledge that informs and creates innovative approaches to tough problems
7.	Supports mutual learning and empathy for the "other"
8.	Transcends communication barriers between disciplines and types of knowledge
9.	Increases effective translation of science to on-the-ground problem solving
10.	Nurtures long term relationships, policies and actions

This manuscript details a transdisciplinary urban ecological design project led by landscape architects using a TDAR framework and incorporating a participatory design approach to test and demonstrate how transdisciplinary design and

research projects can target specific human and ecological health issues in communities. It used the seven dimensions of TDAR to guide and describe the process and to add to the body of TDAR literature. The project worked with an urban slum community located in the floodplain of the Amazon River in Iquitos, Peru, a setting with extreme human and ecological health issues and harsh built environment conditions, and initiated an intervention of community and household performative gardens, referred in this manuscript as the Gardens Intervention. It investigated the role of design and the built environment in addressing global health and disease burdens that disproportionately affect the poor. Lastly this manuscript provides insights into benefits and challenges met in this project.

2. Dimensions of Transdisciplinary Action Research

Stokols identified three axes of TDAR (Stokols, 2006). Thering and Chanse, as well as Stokols, expanded upon these axes to list seven dimensions of TDAR (Table 2) (Thering & Chanse, 2011; Stokols, 2011). To describe the TDAR approach in this project, we detail how our project navigates through each of these seven dimensions.

Table 2: Seven Dimensions of TDAR, adapted from (Thering & Chanse, 2011; Stokols, 2011)

1	2	3	4	5	6	7
Regional Delineation	Interdisciplinarity	Transdisciplinarity / Transepistemologic	Student Engagement	Time	Outcomes	Evaluation

2.1 Regional delineation: This is a community scale study directly impacting an estimated 280 residents in the floating slum community of Claverito, in Iquitos Peru. With 35,000 people living in floating slum communities throughout Iquitos, and 1 billion people living in slum conditions around the world (United Nations, 2016) this project has the potential to act as a demonstration for how to improve health in similar communities using a design intervention and a TDAR process.

Claverito is a floating slum community situated in a floodplain tributary of the Amazon River on the edge of the city of Iquitos, Peru (See Figure 1). Located between a city of 0.5 million residents and the Amazon Rainforest with tens of thousands of different species, Claverito is strongly influenced by and vulnerable to both urban and ecological systems. Claverito has 50 houses that float on large logs during the high river season, and rest on the ground during the low river season. Although the community was established several decades ago, Claverito is not recognized by the local or federal government so residents do not have formal access to services (e.g. water, sewer etc.) and are left out of city management (e.g. they do not appear on city maps, have not been documented in the national census, are not included in health outreach programs etc.). Because of these harsh circumstances, from this study we discovered residents suffer from extreme health issues such as parasitic and vector-borne diseases, food insecurity, bacterial infections, chronic diarrhea, depression, and injuries. Urbanization has also contributed to reduced biodiversity and high amounts of water and land pollution. Claverito's demographics and baseline environmental conditions, human health and wellbeing measures as well as documentation of the species in the community are outlined in detail in Chapter 2.

Figure 1: Claverito in the high river season, with the city of Iquitos to the right and the Amazon Rainforest to the left

2.2. Interdisciplinarity: The project team was co-led by a Peruvian landscape architect/architect and a U.S. landscape architect/restoration designer, both trained in global health research. Professionals on the team were entry level to senior career researchers from universities in the U.S. and Iquitos as well as private consultants who are experts in their fields. The team was comprised of 17 disciplines engaged in different ways at different times of the project. While the overall project can be seen as transdisciplinary, the project wove in and out of multi-inter-and transdisciplinary models (see (Stock & Burton, 2011) for definitions). Figure 2 explains the nuances of the various relationships each discipline had at different stages of the project. Section 2.6 and Figure 5 detail the flow of research and design activities between these stages.

In *Stage 1: Define the Project*, the design team engaged in a community participatory process to investigate community needs and priorities, and also gathered public health, history and land information using available public records. This information was shared with the professional research team who then crafted research instruments and conducted an assessment to establish a baseline of human, environmental and ecological health issues in the community. The design team then converted all of this information into proposed project options that the community then democratically voted on to define what project would be implemented in the community. Details on project selection criteria are outlined in the 2.6 Outcomes section. In *Stage 2: Design the Project*, team members in the ecology fields combined their ideas, as did those in the human health fields, to inform the design team and the community on elements of the project that would target and maximize the identified human and ecological health indicators. In *Stage 3: Build the Project*, all disciplines involved combined forces towards the same goal of implementing the Gardens intervention, regardless of skills or knowledge background, and completed tasks outside their traditional disciplinary boundaries in true transdisciplinary fashion. In *Stage 4: Maintain and Support the Project,* all disciplines involved worked together to train the community on how to take care of the project, and the community engaged the police to increase patrolling in the intervention area. In *Stage 5: Evaluate the Project*, the research team conducted the post intervention assessment, and community members were invited to participate in environmental data collection and a design impact assessment. The team held two brainstorming sessions with all the academic and professional team members involved to discuss cross-disciplinary findings and recommendations, as well as a dissemination strategy to educate the community and municipality of study findings.

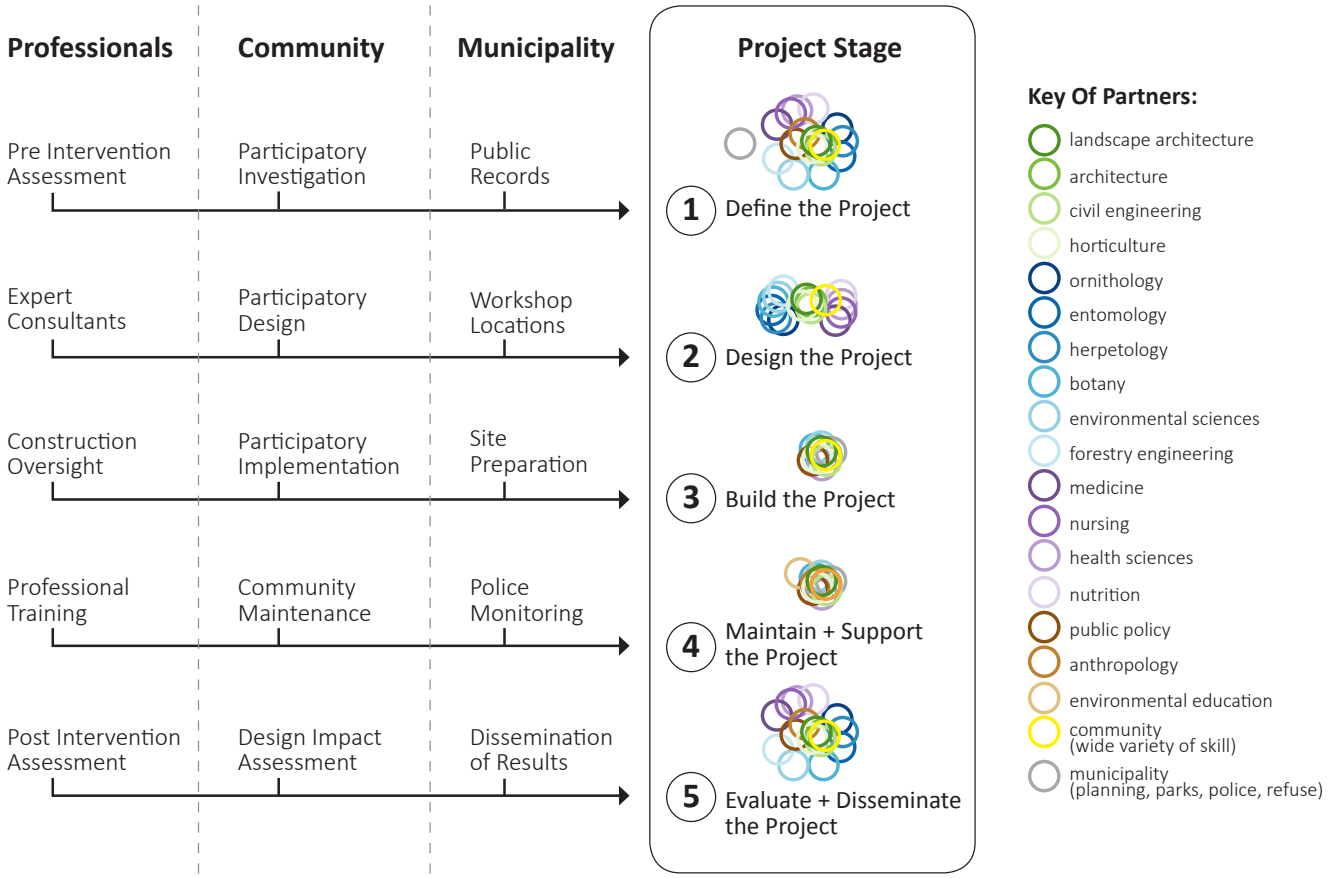

Figure 2: Team relationships in the transdisciplinary process at each project stage. The circles reveal the variability of engagement across disciplines

2.3 Transdisciplinarity / Transepistemology: The diversity of team members involved in the project came from a wide variety of knowledge cultures ranging from academia, to the lived experience of Claverito residents, to the expert knowledge of municipality workers and professionals. Geography also influenced the project: the team partnered with seven research centers across Peru and the U.S.; funding was supplied by both Peruvian and U.S. sources; and the project employed 7 U.S. citizens and 37 Peruvians, 70% of whom are local to Iquitos. In addition, an estimated 130 residents in the community of Claverito participated in the design, construction and research. This diversity of knowledge cultures resulted in mutual sharing of skills which influenced the aesthetics, function and construction techniques of the Intervention and the depth of data collected in the research. For example, community members joined professionals on species research and swapped indigenous and scientific names of animals and medicinal and cultural uses for plants. In another example, the Intervention replicated stair building techniques Claverito residents historically used to create wood retaining walls, contoured the retaining walls to mimic Incan strategies used elsewhere in Peru, and combined the design with infiltration techniques used in the U.S., constituting a blended form and function of the Gardens Intervention.

A semi-formal partnership was also established with the municipality. Because Claverito is an informal community this relationship had to be carefully approached. Residents of Claverito have lived there for up to 45 years and have been applying for formal recognition every month since at least 2011 (5 years) without success. The City had recently zoned this area for recreational use to promote tourism. The team established that it was critical to increase exposure between the municipality and the community to reduce negative stereotypes and increase awareness of this neglected community. As indicated in Figure 2, the municipal planning department helped the team understand the environmental and socio-political context, the refuse department helped remove trash to prepare the site, the parks department granted permission for the team to organize activities in the plaza above the community, and the police department helped monitor the area during and after construction. While the municipality did not outright endorse the work, staff were aware of the activities that the team was conducting and did not interfere with the project. The team organized two "touchpoints" in which decision-makers from the municipality came in face-to-face contact with community members. Thirteen municipal employees, including the heads of the parks department, worked alongside residents and team members to remove 622 bags of trash from the community on a Saturday to prepare the site for construction. Municipal leaders also came to the ribbon cutting ceremony to celebrate the completion of the project alongside Claverito residents and team members. Both touchpoints were documented and praised by the local media.

