DISSERTATION

THE NATURE OF CHOICE:

UNRAVELING INDIVIDUAL DECISION-MAKING FOR CLIMATE-ADAPTATION, SCIENCE-PARTICIPATION, AND ENVIRONMENTAL STEWARDSHIP IN MEXICO

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ABSTRACT

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Broadly, this dissertation research assesses the determinants of individual decision making that constrain or enable livelihoods, for science-policy outcomes and environmental behaviors. This research draws on traditional frameworks for behavior change but integrates novel concepts that have been established in other fields as influencing choice. Though the sustainability field has relied on traditional frameworks for over the past 50 years, the conceptualization of internal cognitive factors like climate perceptions and motivations as well as environmental, socio-economic, and demographics factors remains siloed in their respective disciplines of social psychology and environmental psychology. This dissertation addresses these deficiencies through conceptual, methodological, and empirical contributions to the field of behavior change research.

Conceptually, this dissertation tests the influence of four major frameworks on choice: (1) the theory of planned behavior, which refers to the knowledge, attitudes, and social norms that contribute to behavioral intentions; (2) the volunteer motivations framework, which conceptualizes participation in volunteer programs as due to dispersed motivations to participate; (3) the credibility-relevance-legitimacy framework, which refers to the three components needed for decision-makers to use science for action; and (4) the sustainable livelihoods approach framework that conceptualizes livelihood outcomes as a product of the household assets they control while influenced by their external institutional and environmental vulnerability context. In Chapter 2, I modify the sustainable livelihoods framework by integrating climate perceptions into the livelihood assets that households use to make livelihood decisions, with implications for uptake of adaptation strategies for climate change. In Chapter 3 I

integrate the volunteer motivation framework into the credibility-relevance-legitimacy framework, suggesting that both are needed for explaining participation in public participation in science, i.e. citizen science. Finally, in Chapter 4 I integrate the theory of planned behavior with the credibility-relevance-legitimacy framework, to show that both are necessary for understanding changes to conservation knowledge, attitudes, and stewardship behaviors over time.

Methodologically, this dissertation also contributes novel techniques for encouraging behavior changes for citizen scientists in Chapters 3 and 4. Specifically, conservation decision-makers were included within the traditional citizen science, water-monitoring training to amplify perceptions of project relevance for conservation programs, to improve participation in citizen science as well as to improve social outcomes of knowledge, attitudes, and stewardship behaviors. In an experimental design, half the citizen scientists received the traditional training, while the other half received the intervention training which included an hour and a half presentation from conservation decision makers. We found that while short term perceptions of the relevance of the program was improved, there was a need to enhance legitimacy of program design (i.e., with the voices of citizen scientists), as many volunteers were more interested in studying water quality than water flow. However, the training did positively influence some measures of conservation knowledge and attitudes, and was able to influence frequency of talking to others about conservation. These findings suggest that program managers in citizen science need to know about citizen scientists' motivations to frame recruitment and retention strategies.

Additionally, in Chapter 2 this dissertation empirically tests the role of climate vulnerability and adaptation policy making through an in depth examination of coffee farmer adaptation strategies in the state of Chiapas, Mexico, and what determines adoption of adaptation strategies. These results show that the vulnerability context (including market distance, community location, and experience of disasters) the household assets (including natural, social, and physical capitals), and climate perceptions as an additional asset, play an important role in facilitating adaptation to climate change. This research calls attention to the need for stronger policy making that provides financial encouragement for underutilized adaptation strategies such as crop diversification while simultaneously developing climate workshops to strengthen climate perceptions and encouraging participation in agricultural organizations that facilitate information exchange about climate adaptation strategies.

Overall, this dissertation calls attention to the social and ecological impacts that citizen science and sustainable development policies have, and the influence that internal cognitive and socio-economic factors play, as well as external environmental factors, for influencing choice to engage in these activities. Because many of these factors are immutable in the short term – such as environmental or socioeconomic factors – this dissertation broadly suggests that to influence choice, decision makers need to recognize cognitive factors like perceptions of climate change, motivations to participate, and perception of project relevancy. Only when we can understand these cognitive factors can informational interventions be appropriately designed for social and ecological outcomes.