The team used a series of community engagement strategies throughout the entire life of the project similar to those outlined in the book Design as Democracy: Techniques for Collective Creativity, in which the process is a transactive give-and-take between the professional team and community members to exchange critical information and resources, to create transformative products and outcomes (de la Pena, Jones Allen, Hester Jr, Hou, Lawson, & McNally, 2017). The authors discuss the importance of participatory design: "Shared language is found as knowledge flows from the community, as local and outside technical expertise mix. Everyone gains knowledge beyond their limited experiences. We teach each other. We become smarter together. This initiates thinking multimodally across boundaries of discipline, race and class. This empowers communities and sustains stewardship"(p.2). Figure 3 displays the different participatory techniques used in the project: 1) collaborative community mapping to understand the physical environment and establish structure and dignity since Claverito is informal and does not appear on any formal maps; 2) a community photo journalism exhibit, "Claverito Bonito", to kickoff the project in a positive light and understand aesthetic preferences from resident photography of what they consider beautiful in Claverito; 3) identifying community needs, desires and priorities using cognitive mapping and activity sheets; 4) a series of three design workshops to democratically vote on project types, design elements and aesthetic preferences; 5) "participatory innovation" in which each family received drafting materials to design their household garden at two consultation meetings with designers at their houses; 6) a series of three community "mingas", or work parties, to clean up trash and prepare the site; 7) participatory construction of the community entrance garden where the entire community worked together over four mingas; 8) residents working together with their families and friends on the construction of household floating gardens; 9) three workshops training residents on planting, growing and maintaining the gardens; and 10) education and outreach at a community Health Fair and an Environment Fair in which preliminary results were returned in creative ways.

Figure 3: The project utilized a deep community participatory engagement process with every step of the project including 1) collaborative mapping, 2) resident photo journalism, 3) cognitive mapping, 4) democratic voting of preferences, 5) design consultations, 6) community work parties, 7) community construction of the entrance garden, 8) cross generational family construction of household gardens, 9) maintenance workshops, and 10) education and outreach workshops

2.4 Student Engagement: The project intentionally employed a cross generational team to provide bi-national professional training and mentoring opportunities for both Peruvian and U.S. citizens. The Co-Directors for the project are a Built Environment PhD candidate and a recent MLA graduate, and the project engaged 34 students or trainees, half of whom were Peruvian. An interdisciplinary studio-seminar class in the U.S. involving 15 students from eight disciplines in design, human health and ecology fields generated preliminary design ideas and prototypes from community priorities. Two of these students and two recent U.S. graduates then joined the design team alongside Peruvian students in a summer study abroad that moved through the participatory design process. Remaining team members included 25 mid-to-senior career professionals, university researchers and artisans from Iquitos, half of whom were women.

In addition to the diverse experiences of the academically trained team members, it was important to the team that all generations in Claverito be engaged with the project, from children to the elderly. This was especially important because Claverito is an urban indigenous community, with more than half of residents first generation migrants who moved directly from jungle villages before living in the city, and 47% of the community is children, most of whom were born in Claverito. Involving the whole community promotes the exchange of knowledge – ancient indigenous knowledge of the land paired with formal education found in urban public schools is important for enhancing mutual respect, cultural preservation, and adaptability in this community transitioning from the rural jungle to a harsh urban lifestyle. In addition, children who watch their parents make positive change in their own community carry those experiences with them throughout their entire lives.

2.5 Time: As shown in Figure 4, project leaders began the relationship with Claverito in 2015 and built trust and knowledge using a series of participatory methods identified in Figure 3. While the design team heavily engaged with the community, it was important for team members to respect the limited time that residents have, especially in this impoverished community working within the unpredictable informal economy. The community regularly meets on Sunday mornings for community "mingas", or work parties, and so the team tapped into this existing structure; for any additional time needed, they traveled directly to residents' houses for their convenience. To reduce fatigue, the project was broken into two parts and the design and construction process for each part was condensed into six weeks each. Measurement periods lasted only two weeks, with a maximum of one hour of interactions with researchers per participating resident per measurement period. While this study comprised a relatively overall short time period with the community, the team fully intends to establish a long-term relationship with Claverito, the professional team and the municipality. This case study documents the first project in what we hope will be a long-term initiative, with a second project already begun.

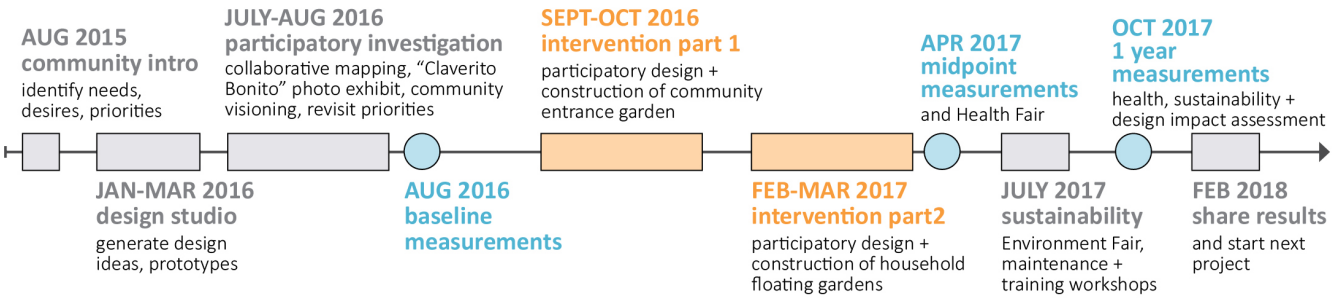

Figure 4: Project timeline and study structure

2.6 Outcomes: The overall purpose of the community project and associated research was to test an adaptation of the TDAR framework to target specific health issues in a community through a Gardens Intervention, aligning disciplines in the human health, ecology and built environment disciplines that do not typically work together in action-research projects, and utilizing a deep community engagement process. This integration grounds cross-disciplinary frameworks such as One Health and Planetary Health, that examine human-species-environment interactions across scales (King, et al., 2008; Whitmee, Haines, Beyrer, & et al., 2015), and tests hypotheses about the built environment and urban ecological design as restorative and preventive medicine and a determinant and supporter of health, especially for disadvantaged populations (Dannenberg, Frumkin, & Jackson, 2011; Solar & Irwin, 2010; Frumkin, et al., 2017).

An intention of implementing a TDAR framework was the distinct way the Gardens Intervention was defined and designed to target specific health issues and priorities in the community. Figure 5 shows a schematic of this process, referring to the same project stages outlined in Figure 2. The schematic is to be read from left to right, and shows how the design (orange) and research (blue) activities are supportive and intertwined. This process is similar to an integrated User Experience

Design (UX) with Evidence-Based Design (EBD) (Hagen, Nicholas, & Rahilly, 2014). Figure 6 extracts the design piece and shows the evolution of the design to detail the schematic in the project.

In *Stage 1: Define the Project*, the team gathered knowledge about the community and landscape using a combination of community listening activities that identified residents' needs, desires, priorities, aesthetic preferences, values and stories (see 2.3), regional public records of history, public health and land information, and embodied place knowledge, or documentation of the social-ecological systems observed in the landscape and community. (See Chapter 2 for more detail). This information was shared with the professional research team who then crafted research instruments with indicator measures to reflect the discovered human and ecological health priorities and suspected health burdens in Claverito. Researchers then conducted the Pre-intervention Assessment using these indicators to establish a baseline of measured human, ecological and environmental health issues in the community. (See Chapter 3 for more detail). Preliminary results were then shared back to the design team who then sifted through the information internally and focused on indicators that demonstrated the greatest need (see 2.7). The design team then provided a dozen project options to the community that responded to the research-identified priority indicators and the community-identified values and priorities. Residents then democratically voted to define what project type would be implemented in the community.

In *Stage 2: Design the Project,* the compiled results of the democratic vote were weighed with logistical realities and an evidence base, and choices were narrowed down through an informed participatory design process. Logistical realities included budget, time, skills and meeting criteria of funders. Evidence included scientific literature, local precedents and professional experience. The participatory design process included a series of design workshops (see 2.3) and design elements were crafted to specifically target and maximize benefits to priority human and ecological health indicators.

In *Stage 3: Build the Project*, the design was then modified based on logistics of acquiring materials, including local availability, cost, sustainability and performance. A series of work parties in which residents were co-building alongside professionals shared local and professional building techniques, promoted skills-building and supported social relationships.

In *Stage 4: Maintain and Support the Project*, a series of community maintenance and education workshops connected professional exerts with residents to guide residents in taking care of the project. A ribbon cutting ceremony helped generate project support and build relationships between residents, professionals and the municipality (see 2.3).

Lastly, in *Stage 5: Evaluate the Project*, a Post-intervention Assessment repeated the Pre-intervention Assessment, and was paired with a Design Impact Assessment and Design Sustainability Assessment (see 2.7). Results of the assessments were shared with residents, and are currently being disseminated to the municipality and professional communities.

As shown in Figure 6, community desires and concerns included elements such as social relationships, work, food, housing conditions, health and the environment. Top priority projects included stairs, pathways, greenspaces, a health post and lights. Results of the Pre-intervention Assessment indicated high incidence of injuries, chronic and vector-borne disease, poor mental health, food and medicine insecurity, land and water pollution, and reduced habitat and biodiversity. Claverito is located in a unique socio-cultural situation because it is composed of impoverished urban indigenous migrants with distinct skills, knowledge and lifestyle, and negative socio-political factors resulting from their informal slum status. Logistical realities included meeting funding criteria, examining skills within both the team and community, utilizing materials available in the isolated city of Iquitos, a limited construction budget ($13,000 USD, 2016) and respect for the community's time and fatigue levels by condensing the participatory design and construction period to only 6 weeks at a time. In addition, because Claverito is informal (see 2.3) and in the Amazon Rainforest ecosystem (see 2.1), the intervention was required to have a gentle eco-socio-political footprint, so large-scale visually permanent moves were inappropriate. The evidence base included examining scientific literature on human and ecological health benefits of urban nature, gardens and green infrastructure in impoverished communities, and visiting local precedents and analyzing professional experiences of team members on projects of greenspaces and infrastructure in slums. All these factors together shaped the design and implementation of the Gardens Intervention and choices were eliminated by weighing logistics with evidence and community preferences. For example, floating pathways were a top community priority with the potential to have a large health impact, however in order to have an equitable impact, they required adoption across the entire community, which was not possible due to budget, time and concerns about municipal backlash for such a visually large construction. In addition the team had not closely observed the community in the high river season and so was not confident in either the community or team's skills in building large durable floating structures, so this idea was tabled for a future project. Another example, while Claverito suffers from chronic diarrhea and other stomach issues likely from the amount of *Escherichia coli* and other coliforms in the water due to the lack of proper sanitation, an improved water source was not a

top priority project for residents and so the team focused on other urgent health needs. The team chose to divide the Gardens Intervention in two parts: A Community Entrance Garden and Household Floating Gardens, outlined in detail in 3.1.

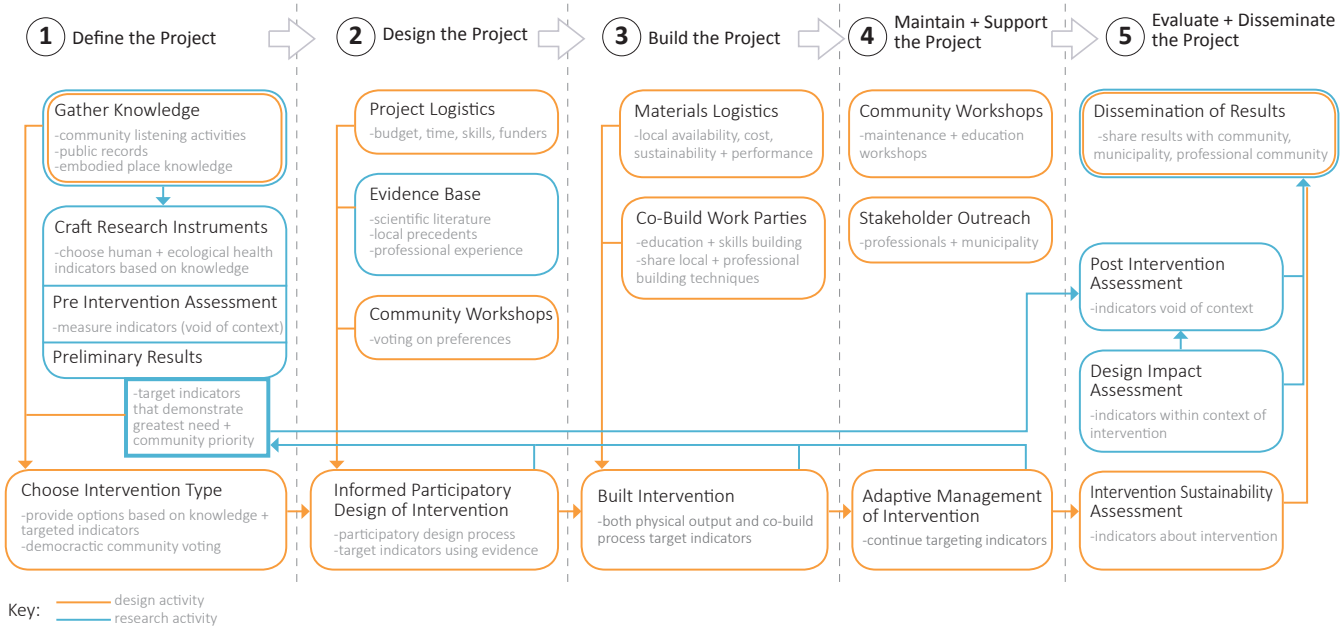

Figure 5: Schematic of the supportive and intertwined design and research activities in this TDAR framework adapted to target specific human and ecological health issues in communities by integrating participatory and evidence-based design.

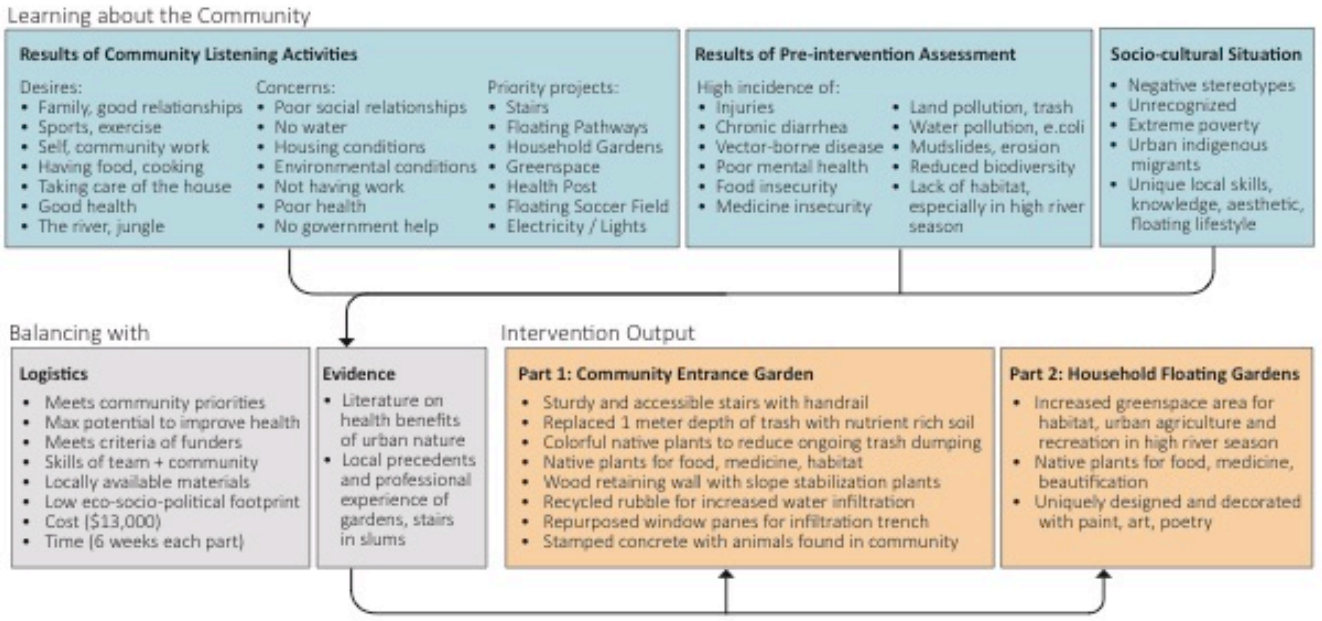

Figure 6: How the TDAR framework informed and shaped the Gardens Intervention to target specific health issues

2.7 Evaluation: Because of the overall goal to improve human and ecological health, there was a strong focus on evaluation of the physical intervention and its impacts on the community and environment. Figure 7 shows project evaluation measured in three parts: 1) a Health Assessment used priority indicators across dimensions of ecological, community and individual and family health to measure changes pre and post intervention in the context of a larger longitudinal study, 2) A Design Impact Assessment measured the same priority indicators a month after the post intervention health assessment, but this time asking residents how the Gardens Intervention impacted each of those indicators, and 3) A Design Sustainability Assessment, documented indicators of project sustainability by observing community interactions with the

Gardens Intervention over time. To explain the difference between these three assessments and their complementary measures, below is an example of measures in the indicator of food security:

> *Health Assessment measure:* 'In the past 4 weeks did you or any other household member go to sleep at night hungry because there was not enough food?' 0 (never), 1 (rarely), 2 (sometimes) or 3 (often)
>
> *Design Impact Assessment measure:* 'I feel like the Gardens Project has made my access to food…' 1 (much worse than before), 2 (worse than before), 3 (the same as before), 4 (better than before), or 5 (much better than before)
>
> *Design Sustainability Assessment measure:* Counting food producing plants per house over a year.

This manuscript focuses on the third assessment (blue in Figure 7). Sustainability indicator measures were taken at project construction to establish a baseline and again one year later: a) Financial Investment in the project documented number of households with garden elements that the Team did not purchase, b) Emotional Investment in the project documented number of households with artistic expressions in garden elements including art, signage and poetry, c) Durability and Use documented number of gardens in operation and size of gardens measured through the number of plants, d) Ownership descriptively documented examples in which residents took ownership over the project after construction by altering the gardens to make them their own, e) Economic Impact asked residents how the project impacted their overall finances, and f) Education asked residents if the project helped the learn about their health and the environment in which they live.

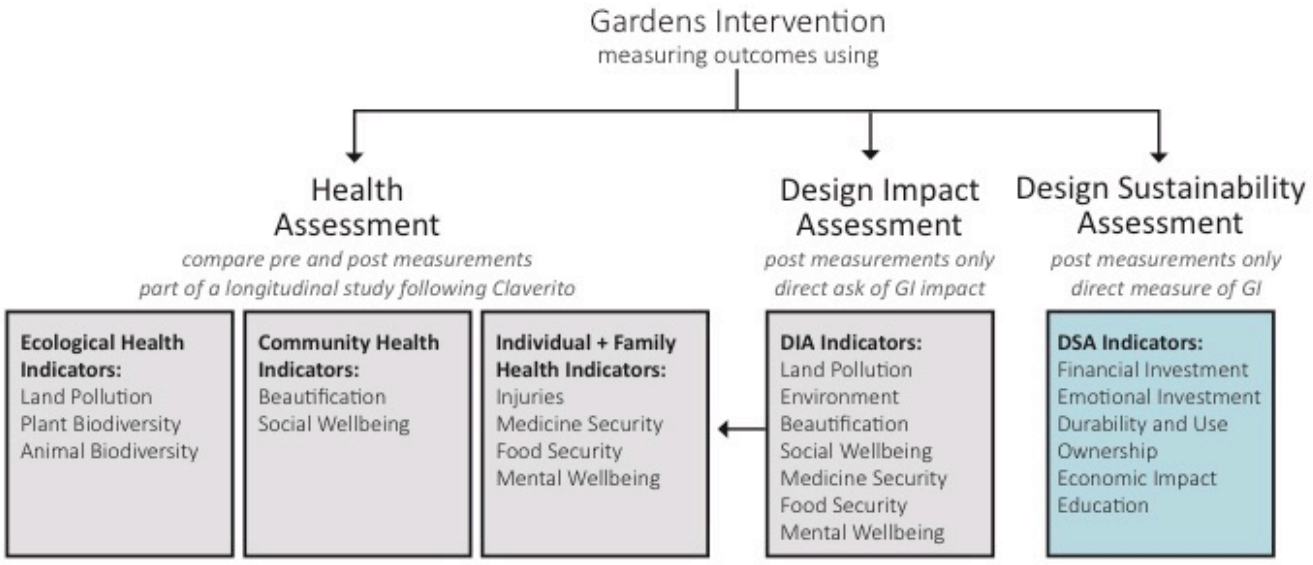

Figure 7: Project outcomes measured in a Health, Design Impact, and Design Sustainability Assessment

3. Outcomes: The Gardens Intervention and Assessment Results

The outcomes of using a TDAR framework in this study are: 1) the physical outcome that emerged from the transdisciplinary design and research process, or the Gardens Intervention, and 2) the enhanced function of the Gardens Intervention as understood from the project assessment outcomes. The Gardens Intervention output is broken into two parts, a Community Entrance Garden and Household Floating Gardens (Figure 8), detailed in Section 3.1. The results of the project assessment are described in three parts, Health Assessment, Design Impact Assessment and Design Sustainability Assessment (Figure 7). Due to the level of detail in methods and results, the Health Assessment and Design Impact Assessment are detailed in Chapter 3. Section 3.2 shows the results of the Design Sustainability Assessment.

3.1 Physical Outcome: The professional landscape architects leading this project, struggled with the term "garden" to describe the design, which on the surface seemingly diminishes the complex systems and intentionally performative design thinking incorporated into the intervention. However we felt the community ownership, scale, ephemeral and malleable

form, and productive qualities of the intervention, as well as the multi-cultural and multi-disciplinary accessibility of the word, was worth celebrating. We place these gardens in the category of "defiant gardens", a term coined by landscape architect professor Kenneth Helphand who explains, "*defiant gardens*, gardens created in extreme or difficult environmental, social, political, economic or cultural conditions… stand not in harmony with but in opposition to their locations… These gardens represent adaptation to challenging circumstances, but they can also be viewed for other dimensions as sites of assertion and affirmation." (Helphand, 2006, pp. ix, 1) Claverito is an informal community viewed negatively by the public. Extreme health issues in the community are exacerbated by public stereotypes and stigmas towards indigenous migrants and informal floating communities in Iquitos. The hillside above Claverito is a location of crime, drugs, human defecation, and trash dumping, all of which community members must walk through daily to get to their homes, and with a plaza perched at the top, the public is invited to literally look down upon the community and observe their conditions. The Gardens Intervention invited beauty into public dialogue. As Helphand states, these defiant gardens provide a voice for the voiceless and a place of hope, escape, cultural pride, and a making of home. They "domesticate and humanize dehumanized situations" and celebrate the dignity of life for human and non-human species (pp. 212). While we present the outcomes of this project, it is important to note that while gardens are gardens, they are also so much more to this community.