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1. CHAPTER 1: INTRODUCTION

1.1 INTRODUCING THE DISSERTATION

How people make choices has been a mainstay of behavioral social science research over the past fifty years (Ajzen & Fishbein, 1972; Thaler, 1980; Tversky & Kahneman 1974). Determinants of choice can be classified as either internal factors, e.g. demographics, or external factors, e.g. social norms. For example, internal psychological factors are considered important for environmental volunteers, these include values (Bruyere & Rappe, 2007), motivations (Ryan et al., 2002), and perceptions (Bennett, 2016), while internal personal factors such as age, education, and income may enable or constrain interest and ability to volunteer altogether (Penner, 2002). Meanwhile, external factors such as the social, economic, and political context may enable or constrain an individual's capability to make their own choices on the most basic needs like whether and what to eat (Sen, 2005).

Individual decision making was originally characterized by traditional behavioral researchers as purely rational (Simon, 1955; Becker, 1967), where individuals decide on the optimal option based on an objective understanding of the costs and benefits (Thaler, 2000). However, there is considerable evidence to suggest that individuals make decisions that depart from rational choice models. For example, many economists in conservation sciences have posited that paying landowners for forest conservation should incentivize pro-environmental behavior like planting trees (Ferraro & Kiss, 2002). However, emerging research suggests that such payment-based conservation strategies can unexpectedly backfire by reducing intrinsic motivations and increasing deforestation (Muradian et al., 2013). This phenomenon, termed 'crowding out', is one of many cognitive biases that lead to unexpected outcomes (Wunder, 2013). Therefore, understanding in what contexts choices get enacted (e.g. environmental and socio-economic factors), who is enacting them (e.g. demographic factors), as well as what cognitive biases influence social and ecological outcomes is of increasing concern for researchers across disciplines.

The science of choice, and how to influence choice, has increasingly been applied to disciplines as diverse as: medicine, e.g. convincing patients to change their patterns of smoking, drinking, eating, or exercising (Rollnick et al., 1992); finance, e.g. promoting individual contributions to their retirement plans through automatic enrollment (Langley & Lever, 2013); science and education, e.g. encouraging senior high schoolers to enroll in college by text messaging deadlines (Schneider et al., 2013); conservation, e.g. reducing deforestation in poor regions through individual payments to land owners (Pattanayak, Wunder, & Ferraro, 2010); and water consumption, e.g. encouraging hotel patrons to re-use their towels to reduce water use (Goldstein & Cialdini, 2007). The breadth of research on this topic of behavior reflects its importance, while highlighting the underlying interest across disciplines in understanding how to change behaviors for social and ecological outcomes.

Research in this vein is critical in a time when inaction can result in social and ecological impoverishment. In 2018, scientists from the International Panel on Climate Change (IPCC) warned that without coordinated action to combat climate change, the Earth will cross the critical threshold of two degrees Celsius resulting in more catastrophic flooding, droughts, forest fires, and hurricanes. Nations from the Global South will suffer much of the consequences of climate change because of their vulnerabilities, while bearing little of the responsibility for contributing to greenhouse gas emissions (Beer, 2014; Comim, 2008; Füssel, 2010; Heyward, 2007; Leichenko & Silva, 2014; Mendelson, Dinar & Williams, 2006). For smallholder farmers in the Global South, facing the double exposure of economic globalization and climate change threatens their very way of living (O'Brien & Leichenko, 2000; Eakin, 2005). Therefore, to combat this threat IPCC has made a clarion call to nations to reduce their greenhouse gas emissions, encouraging nations to simultaneously adapt to foreseeable threats. To do so, local, national and international, governmental, and non-governmental agencies have developed numerous informational campaigns and disseminated countless toolkits to encourage individuals and communities to engage with mitigation and adaptation strategies.