Figure 8: Location of Gardens Intervention in Claverito, shown in two parts.

The Gardens Intervention has two parts, a Community Entrance Garden and Household Floating Gardens. Figure 9 shows details of the 150 m^2 Community Entrance Garden: 1) The hillside was dominated by over 1 meter depth of trash providing mosquito habitat, and only two grass species. The team replaced 622 bags (5,443 kg) of trash with nutrient-rich soil and 1,300 native plants of 17 species chosen for beautification, food, medicine and habitat for beneficial species, all for community use. Concrete stairs replaced precarious wood and mud stairs, on which community members frequently experienced falls. Concrete is a symbolic material for this community transitioning from jungle to urban life, communicating progress and stability; 2) wood retaining walls emulated stair building techniques in Claverito using vertical posts and horizontal planks. Retaining walls contoured to the topography, mimicking Peruvian Incan strategies, and providing structure for slope stabilization, erosion control, and stormwater slowing; 3) six months after construction the mixture of plant colors and textures created a bright palette attractive to both people and pollinators. The site transitioned from a garbage dump to a selfie spot; 4) The vertical growth of plants supported amphibians, reptiles, butterflies and birds, and the garden provided a lush and productive entrance to the community 18 months after construction; 5) detail of concrete stairs with multi-level metal and wood handrail; 6) detail of animals found in Claverito stamped into stairs; 7) discarded construction rubble found on site (concrete, brick) was recycled to enhance infiltration. Claverito harvests domestic water

from a spring at the base of the hill; 8) decorative concrete window panes, a typical housing material used in Iquitos, were repurposed with recycled on-site rubble to create an infiltration trench to protect the stairs in heavy tropical rainstorms.

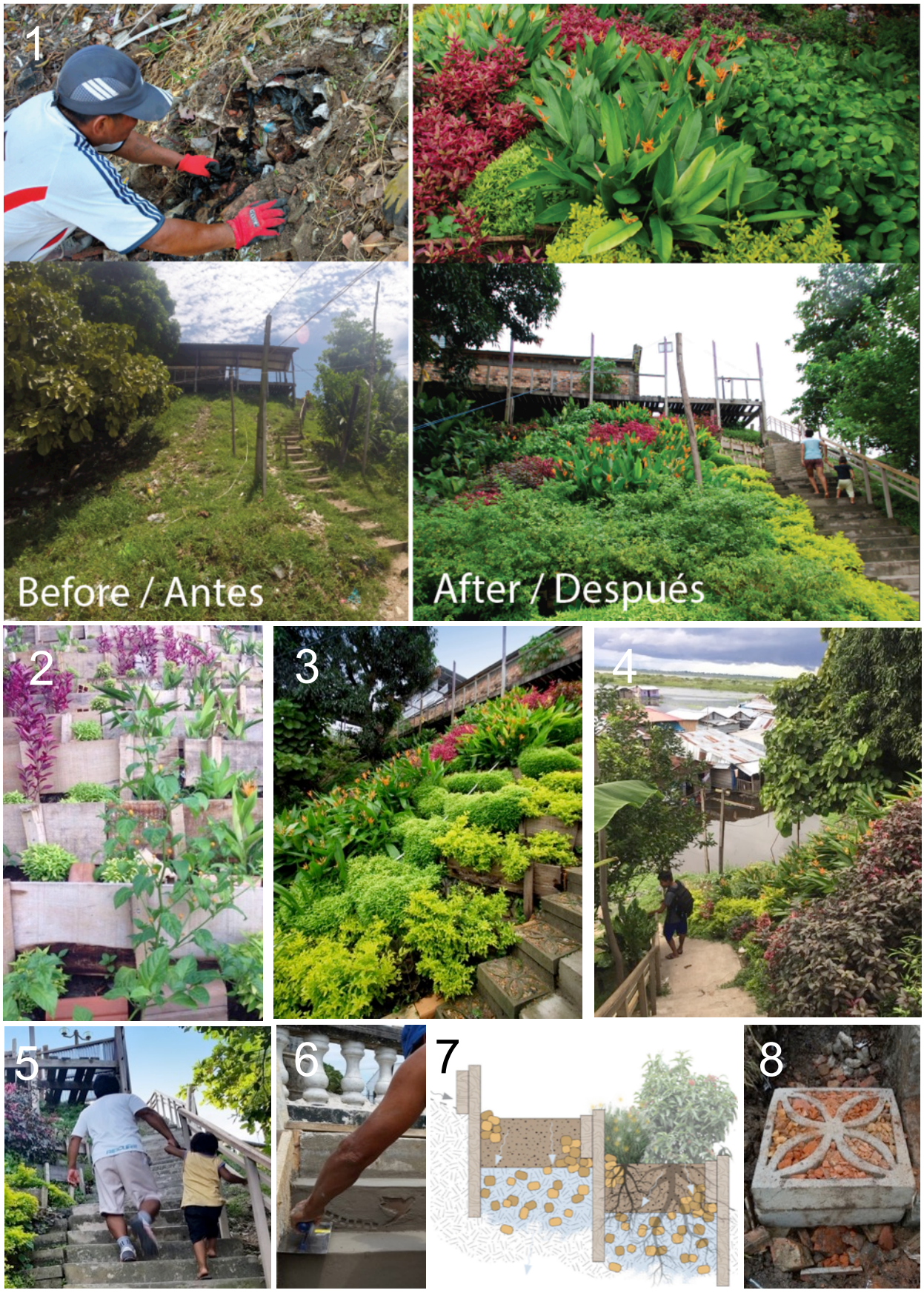

Figure 9: Details of the Community Entrance Garden including 1) before and after images, 2) infrastructure details, 3) six months and 4) 18 months after construction, 5-6) stairs details, and 7-8) infiltration details.

Figure 10 shows details of the 28 Household Floating Gardens: 1) residents designed the gardens using a "participatory innovation" approach (see 2.3), with customized shapes, materials, paint and plants; 2) a family chose to walk through their garden; 3) a family oriented their gate out towards the community, demonstrating how household gardens are part of a larger social greenspace system in Claverito; 4) one family harvested plastic bottles from the river outside their house to float their garden; 5-6) personal expression emerged through art, paintings and poetry. A poem on 6 says *"Savage is not who lives in the jungle, savage is who destroys it. We only have one planet. Take care of it."* 7-8) 6 months later families consumed the food, herbs and medicinal plants; 9) one year later the gardens became part of the house and character of Claverito.

Figure 10: Examples of the Household Floating Gardens with customized designs, plantings, art, and poetry.

3.2 Project Assessment Outcomes: One of the benefits of using TDAR in landscape architecture is the production of highly informed multi-functional landscapes (Neckar & Pitt, 2011). For example removing one meter's depth of garbage on the hillside and replacing it with colorful, big-leafed, rhizomous, native plants improved domestic water quality (residents use a spring below the garden), reduced vector-borne disease risk (trash supports mosquito habitat), created habitat to increase biodiversity for beneficial species (mosquito eating animals, pollinators etc.), stabilized the slope, and improved upon mental wellbeing, community image and negative stereotypes towards slum dwellers all simultaneously. Incorporating research quantifies these outcomes to understand the degree of change and success of the project.

As described in 2.7, the evaluation of this study was broken into three assessments. A full report on methods, results and statistical testing in the Health Assessment and Design Impact Assessment can be found in Chapter 3. In sum all measures of ecological, community and individual and family health in the Health Assessment improved significantly over the course of a year, with exception to household beautification and biodiversity of amphibians (Figure 11). Results from the Design Impact Assessment showed the Gardens Intervention had measured positive change in residents' lives in each of the indicators (Figure 12).

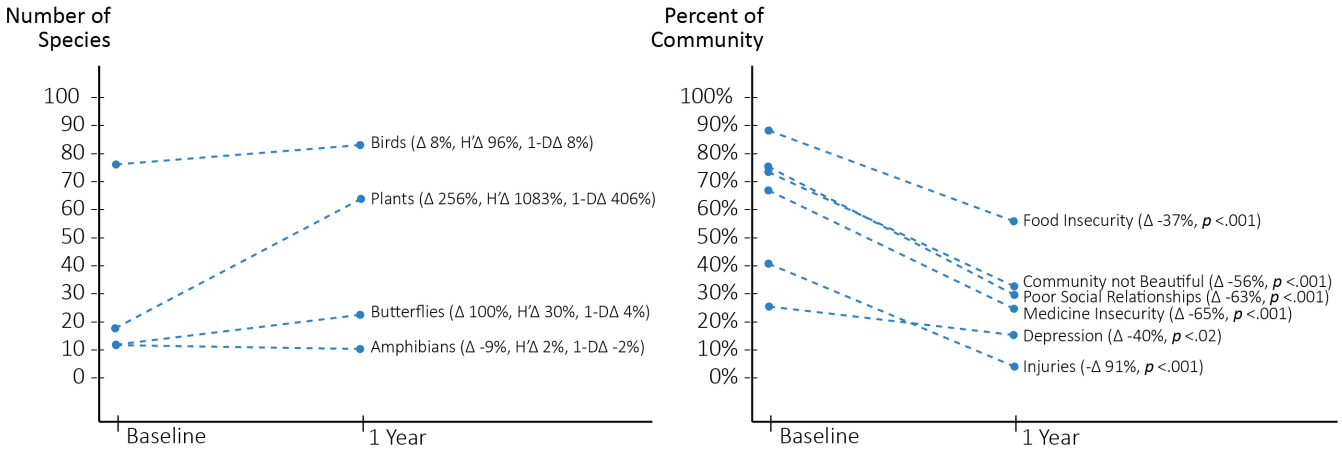

Figure 11: Summary of human and ecological health indicators with statistically significant results in the Health Assessment. Graphic extracted from Chapter 3

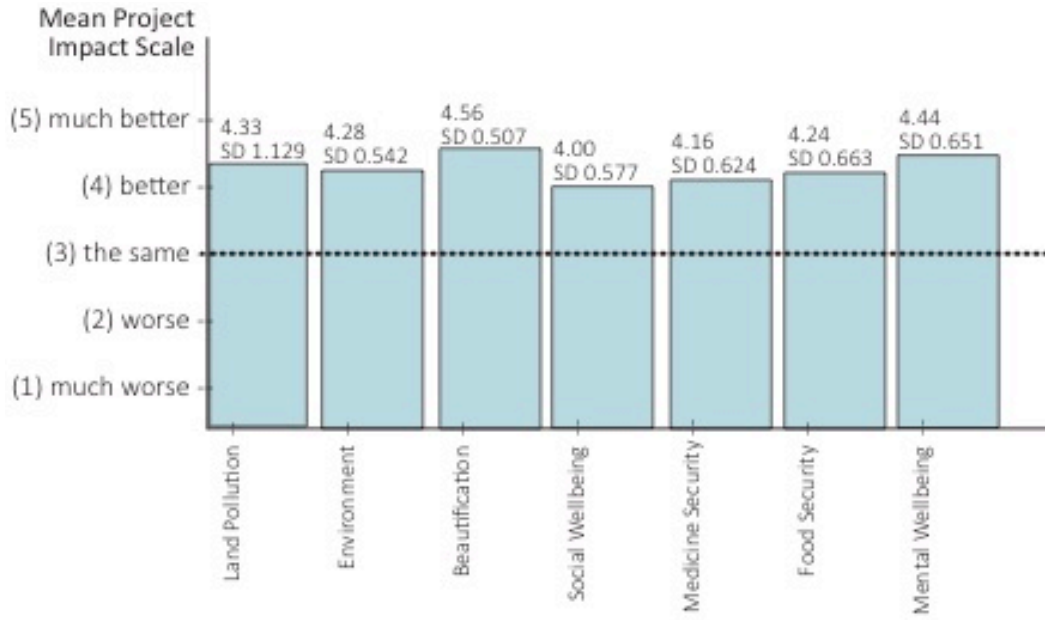

Figure 12: Perceived Impacts of the Gardens Intervention Project by Community Members (n=25, means and standard deviations). Graphic extracted from Chapter 3.

Team members also documented indicators of project sustainability in the Design Sustainability Assessment. Of the 28 families participating in the Household Floating Gardens project, 78% showed *Financial Investment* in the project, contributing their own resources such as wood, pots, sculptures and plants, and 54% used expressions of art, paintings or poetry in their gardens showing *Emotional Investment* in the project. A year later, the project was showing signs of *Durability and Use.* All but two floating gardens were in full operation, and 62% of gardens increased their number of plants at an average of 5.25 plants per garden. The maximum increase in plants per garden was 28 plants, and the maximum decrease in plants was 6 less plants. Additionally, 18 months after initial construction the Community Entrance Garden was fully planted and 38% of families reported using the community plants. The community showed several signs of taking *Ownership* over the project and making it their own: they extended the concrete stairs with additional wooden stairs; the wood retaining wall technique was used elsewhere on the hillside; floating gardens were expanded and adapted to dry season conditions; and repairs or adaptations were made on floating gardens that required them. A confidential survey asked residents representing 38 households in the community if the Gardens Intervention has influenced their family's *Economic Situation* from 1 (much worse than before) to 5 (much better than before) resulting in a mean of 3.8 (SD = 0.94). Additionally of these same families 84% reported using their plants and produce for food, 80% for medicine, and 12% for selling. This same survey asked *Education* questions, with a learning scale of 1 (learned nothing), 2 (learned a little), and 3 (learned much). Residents reported an average score of 2.4 (SD = 0.72) for learning about their health, and an average of 2.2 (SD = 0.77) for learning about the environment in which they live.

Figure 13: An example of emotional investment, ownership and skills building, indicators of project sustainability. When a family's floating garden (left) was destroyed in a heavy storm, they salvaged their painted wood panels and reconfigured their design on the hillside (right) emulating construction techniques used in the Community Entrance Garden.

4. Discussion

This project uses a TDAR framework, integrating design with research in an actionable project, incorporating disciplines that do not typically work together with a deep community participatory design approach and initiating a municipal dialogue. Lessons learned about the TDAR framework adapted for use in an urban ecological design project aimed at measurably improving human and ecological health are outlined below. While many align with findings of other TDAR teams in land use and planning projects (Thering & Chanse, 2011; Hester, 2011), the unique focus on human and environmental health provides additional opportunities and challenges.

1. **Team diversity enriches projects but you need the right team.** This project benefited from ideas and perspectives provided by the high diversity of team members across disciplines, generations, geography, and knowledge types, from indigenous and lived knowledge to academically trained. The common phrase "diversity begets innovation" was our experience, manifesting in the breadth of data captured, which then influenced physical forms and functions of the garden intervention, and ultimately the impact and understanding of the human and ecological health outcomes and project sustainability. While the diverse team was an overall positive aspect of the project, the large team had many different needs, data sets and perspectives to manage which required substantial time and energy. Finding the right team is key. A TDAR project requires flexible and well-organized management, and an open-minded and patient team.

Defining expectations upfront, discouraging disciplinary jargon, frequent team meetings, and opportunities to work and synthesize results between team members helped facilitate team management.

2. **Health can be improved but more case studies are needed.** This project explored an unconventional approach to addressing complex health issues using a built environment intervention. This TDAR approach grounds and measures health frameworks such as One Health, Planetary Health, and the built environment as a Social Determinant of Health. Disciplinary methods, data and ideas were shared and combined throughout the project to support the common goal of improving human and ecological health. The collaboration of disciplines in the human health, ecology and built environment fields was necessary to gather and react to community and site-specific health data, and to comprehend the multiple health outcomes of the intervention. While the team is confident this TDAR project improved health in Claverito, which in and of itself is a valuable outcome, we are cautious about scaling results out and up, as each community encountered will have its own nuances and the participatory process cannot be rushed. The team recognizes more case studies are needed. For example, this process likely will not work in every informal settlement, as these projects need to happen at the right stage of slum development, when the community has at least begun to organize and is ready for community-wide changes.

3. **Intervention shows indications of sustainability though more time is needed.** The results of the Design Sustainability Assessment indicate the Gardens Intervention is durable and being used by residents, and the community is showing signs of financial and emotional investment and ownership in the project. Additionally, for many residents the project and process has helped them learn about their own health and environment and improved their economic situation. These observations indicate that the intervention has the potential for long-lasting benefits. However, Claverito has a long way to go before meeting regulatory and residents' standards of both their built environment conditions and their overall health. This is intended to be the first of a series of projects establishing a long-term relationship with this community, research team, and the municipality. Identifying the nuances of what affects durable outcomes requires longer term evaluation. Change in human and ecological health, project stewardship and durability, building and strengthening relationships with informal communities and municipalities, and translation to larger scale recommendations, policies and actions all take time. We intend to contribute a series of articles to record these longitudinal changes.

4. **Design and research are political, with external consequences.** The deep collaboration in this project pushed through common communication barriers between disciplines, knowledge types and social strata, supporting mutual learning and empathy for the "other". By equalizing communication, including visual communication from the garden intervention visible to the public, power dynamics also shifted a small step towards equality for community members. This acknowledges the political nature of design and research and stimulates conversations and actions that begin to break through stigmas and cycles of poverty. For example, one year after the garden intervention, without any initiation of team members, Claverito was included in the national census for the first time in the 45 years that residents have lived there. Additionally, the community was included in city-wide mosquito eradication efforts for the first time, residents are self organizing to work with the Ministry of Health to create a health post in the community, and residents created additional built environment manipulations to protect their safety and security when the bridge above their community collapsed. TDAR teams should be aware of these larger consequences and responsibilities.

5. **TDAR improves design and research ethics of working with underserved communities, and complements and complicates outcomes.** The community engagement used in the participatory design process as part of this TDAR framework changed the typical role of the design expert to one of an empathetic listener and professional responder. It also provided opportunity for residents of this neglected and informal community to drive the development of their own community, strengthen relationships with the municipality and its resources, and nurture cultural pride and project stewardship. Additionally the physical design intervention partnered well with typical community health research in terms of the give and take dynamics of research ethics. The built environment contribution offset the generosity of residents' time and willingness to give their data and provided residents with the satisfaction of seeing their health goals manifest physically in the community. Both the research and design activities contributed to education for both residents and professionals about the health, nearby flora and fauna and environmental conditions in Claverito from a dual indigenous and academic lens. And the professional benefit that the research team received from the project was offset by measured and meaningful beneficial change documented in the community. However, the TDAR framework embraces the idea that the product, process and agents are all part of the intervention, and therefore it is impossible to separate the changes in human and ecological health or sustainability measures from the

community engagement process and working with the team, which complicates data analysis and understanding of mechanisms. Team leaders paid close attention to assure the design team, of whom had the closest relationship with residents, were never conducting human subjects data collection (i.e. asking health survey questions to the residents) so as to both reduce bias in resident responses and distance the design team from personal and sensitive information that might impact individual relationships with residents. Future studies would more closely analyze the risks and rewards of engagement.

6. **Funding TDAR projects are possible but difficult.** This project was funded by a combination of a national global health research training fellowship, private foundation scholarships, and a national environmental health innovation research grant. The overall budget was $83,000, which paid for intervention design and construction costs and salaries for 37 team members (appropriately compensated for Iquitos), a relatively small budget for a health intervention project. The multiple funding sources were necessary because of different funder goals: some are more open to funding research, others personnel, others student exchanges, and yet others constructed design projects. It could be challenging to find a funding source applicable for the entirety such a project. Multiple funders also bring multiple requirements, expectations and paperwork. While this team was fortunate to have a funder open to "social innovation" in research by adopting a TDAR and participatory design framework, it is also often difficult to convince funders to buy into a project that has an unknown outcome to be determined by a participatory process. More funding sources supportive of a TDAR or transdisciplinary framework are needed.

5. Conclusion

This manuscript details a design-build-research project led by landscape architects through the lens of TDAR with the intention of testing how robust transdisciplinary teams can target specific human and ecological health issues in communities by using urban ecological design interventions and a participatory design approach. It uses the seven dimensions of TDAR to model the process and to add to the body of TDAR literature. The highly diverse TDAR team stretches across disciplines, generations, geography, and knowledge types to collaborate with an urban slum community in Iquitos, Peru, seven research centers and a municipality. The project evaluates the sustainability of the design and summarizes health outcomes, investigating the role of the built environment in addressing global health and disease burdens that disproportionately affect the poor. Human and ecological health in the community has improved through the Gardens Intervention, and the TDAR process utilizing a highly diverse team has increased communication between government and informal residents, which is beginning to have larger political ripples. Successful TDAR projects require strong, patient, organized and open-minded team dynamics, multiple or progressive funding sources, and time to nourish relationships and understand their long term impacts. Benefits of using TDAR include highly informative, multi-functional interventions held accountable for their design intentions and strong design and research ethics. More TDAR built environment case studies are needed, and particularly for health focused TDAR landscape planning and design projects. The New Landscape Declaration calls for landscape architects to lead integrated projects that "create places that serve the higher purposes of social and environmental justice for all peoples and all species" and "serve the health and wellbeing of all communities," (Landscape Architecture Foundation, 2017). The TDAR framework shows promise in guiding designers to lead integrated teams to address these complex global problems through action-oriented and measured solutions.

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Chapter 5

Reflections on Topic of Inquiry: Health and the Built Environment

This research investigated several themes within the topic of the relationship of the built environment to human and ecological health. This section provides reflections within these themes, highlighted in bold below.

The built environment has a major and multi-faceted role in human and ecological health. This research demonstrates the value of landscape architecture and community design in global and public health work, and demonstrates how urban nature/urban ecological design should not be viewed as a single focused "pill" that solves individual and isolated health problems, but rather a carefully crafted complex and dynamic "multi-vitamin" that addresses a wide range of human, ecological and environmental health issues simultaneously and at multiple scales. Design interventions in the built environment, especially ones examining urban nature and the transdisciplinary process, are a relatively low cost investment for promising multi-faceted positive co-benefits to health. This research suggests that health research should be incorporated into design practice, and that community design interventions should be part of health initiatives, and community action research projects should be explored to advance science while meeting a great global need.

The health of humans, species and the environment are co-dependent. This study manipulated the built environment and documented changes in indicators of human and ecological health. Results showed a positive trend in land pollution reduction, biodiversity of plants, birds and butterflies, and significant positive changes in community beautification, social relationships, injuries and falls, access to medicine, self grown medicinal plants, food security and mental wellbeing. The Design Impact Assessment showed positive meaningful change also in each of these indicators. Household beautification and biodiversity of amphibians did not show significant change.