The success of these campaigns to influence decision-making rest on the basic assumption that people choose the best option for themselves, given the available information (Thaler et al., 2000). However, countless studies have shown that people do not necessarily act in their own self-interest, even if they have the best information available (Fehr & Gächter, 2000; Henrich et al., 2001; Roth et al., 1991).

Indeed, there are certain biases that inevitably sneak into decision-making, particularly when the outcomes are uncertain. For example, individuals tend to opt to do nothing and maintain current practices when the future is uncertain, a phenomenon known as *status quo bias* (Fernandez & Rodrik, 1991). Indeed, people tend to choose the known rather than unknown, particularly when the decisions are risky. This effect is evident across disciplines. For example, in finance many people opt to avoid participating in the stock market which have unknown but potentially devastating risks (Easley & O'Hara, 2009), and in medicine people will strategically avoid treatments when the risks are not well known (Berger, et al., 2013). Alternatively, when individuals are unsure of the best course of action, they often rely on others to form their own opinions and decisions, a bias known as the *consensus effect* (Darke et al., 1998; Panagopoulos & Harrison, 2016). One quasi-experimental study found that by emphasizing the near-unanimity of climate change science, people were subsequently more likely to say they 'believe' in climate change which they attribute to the consensus effect (van der Linden et al., 2017). Social norms targeting the consensus effect have been used in energy programs nation-wide, where comparing one person's energy consumption to the regional average influence residential energy consumption (Allcott, 2011).

Despite these biases, or perhaps because of them, there is a strong need to not only understand why people behave the way they do while encouraging behaviors to: improve their own lives (e.g. encouraging farmers to adapt to climate change), benefit social outcomes (e.g. improving public participation in science research), and improving ecological outcomes (e.g. increasing pro-environmental behaviors). To encourage these changes, researchers have increasingly turned to gentle encouragements, called 'nudges' (Thaler & Sunstein, 2008). Unlike costly regulatory policies that restrict choice, with nudges people are free to make any range of decisions, or opt out entirely (Thaler & Sunstein, 2003). For example, by providing people with trainings that specifically target motivations to participate in a science program, we can potentially influence retention, but participants have the option to drop out altogether. Because nudges are relatively weak or soft, people may choose not to engage in those behaviors. The approaches I employ in this dissertation provides insight into whether and how we can move people towards making the ‘right’ decisions, while recognizing the inherent ethical dilemma that is involved with influencing choice (Coghlan & Shani, 2005; Kelman, 1965; Walter, Marks, & James 1981). Therefore,

> *At the broadest level, this dissertation research explores the question of what determines how individuals make decisions for climate-adaptation, science-participation, and environmental stewardship, with the goal of improving social and ecological outcomes*.

In Section 1.2, I discuss the theoretical foundations that I rely on and contribute to, including: behavior change theories; volunteer motivation theories; credibility, relevancy and legitimacy framework; and the Sustainable Livelihoods Approach framework. In Section 1.3, I discuss the setting within which this dissertation research was conducted, detailing the study area in Mexico and my research questions. In Section 1.4, I conclude with the dissertation structure, giving a brief overview of each chapter and how it contributes to theory.

1.2 THEORETICAL FOUNDATIONS

Theoretical research on behavior change is robust, ranging from disciplines as diverse as economics, psychology, sociology, political science, human dimensions of natural resources, social marketing, and sustainable development. This research draws on, and contributes to, four behavioral conceptual frameworks that will be explained in more detail below: 1. Behavior change theories (i.e. Ajzen & Fishbein, 1972; Hungerford & Volk, 1990); 2. Volunteer motivation theories (i.e., Clary et al., 1998; Ryan et al., 2001); 3. The credibility, relevance, and legitimacy (CRELE) framework (i.e., Cash et al., 2003); and 4. The Sustainable Livelihoods Approach (SLA) framework (i.e., Bebbington et al., 1999). These conceptual frameworks provide a structure for identifying why individuals enact stewardship behaviors, engage in and utilize science, and adopt climate-related adaptations.