This study had a seemingly unusual amount of statistically significant positive change in human and ecological health for a study with a wide range of indicators and a relatively small physical intervention. This may be a result of several reasons: **1)** because health conditions are so poor in Claverito, a small amount of change could show a large improvement; **2)** there is evidence the suggests that urban nature may create an *equigenic environment*, or one that supports the health of the less advantaged potentially more than the more advantaged (Frumkin, et al., 2017); **3)** community interventions may have an especially high rate of benefit in slums because outcomes are shared across dense and integrated populations through an intimate "neighborhood effect" (Lilford, et al., 2016); **4)** gardens may be particularly beneficial in the harsh socio-political-environmental situation of slums due to the "defiant gardens" concept (Helphand, 2006); **5)** the TDAR process asked about specific indicators that residents cared about as discovered in the participatory process instead of researcher-determined indicators. Likewise the design intervention was crafted to target these specific health indicators; **6)** women consisted of 80% of respondents of the household survey. These women were mostly housewives, who live on floating houses, and their mobility is limited. Gardens at their houses and nearby may provide the most positive benefits to this population because they may spend most of their time in close proximity to the interventions; **7)** the presence of outsiders and the complex participant-observer social dynamics on top of the desire to please. The TDAR process embraces agents and process as part of the change. While many indicators are less likely to have been affected by attention from outsiders (e.g. food or medicine security, biodiversity), some may have been affected (e.g. mental and social wellbeing, beautification). Cross comparison of indicators in the Health Assessment with the Design Impact Assessment, and for some measures, the Design Sustainability Assessment, adds another layer of confidence to the findings. In addition, a household gardens project of similar scale in a slum community in Lima, Peru showed statistically significant increases in all domains of quality of life including physical, psychological, social, environmental and overall social capital (Korn A. , Bolton, Spencer, Alarcon, Andrews, & Voss, 2018 (in review))

Complex human, ecological and environmental health challenges require integrated research and collaborative action strategies across the health, ecology and built environment design fields. This research integrated these fields of study in two main ways: documenting existing human, ecological and environmental health conditions in Claverito using a Community Social-Ecological Assessment (Chapter 2), and conducting a Transdisciplinary Action Research project measuring changes in human and ecological health after the implementation of a Gardens Intervention (Chapters 3 and 4). The Community Social-Ecological Assessment, Gardens Intervention and Assessments all were derived from each of the multiple disciplines involved in the project in order to employ both scientific and participatory methods of data collection

and built environment design. This integration was not without its challenges. The team leaders had to navigate through a multitude of research methods, data types, and terminology throughout the project. Further insights into the process and regarding work with transdisciplinary teams are in the following section.

Reflections on Method and Process: TDAR Process Targeting Health

This research tackled the challenge of integrating scientific human health and ecology methods with a community participatory design approach implementing a built environment intervention that targeted and measured specific human and ecological health issues in Claverito. It utilized an adapted Transdisciplinary Action Research framework to conduct this research. This section answers several common questions of feasibility of the TDAR framework in Claverito.

1) What are the benefits and challenges of blending an organic and reactive participatory design method with the postpositivist scientific measures? The biggest hurdle was the lack of prior models, standard operating procedures or guidelines for how to conduct projects such as this. The team developed a pragmatic culture of sharing knowledge between team members. Results were shared after both engaging in the participatory process, and developing and administering the research instruments, and the project developed from there. A big challenge was the necessary quick turnaround for human subjects modifications for both Peru and UW IRB approval. A preliminary version of the survey research instrument was submitted prior to the start of the project based upon data collected the previous year. As soon as the indicators were finalized, team members worked quickly to submit the modification. Unfortunately, once the gardens design process began, the team discovered the community wanted concrete stairs due to informal conversations about frequent falls and injuries on the existing stairs. At this point it was too late to change the research instrument again, and so a separate injuries survey had to be conducted to cover this important data point. As mentioned previously, a potential positive outcome of this process is the team measured only indicators that the community cared about, rather than what the "outsiders" deemed important. A potential downside of this may be that the community may miss an indicator that they are not knowledgeable about. For example, many residents do not realize they have chronic parasitic infections, when 82% of the community was found to have active parasites.

2) What were the biggest successes with using this adapted TDAR process? Referring to Table 3 in Chapter 1, the TDAR framework had several successes in application to this design-build-research project. The team was able to capture multi-functional benefits of a built environment project and quantify improvement in both numbers and resident experience. Combining designers with scientists and health workers increased the overall ethics of the project because the design intervention balanced taking the residents' time and data. The TDAR process encouraged partnerships between the municipality and community, potentially stimulating a larger political impact. The complexity of the team composition kept the project interesting and in a constant state of learning. The team was engaged and interested to learn about the professions they do not often encounter in their daily work. Training students led to several success stories. One team member used the training in this project to qualify for a job at a U.S. community design firm doing similar work. Another team member made connections with a senior researcher in the team and worked as an intern in his lab afterwards. Other team members came back to work with Claverito the following year.

3) What were the biggest challenges with using this adapted TDAR process? The large integrated team was challenging to manage. Empathetic listening and learning about other fields of study on top of the community's needs takes a lot of time and energy. Interestingly, team leaders found themselves prioritizing other fields above their own profession. Because of this tendency, the team should assure equal representation from all professions outside of team facilitators. The TDAR framework does not separate the process, product, or agent when analyzing the outcome. For a low resource setting such as Claverito this may not be an issue but a deeper dive into science may require more isolated variables and control conditions and/or more complex and integrated variables. The extensive community engagement also came as a challenge in research logistics and data analysis. For example, the team intended to count trash on other parts of the hillside to compare to the trash counts done in the garden intervention area, but the community kept cleaning up the trash in the control location. Additionally, team leaders had to pay close attention to assure the design team, of who had the closest relationship with residents, were never conducting human subjects data collection so as to both reduce bias in resident responses and distance the design team from personal and sensitive information that may have impacted working with residents in the design process. Future studies should more closely analyze the risks and rewards of community engagement.

4) What were the challenges of leading a project as an "outsider"? From the start, team members acknowledged their "outsider" status in terms of socio-economic status, education level, health level, spiritual differences, and for the few U.S. citizens on the team, their race and ethnicity. While the community participatory process helps reduce hierarchies between team members and residents by flipping the designer and research dynamics to one of listening and responding to the clients' needs, team members constantly revisited conversations of ethics. With work such as this, it was also important for team members to not just "fly in and fly out" but rather establish a trusting relationship with community leaders and feed back into the local economy. A local leader that lives in the city is necessary for this type of community work.

5) What is challenging about working in slums and conducting scientific studies and design in this setting? The entire team, including project funders, needs to approach this type of work with a flexible and open mind. Despite conservative planning efforts, the physical intervention did not adhere to a predictable timeline. The river flooding season has been unpredictable to residents in recent years, and transitions between high and low river seasons are periods where residents must tend to their houses first before participating in community work. An intense wind and rainstorm destroyed a half dozen houses in the community during the middle of the Community Entrance Garden construction, of which the "mingas" were needed to gather the community to help repair those houses instead of working on the gardens. The team also needs to be prepared that the physical intervention is not permanent. Slums are dynamic and constantly changing, and a process that encourages ownership and stewardship means that gardens were adapted. A few gardens sank, residents relocated, and houses moved to other parts of the community. Additionally, trust is key to conducting all TDAR work, and especially with slum communities. The community was cautious about science, and scientists were cautious about listening to local knowledge. Locally known medicinal plants were found to be a successful bridge between these knowledge cultures, as there was a mutual respect for both local and academic perspectives of plants. Lastly, all work in slum communities must be conducted with caution. Informal communities are still illegal. A backup plan must always be in place in case the community is asked to relocate by the government.

6) With this large of a team, was using the TDAR approach affordable? The cost of the built environment intervention was $13,000 (USD, 2016) including the Community Entrance Garden and 28 Household Floating Gardens. The cost of stipends for the 37 team members working in Iquitos totaled $50,000 (USD, 2016). The two project leaders were compensated for 12 months of work each, five team members were compensated for approximately three months of work, and the remaining team members were employed for an average of 1.5 months spread out over the course of the year. Costs were kept low in part because all but three paid team members were from Iquitos and therefore housing and travel costs were not needed. These costs are relatively low for an 18 month long research project, a design-build project or a community health intervention project. The average size of a National Institutes of Health Research Project Grant in 2016 was $499,221 (NIH IMPAC, 2017), or equal to six Gardens Intervention projects.

7) With this level of community engagement, does it take too much of the community's time? In the very beginning of the project there was a steep learning curve for how to properly engage with Claverito residents so as to respect their time. The team learned that they hold "mingas" or work parties every Sunday morning and so tapped into that existing infrastructure when possible. The team made sure that they did not take more than six weeks from design to construction for each intervention, and each research period was 2 weeks long, with only one 1-hour "touchpoint" with each resident. Most design projects take about 1.5 years from design to construction. Public health campaigns could take even longer, sometimes lasting 2-5 years.

8) Is this project replicable within Claverito, another floating slum in Iquitos, or other slums around the world? Can it be applied to impoverished communities in the U.S.? It is important to note that because this project was highly customized to the social-ecological and political situation in Claverito, the *process* is replicable, not the Gardens Intervention *product* or the health *outcomes*. Each community encountered will have its own nuances and the participatory process will reveal different project priorities and health needs. This process likely will not work in every informal settlement, as these projects need to happen at the right stage of slum development, when the community has at least begun to organize and is ready for community-wide changes. There is, however, a carrying capacity for this type of community work. In order to have an intimate and effective participatory process the team estimates a maximum of 30 households per team leader. Larger neighborhoods would need to be broken down, or more staff is needed. Additionally, slum communities in Peru have a culture of community meetings, self-organization, and an overall acceptance of "outsiders". These are necessary elements to work in this capacity, and not every slum or community will meet this criteria. Every culture and community is different.

Reflection on Project Outcomes: The Physical Gardens Intervention

While there is no control situation to understand exactly how the TDAR framework changed the physical outcome of the Gardens Intervention, Chapter 4 describes a few examples of how the integration of ideas across professions, geography, knowledge types, and other factors may have contributed to a more complex physical outcome. As noted in Table 3 in Chapter 1, one benefit of TDAR in application to landscape projects is maximizing the understanding and making of multi-functional landscapes. For example, biologists, nutritionists and horticulturalists on the team were able to apply their professional knowledge and act on results from baseline data in Claverito to recommend a local plant species that was attractive to butterflies, provided nutrition and aesthetics for people and had cultural relevance, all of which factored into the measured indicators of butterfly biodiversity, food security, and mental wellbeing.

Sustainability of the project was assessed through the Design Sustainability Assessment. While it is still too early to understand the long-term impact in Claverito, the community is showing signs of stewardship and ownership of the project. Given the literature on TDAR and community engagement, these processes may have contributed to these values. Although not measured directly, sustainability extends beyond the physical intervention. A strong relationship with the community, positive physical changes in the built environment, and the shared results of positive change in the community increases the likelihood the Claverito will want to continue participating in research and design projects with the team in the future.

One unexpected outcome of the project was increased attention on the community by the municipality and media. After hearing about the amount of biodiversity found in the community, the municipality volunteered fourteen staff on a Saturday to work alongside the residents of Claverito to remove 622 bags of garbage in the community. Tourists, artists and urbanites not living in Claverito began taking photographs, drawings and selfies of the Community Entrance Garden and on-going dumping in this beautified area has decreased over time- indicators that public stereotypes towards this community may be beginning to change. With this increased attention, the police began soliciting residents from Claverito to join the neighborhood watch program. In September 2017, Claverito was included for the first time in city-wide mosquito eradication efforts. In February 2018, the Ministry of Health approached Claverito residents to invite them to participate in a mobile clinic program. On October 22, 2017, just a year after the initial study assessment, the Community of Claverito was included in the National Census for the very first time in the 45 years since the first resident moved there. One could speculate several reasons for this increased attention: the presence, name and power dynamics of the University of Washington team and a United States endorsement of the city; an improved image of the city and the prospect of increased tourism- research tourism, slum tourism or eco tourism (Frenzel & Koens, 2012; Sanyal, 2015); the social influences of the project team and TDAR process providing residents exposure to political nuances and effective interactions with outsiders; or the mere presence of the gardens and outsiders as a reminder that Claverito existed. While the local newspaper wrote two positive articles on the way Claverito was working with the municipality to clean up the environment (Proyectos: "Claverito, Trabajando para todos", 2016) and doing research with the University of Washington and the local Universidad Nacional de la Amazonia Peruana (Romero, 2017), after a big storm knocked the bridge above the community over, the local news station did a negative piece on how Claverito residents were responsible for tearing down the public bridge (record not available) demonstrating a long road to change public stigma.

Lastly, with improved built environment projects, and especially ones that prioritize beauty and contact with nature in vulnerable communities, there is always the question of “green gentrification” (Anguelovski, 2016). The fear is that the conditions will improve to the degree that the land will become attractive to wealthier residents and Claverito will be pushed out of their community. Claverito has a long way to go in their built environment conditions for this to be a possibility, however it is worthy of discussion. It is more likely in the short term that increased improvements will attract more slum dwellers to move to Claverito, which also may have health consequences for residents in addition to increased political strain on their tenure prospects.

Limitations and Recommendations for Future Research

This research had several limitations that could be explored in future research:

1) The frameworks employed in this research – the Community Social-Ecological Assessment Framework and adapted Transdisciplinary Action Research framework – were developed through real-time work in this study, using Claverito as a demonstration community. With replication and refinement, these frameworks have the potential to be **developed into a toolkit or guide** for conducting human-species-environment assessments or transdisciplinary design-build-research projects in slum communities. This toolkit or guide may appeal to community designers, landscape architects, municipal surveyors, or those looking to improve human and ecological health conditions in slum communities.

2) Employing a control in this initial study in Claverito was deemed unethical by the project team, however could provide additional statistical rigor in future studies. Further research would investigate **ethically responsible ways to have control populations.** For example a quasi-experimental design in which interventions and data capture are staggered within or between communities could be employed. However, this would require a larger budget and more extensive team and timeline. Finding comparable communities in terms of size, environmental conditions and income status within Iquitos would be challenging. While there are over 30,000 people living in floating slum conditions in Iquitos, Claverito is unique in its relationship to floodplain agriculture, aquatic vegetation, and close proximity to the public waterfront. One promising option could be to have a quasi-experimental study design within Claverito (in which interventions are staggered between Claverito residents). At the time of writing this dissertation, a second household and community gardens project has begun with 30 participating households, so this shows much promise.

3) With every built environment research project, it is difficult to control variables and outside influences. Aside from a control, future studies might investigate **other techniques for increasing data confidence and depth**. This study employed the GAZER survey on only one person per household, limiting statistical power and rigor due to a small sample size. Surveying all the teenagers and adults in the community may increase rigor and reduce potential bias from having a majority of women respondents. In addition to the Health Assessment (ongoing measured change in a longitudinal study context), the Design Impact Assessment (resident reported change *due to* the Intervention), and the Design Sustainability Assessment (documented change *of* the intervention) future research could also incorporate complementary biometrics. For example, the Household Food Insecurity Access Scale (HFIAS) and 24 hour dietary recall could be employed in the Health Assessment, a question in the Design Impact Assessment would ask how residents thought the gardens intervention impacted their access to food, the Sustainability Assessment could document food bearing plants over time, and a fourth dimension of biometrics could measure micronutrients, BMI, blood pressure, parasites etc. Other ideas include incorporating complementary qualitative data, performing deeper anthropological studies of community dynamics, adding rigor to assessing social changes and observer-participant dynamics, or investigating citizen science techniques, with potential for employment of Claverito residents.

4) This research showed improvements in human and species health with the built environment improvement, however it did not make **connections between humans and animals** to round out an understanding of human-species-environment relationships. Future topics that may add to this discussion could be: research on zoonotic disease transmission, pets and domestic animals and human health, the relationship of contact with animals to human wellbeing, the role of the built environment and mosquitos, or the role of fish in daily life in Claverito. With almost as many domestic animals (240) as people (280) in Claverito, all living in close proximity because of their floating conditions, and the influence of fish and other animals from the Amazon Rainforest on their lives, there is much potential to strengthen these connections.

5) The last limitation and recommendation for future work is not related to research, but rather advocacy. To date, results of the study have been only been shared with the residents of Claverito. This research requires **a careful dissemination strategy** with municipal leaders, local and national research organizations and the media in order scale up in impact. Because Claverito is still an informal community, this requires sensitivity and a clear message in order to not put the community at risk. The team fully expects the dissemination plan to be slowly and gently implemented over the long-term. With over 30,000 people in Iquitos living in floating informal communities, and approximately 10 million people in Peru living in slums, this research alongside future replication has the potential to influence substantial community change.

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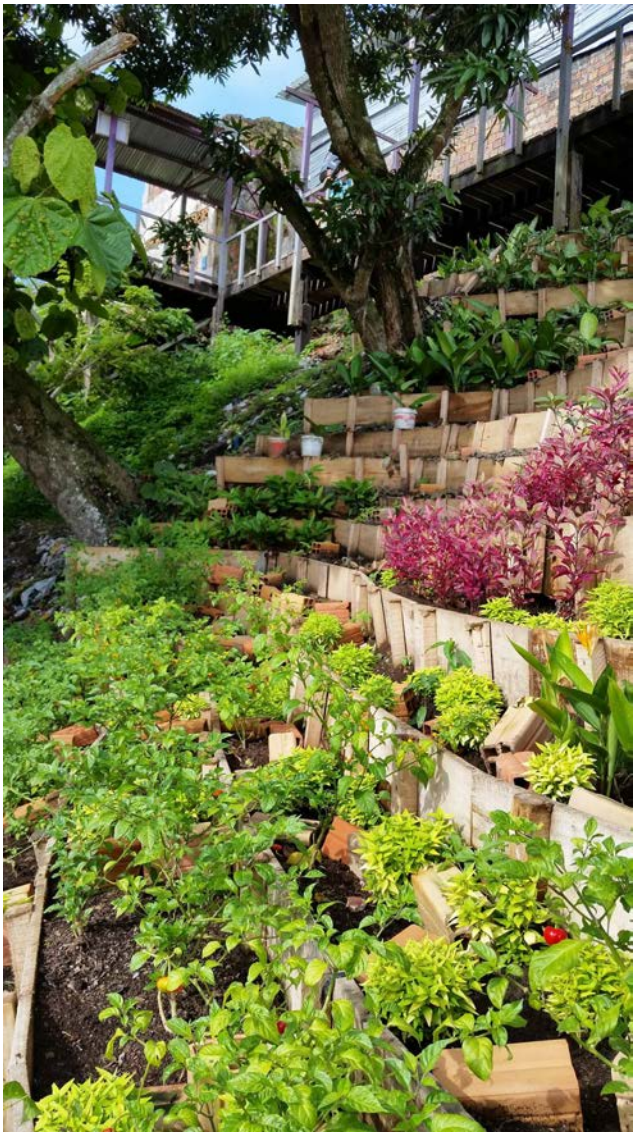
Impact of **garden technologies** on human, environmental and ecological health in floating communities in the Peruvian Amazon

Community of Claverito, Iquitos, Peru

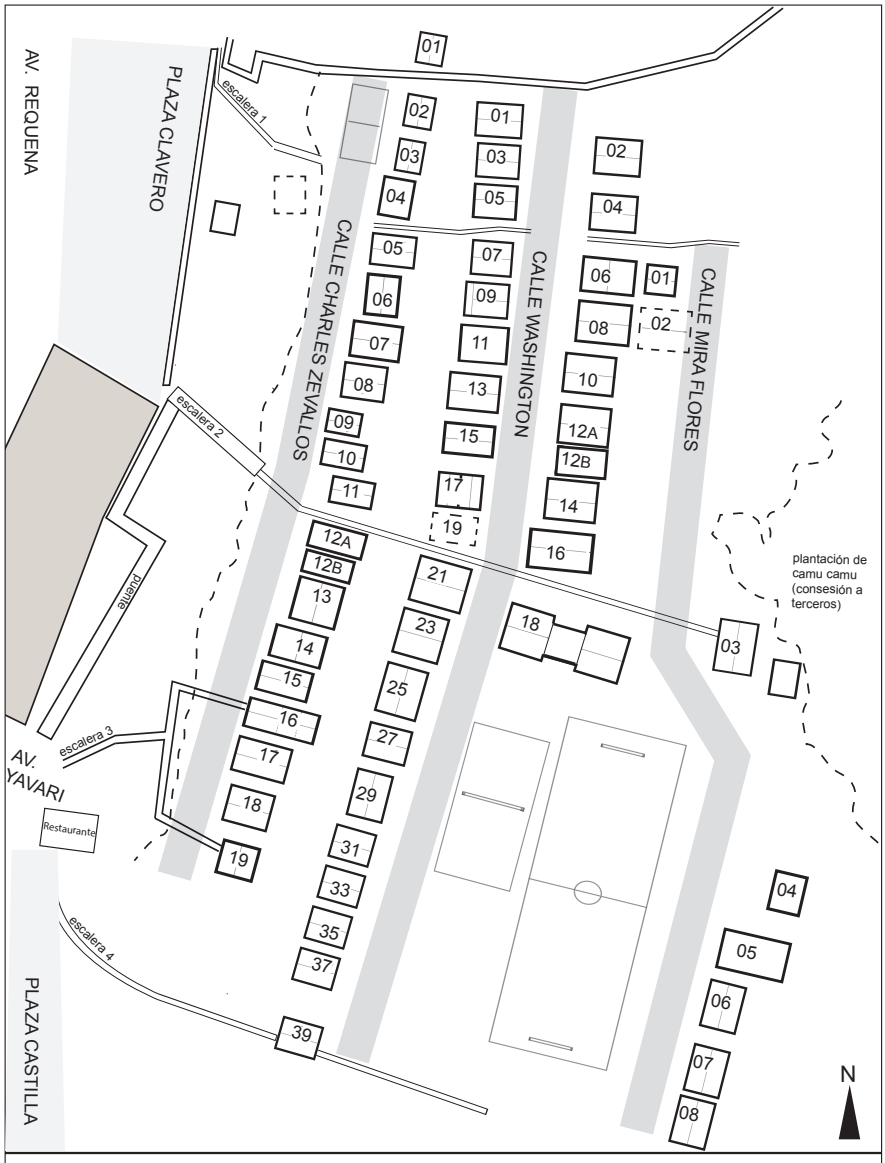
Excerpt Images from Final Funding Report

FEBRUARY 2018



The Community Entrance Garden in construction (top), immediately after construction (left), and 6 months later (right)