1.2.1 Behavioral theories

To address global environmental challenges, researchers have increasingly recognized that it is essential to understand how humans make decisions about how to act (Klöckner, 2013). The Theory of Planned Behavior (Ajzen, 1991) is one of the most widely used frameworks within the field of environmental psychology for understanding attitudes and behavior. The framework posits that behavior can be predicted reasonably well from behavioral intention. Within medicine it has been applied to understand drug use, dieting and blood donations (Armitage et al.,1999; Connor, Norman, & Bell, 2002; Giles et al., 2004); within political sciences it has been used to understand voting behavior (Netenmeyer & Burton, 1990); while in conservation it has been applied to understanding reforestation practices (Karppinen, 2005), soil conservation (Lynn & Rola, 1988), green hotel choice (Han et al., 2010), public transportation use (Heath & Gifford, 2002), recycling behavior (Tonglet et al., 2004), and modified for citizen science participation (Toomey & Domroese, 2013).

A central assumption is that behavioral intentions capture the motivational factors that influence behavior. The stronger the intention, the more likely that the behavior is adopted. Within the theory of planned behavior, Ajzen (1991) asserts that it is necessary to measure a person's attitude towards performing the specific action, rather than their attitude towards the object itself, as well as the subjective norms to perform the action and the perceived sense of control. In this theory, attitudes are a measurement of favorability of the behavior; subjective norms are the perceived expectations of others and disposition to comply with those expectations; and perceived behavioral control is a measurement of perceived ability to enact a behavior (Klöckner, 2013). Therefore, the theory supposes that if we hold a positive attitude towards an environmental outcome, if we feel expected to act in a certain way, and if we can envision ourselves enacting our behavioral intention then we will choose to adopt an environmental behavior. Although there is some empirical evidence to support the Theory of Planned Behavior, because it assumes that the variables are additive, unidimensional, and linear in nature, and because of its inability to predict repeated behaviors, the model has received significant criticism (e.g. Connor & Abraham, 2001; Klöckner & Blöbaum, 2010; Sniehotta, Presseau, & Araújo-Soares, 2014).

Indeed, there remains a significant theoretical gap between attitudes towards the environment and stewardship behaviors (Kaiser, Wolfing & Fuhrer, 1999; Kollmuss & Agyeman, 2002), as well as a gap between knowledge and behaviors (Courtenay-Hall & Rogers, 2000; Kennedy et al., 2004; Sligo & Jameson, 2000). To close these gaps, theorists from environmental education have proposed operationalizing environmentally responsible behaviors through more complex models. For example, Hungerford and Volk (1990) suggest that an environmentally responsible citizen is one who has: (1) an awareness and knowledge of environmental issues as a basic prerequisite for acting; (2) a knowledge of the courses of action available to confront such issues; (3) the skill in applying such knowledge; (4) a desire to act, which is influenced by locus of control, attitudes towards the environment, and feelings of personal responsibility. Additional situational factors such as external barriers (e.g. time, money, ability), and social pressure (i.e. social norms) may also enable or constrain action for environmental stewardship, as well as internal motivations (e.g. Stern, Dietz & Karlof, 1993).

1.2.2 Volunteer motivations theories

Although the Theory of Planned Behavior assumes that behavioral intention is directly influenced by the strength of motivations, it does not explicitly parse out what motivations influence behaviors. Indeed, personal motivations for each person vary significantly, despite apparently similar behaviors (Katz 1960). To understand what these motivations are and how they vary, several classical psychological theories have been developed to consider motivational foundations, which is particularly useful for volunteerism. For example, Clary et al. (1998) proposed six key themes underlying motivations, called the Volunteer Functional Inventory, where: 1. People volunteer as a means to express their values such as a desire to contribute to the community; 2. Those who volunteer are interested in learning about the world, understanding an issue, or discovering new ideas; 3. Volunteers have a desire to grow psychologically through a process of enhancement, e.g., to improve self-esteem; 4. The process of volunteering allows people to develop new skills and gain experience for their careers; 5. Volunteering provides a venue to build and strengthen social relationships through meeting new people and making friends; and 6. By volunteering people can reduce negative feelings through a protective process, e.g., to escape stress or guilt.