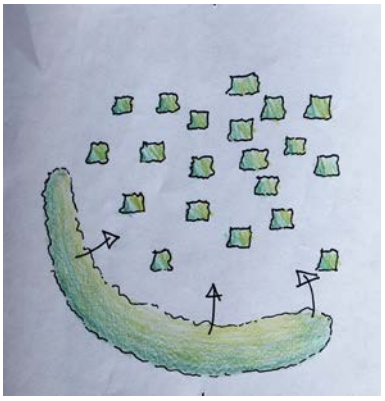
A sample of species found in the Community of Claverito

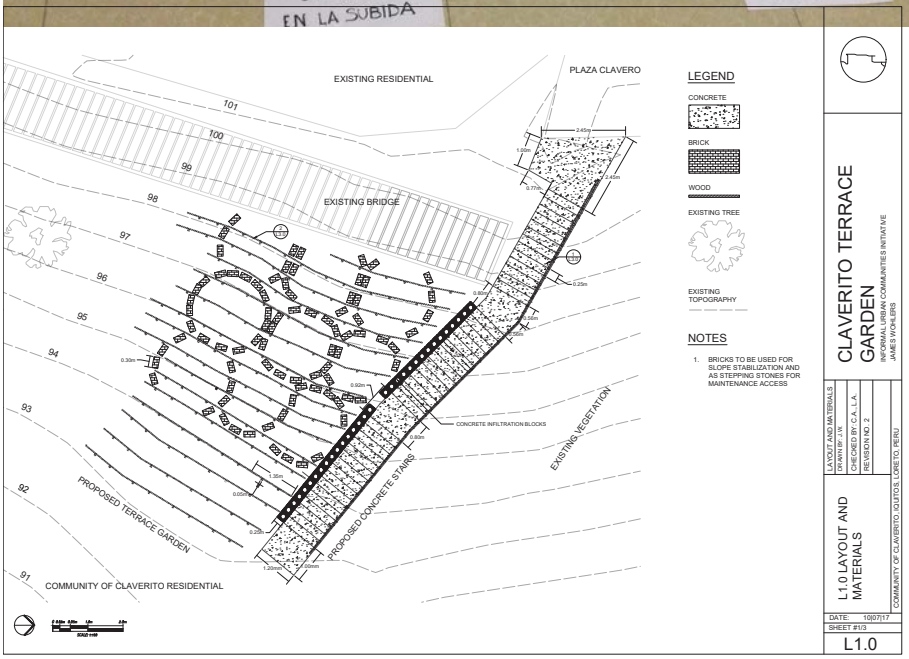


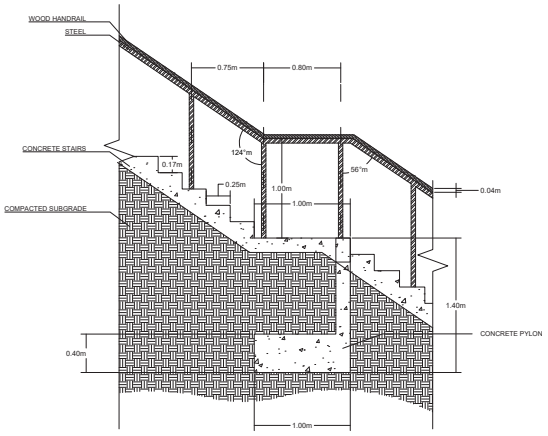
PLANO DESCRIPTIVO
COMUNIDAD FLOTANTE DE CLAVERITO

Iquitos, Maynas	22 / 05 / 2017	ESC 0 5 10 20 m.

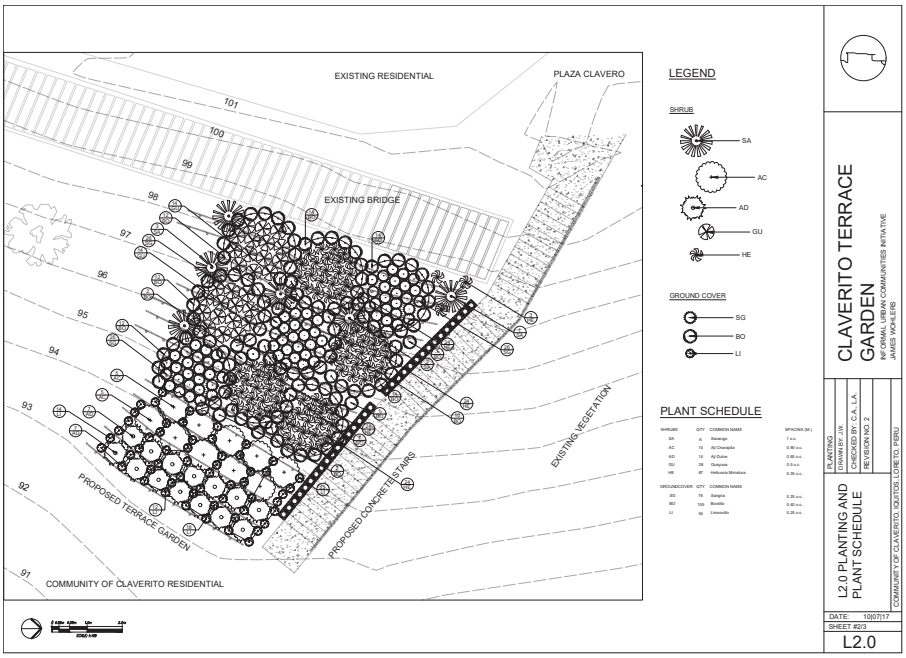
Mapping of the community

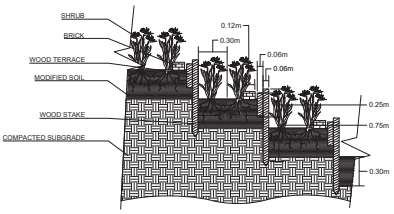






1 L1.0 CONCRETE STAIR DETAIL 2:1





2 L1.0 TYP. WOOD TERRACE DETAIL 2:1

Participatory and Technical Design

Before, during construction, and 4 months later

Immediately after construction and 4 months later

4 months after construction

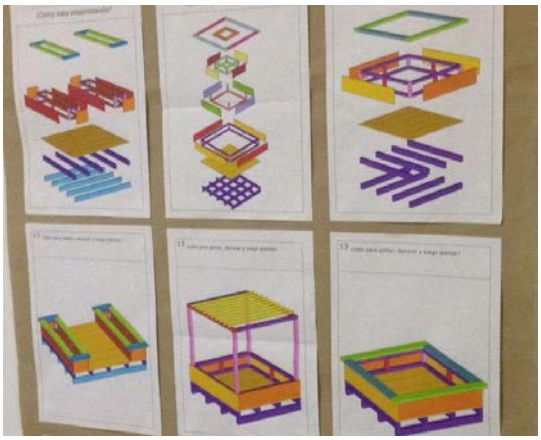
1 year after construction





Design details, from top right going clockwise: decorative infiltration trench using repurposed window blocks and salvaged brick; multi-tiered handrail for children and adults; brightly colored circular planting scheme to deter future trash disposal; stamps of animals found in the baseline survey; local wood terracing technique to stabilize hillside, slow water and enhance plant cleaning and infiltration.

The community of Claverito working together to construct the terraced hillside garden, sharing skills and community






Participatory Innovation techniques in the Household Floating Gardens


Bienvenido al Jardín
LAS AMAZONAS


CANTILLA


Jardín Flotante
El
Arco Iris
BIENVENIDOS A CLAVERITO-JARDIN FLOTANTE N°9
La naturaleza no necesita al Ser humano.
ES el ser humano QUIEN necesita a la naturaleza.
¡AYUDEMOS A CUIDARLA!
Salvaje no es Quien vive en la Selva.
Salvaje es Quien la destruye
Solo tenemos un Planeta
¡Cuidemoslo!


BIENVENIDOS AL JARDIN FLOTANTE
VICTORIA REGIA
WELCOME TO THE FLOATING
GARDEN


BIENVENIDOS AL JARDINCITO
"CLAVERITO"
CALLE CHARLES ZEVALLOS


ENVENIDO
AMI
SPACIO DE
JUEGO


BIEN VENIDOS
JARDIN FLOTANTE
LAS FLORCITAS

Harvesting from the Community Entrance Garden

Productive Household Floating Gardens, 1 Year Later

RIbbon Cutting Ceremony. RIbbon cutting was performed by the President of Claverito and representatives from the University of Washington, Municipality of Maynas and the NIH Fogarty Global Health Program

La Región
24 años informando al pueblo
Diario del Distrito Judicial de Loreto
"Año de la consolidación del Mar de Grau"
Año XXIV - Edición 7937 - Región Loreto
Iquitos, lunes 26 de setiembre de 2016
Director: Carlos Raúl Cornejo Sifuentes
PRECIO: S/. 0.70

Proyectos: "Claverito, trabajando para todos"

"Impacto de tecnologías de jardín en la salud humana ecológica y ambiental"

Es una iniciativa organizada por ocho organizaciones e instituciones que incluye: la Universidad de Washington, Informal Urban Communities Initiative (IUCI), el Centro de Investigaciones de Recursos Naturales la Amazonia (CIRNA) de la UNAP, la Municipalidad Provincial de Maynas, el Centro de Investigaciones Biomédicas, Tecnológicas y Medioambientales (CITBM), Northern Pacific Global Health Research Fellows Training Consortium, Landscape Architecture Foundation (LAF) y Fogarty program de los Institutos Nacionales de Salud de los Estados Unidos.

El objetivo de la iniciativa es mejorar las áreas verdes e incluir nuevas tecnologías para su mantenimiento y sostenibilidad con la participación activa de más de 50 familias de la comunidad de Claverito, ubicada en la zona baja de la plaza Clavero. Al mismo tiempo, el proyecto evalúa el impacto de los espacios verdes y públicos en la salud humana, de los animales y el medio ambiente.

Más de 10 profesionales extranjeros y 20 de Iquitos han venido realizando diversas actividades que incluyen: análisis de salud, flora, fauna y ambiente en la zona, diseño y construcción de áreas verdes y remediación ecológica, mejora de accesos y educación para los vecinos de la comunidad de Claverito. Las actividades están programadas hasta junio del 2017 y se espera poder extender labores unos años más.

UNAP busca alianza estratégica con la Universidad de Washington, USA

la Universidad de Washington ocupa el puesto número 11 entre las universidades a nivel mundial...

(Foto: Erick Romero)

La Universidad Nacional de la Amazonía Peruana (UNAP) recibió la visita de docentes e investigadores de la Universidad de Washington de los Estados Unidos de América, el viernes 24 de marzo en horas de la mañana, con el objetivo de fortalecer los lazos interinstitucionales, y la posible firma de convenios relacionados con la investigación científica y el intercambio de docentes y estudiantes.

La delegación visitante fue recibida por el vicerrector de Investigación Alberto García Ruiz, quien convocó a la reunión a los decanos y jefes de las Oficinas de Investigación de cada Facultad. También estuvieron presentes el jefe de la Oficina General de Investigación Rodil Tello Espinoza, y la directora del Centro de Investigaciones de Recursos Naturales de la Amazonía (Cirna-UNAP) Teresa de Jesús Mori del Águila. Conformaron la delegación visitante el director del Centro de Investigación en Salud de la Universidad de Washington Peter Rabinowitz, la bioingeniera Molly Blanck, la arquitecta paisajista Nancy Rottle, la catedrática Lia Andrews, entre otros destacados profesionales.

(Foto: Erick Romero)

Project in the local Iquitos Newspaper September 26, 2016 (left) and March 30, 2017 (right)