Building on these theories, researchers have increasingly focused on 'environmental volunteers,' a catch-all term to describe people who commit their unpaid time, skills, and knowledge to conservation and environmental programs (Higgins & Shackleton, 2015). Research into the motivations of environmental volunteers is increasingly recognized as having important implications for their recruitment and retention. A study by Ryan et al. (2001) found five distinct dimensions related to environmental volunteer motivations, including the desire to: 1. help the environment (i.e., values); 2. learn about their surroundings (i.e., understanding); 3. connect socially with others (i.e., social); 4. experience opportunities for personal reflections (i.e. escape); and 5. enjoy the organizational structure of the team (i.e. to be part of something). The study examined long-term environmental volunteers in Michigan and remains a cornerstone of environmental volunteer research.

Since Ryan et al.'s (2001) study, researchers have adapted and validated their findings, which has brought up several contentious issues. For example, although some studies show that 'helping the environment' is the salient factor in environmental volunteer participation (e.g., see Bruyere & Rappe, 2007), it is unclear whether this translates into a predictor for behavior. Indeed, researchers Asah and Blahna (2012) found that volunteers ranked the environment as the most important motivator for volunteering, but it had absolutely no influence on the duration of their involvement in the environmental volunteer program. This suggests that values may be a necessary prerequisite for participation but not sufficient in fully understanding why and for how long people engage.

1.2.3 Credibility, Relevance, and Legitimacy Framework

Critically, there is a need to strengthen the connection between scientists and policy makers, particularly for environmental decision-making (Sarkki et al., 2015). Special mechanisms such as the Environmental Impact Assessment (EIA) in the U.S., explicitly require the use of science for policy making (Morrison-Saunders & Fischer, 2010). However, the use of science for policy is rarely required, and the relationship between science and policy making is hotly debated (Cash et al., 2002; Cook et al., 2013; Sarkki et al., 2015).

Increasingly, researchers in the science-policy arena have contended that "efforts to connect knowledge to action are effective only if they are sufficiently salient, credible, and legitimate with multiple audiences simultaneously" (Cash, 2002, p. 6). The credibility, relevance (or salience), and legitimacy framework—also known as the CRELE framework—conceptualizes how these three interlinking attributes influence the production of knowledge, exchange of information, and interpretation of data (Sarkki et al., 2015). In CRELE, credibility refers to the perceived quality, validity, and reliability of data where sources are trustworthy, unbiased, and authoritative. Relevance refers to the usefulness and timeliness of the science to all stakeholders. Legitimacy refers to the process of including all stakeholder voices in the research process in a fair, respectful, and unbiased way (Dunn & Laing, 2017). These attributes are often strongly linked (Koetz et al., 2012), but are each essential for science to be translated into action (Cash et al., 2003). Without any one component, the use of science for decision-making is debilitated (Cook et al., 2013).

Although some scholars in the science-policy realm are increasingly using and evaluating the CRELE framework (Heink et al., 2015; Sarkki et al., 2015; van Enst et al., 2014), certain types of conservation science (e.g. citizen science) often focus almost exclusively on the credibility of their research (Conrad & Hilchey, 2011; Henderson, 2012; Wiggins et al., 2013), to the detriment of research relevance and legitimacy. Empirical research has shown that if local perceptions of costs and benefits are mismatched to program managers and designers, conservation decision-makers are unlikely to enact and achieve articulated goals (Suich, 2013).

1.2.4 Sustainable Livelihoods Approach framework

Grounding science and policy to improve the livelihoods of individuals, households, and communities, is a fundamental concern of many scholars that work in sustainable development (Bebbington, 1999). Household-centered theories like the Sustainable Livelihoods Approach (SLA) have been particularly useful in their focus on how livelihood diversification – specifically natural, financial, physical, social, and human assets – can reduce impoverishment and vulnerability (Scoones et al., 1992). Inherent within the SLA is the recognition that livelihoods are only sustainable "when they can cope with and recover from stress and shocks, and provide for future generations" (Chambers and Conway, 1992, p. 1). The utility of SLA is in its holistic inclusion of vulnerability context and household factors, with livelihood assets at its center, in understanding how households reduce vulnerabilities, increase well-being, improve food security and sustainably use natural resources (i.e., livelihood outcomes).

In the framework, the vulnerability context includes external factors such as exposure to natural disasters (Dessai et al., 2004) and economic forces like market prices (Tucker, Eakin & Castellanos, 2010), which can constrain or enable livelihood strategies and ultimately wellbeing. So too can governance and institutions, for example land tenure policies, constrain or enable livelihood strategies by allowing people to access land (Scoones, 1998).

Livelihood strategies are also influenced by the capital assets that households maintain. In this framework, natural capital refers to the stock of natural resources and environmental services useful for livelihoods (Scoones, 1998). Financial capital refers to the base of cash and economic assets useful for livelihoods (Scoones, 1998), which has well-documented influence on the household adaptive capacity (Moser, 2008). Closely connected to financial capital are physical assets (e.g. farm or household goods). Social capital, the extent and strength of social networks that facilitate access to information and financial support (Scoones, 1998), is typified by trust, reciprocity, social norms, and agency (Pelling and High, 2005). Human capital is the stock of labor, knowledge, health, and skills to actually implement adaptation strategies (Scoones, 1998).

In addition to the traditional five livelihood assets, researchers have increasingly added other assets to the SLA (Reed et al., 2013). Climate change perceptions is an asset that is known to be crucial for farmer decisions to adapt to climate events (Adger, Eakin and Winkels, 2009). For example, livestock farmers in South Africa that perceived climate change to be a threat are more likely to plant drought-resistant maize, invest in new businesses, and go to community meetings (Thomas et al., 2007). These livelihood outcomes, however, are often context specific.

1.3 RESEARCH SETTING

1.3.1 Environmental Change in Mexico

Human impacts on global climate and natural ecosystems are increasingly hard to ignore (IPCC, 2007). We have reached a point where no place on Earth can be considered a refuge from human impacts; some researchers consider this a new epoch—characterized by humans as the primary driver of change on Earth—called the Anthropocene (Lewis & Maslin, 2015). Perhaps one of greatest impacts humans have had on Earth is to forest health, where forest loss has critically increased greenhouse gas emissions (Fearnside & Laurance, 2004), accelerated landscape fragmentation (Laurance, 2004), and contributed to the loss of biodiversity (Barlow et al., 2016).

This loss of biodiversity is particularly concerning in regions of high biodiversity like Latin America (Martínez et al., 2006). The region contains seven of the 25 most biologically rich terrestrial ecoregions in the world (UNEP, 2002), where Mexico is ranked as the fifth most biodiverse nation in the world (Mittermeier et al., 1998). Because of its geographical extent across a latitudinal gradient (Willig, Kaufman, & Stevens, 2003), its highly variable topography (Garrick, 2011), and evolutionary factors such as glacial refuges (Svenning et al., 2015), Mexico contains a rich concentration of biodiversity (Mittermeier et al., 1998). Much of this biodiversity is endemic to Mexico, where 31–33% of mammals, 60–62% of amphibians, 49% of freshwater fish, and 40–50% of species of flowering plants occurring in Mexico are considered endemic (USAID 2002).

In addition to its ecological biodiversity, Mexico has also developed a rich cultural diversity (Martínez et al., 2006). It is to home of the earliest major civilizations, including the Olmec, Maya, Teotihuacan, Toltec, and Aztec. These civilizations left behind some of the most impressive architectural monuments in the world (Kubler, 1990). In part because of its geographic variance and isolation, many cultures have retained their cultural folklore, customs, and languages (Cline, 1944). Currently, the Mexican government recognizes 54 indigenous groups, who speak 240 different languages (Martínez et al., 2006).

However, despite this biological and cultural richness Mexico's political and economic instability, particularly neoliberalism, has caused uneven distribution of wealth which has led to the exploitation and resulting degradation of natural resources (Eakin, 2005). Indeed, large regions of Mexico's native forests have been converted to cash crops or cattle ranching, increasing its landscape and household vulnerability to unexpected natural shocks (Eakin & Lemos, 2006; Castellanos et al., 2013). However, vulnerability is not homogenous across Mexico, but must be locally contextualized (Eakin, 2005).

1.3.2 Environmental Change in Chiapas and Veracruz: Study Site Background

My dissertation research is located in highland regions in the southern Mexican states of Chiapas and Veracruz. The natural landscape is largely comprised of tropical montane cloud forests—with pine oak forests in some parts (Jones et al., 2019)—which are typified as richly biodiverse but threatened by deforestation (Toledo-Acevez et al., 2014). These forests are limited to mountain zones within a restricted cloud belt and are analogous to an archipelago of forest patches (Vázquez-García, 1995). Deforestation has therefore increasingly led to further isolation, fragmentation, and biodiversity loss (Cayuela et al., 2006).

These forests are typified by epiphytes, bromeliads, ferns, and broad-leafed evergreen trees (Hietz-Seifert et al., 1996; Martínez-Meléndez et al., 2009). However, 60 percent of tree species within the tropical montane cloud forests in Mexico are considered vulnerable, threatened, or endangered (González-Espinosa et al., 2011), specifically threatened by ranching, farming, and logging (Cayuela, Benayas, & Echeverría, 2006; López-Barrera, Manson, & Landgrave, 2014; Ochoa-Gaona & González-Espinosa, 2000; Trejo & Dirzo, 2000). For this reason, many of these tropical montane cloud forests represent priority areas for conservation in Mexico (Gómez-Díaz et al., 2018). The loss of trees has impaired the provisioning of resources such a timber, food, and medicine, but also important services: they buffer soils from erosion, protecting downstream communities from landslides, while providing a clean supply of water (INIFIFAP, 2012). Because many of these services are provided to beneficiaries downstream by land use practices of landowners upstream, their benefits upstream are often under-appreciated (Asbjornsen et al., 2018).

To fill this apparent gap, the Mexican government instituted a national payment for watershed services (PWS) program through its National Forestry Commission (*Comisión Nacional Forestal,* CONAFOR), focusing on paying landowners in areas of high deforestation risk to conserve upstream forested land for long term sustainable water supply downstream (Muñoz-Piña et al., 2008). These PWS programs provide cash or non-cash benefits in exchange for participation in conservation activities to improve water quality and/or supply—a potential win-win scenario for both conservation and poverty alleviation (Wunder, 2007). In addition to the national PWS approach, the Mexican government created a policy in 2008 allowing locally-funded PWS programs to develop through matching of funding between the national government with the private sector and/or local municipalities (Saldaña-Herrera, 2013). This decentralized program, called *fondos concurrentes*, has allowed PWS programs to reach every corner of Mexico, and occur in both my study sites.

Thus, my research sites in Chiapas and Veracruz are directly influenced by conservation agencies, funding bodies of *fondos concurrentes*, and research organizations within the PWS region. In Chiapas, funds are managed and matched by a non-profit organization, Funds for the Conservation of El Triunfo biosphere reserve (*Fondo para la Conservación El Triunfo*, FONCET). Here, the National Institute for Agricultural and Aquaculture Research (*Instituto Nacional de Investigaciones Agrícolas y Pecuarios,* INIFAP) also provides technical support, workshops, and funds in the region to improve livelihoods and land use practices of farmers, while reducing threats from climate change for downstream communities. In Veracruz, PWS funds are managed and matched by the non-governmental organization, Fidecoagua, in the town of Coatepec. Additionally, the trust fund for Xalapa was established by the non-governmental organization SENDAS (*Senderos y Encuentros para un Dessarrollo Autonomo Sustentable)*, which now promotes sustainable livelihoods. Matching funds in Xalapa are managed by the town's Municipal Water Commission (*Comissión Municipal de Agua Potable y Saneamiento*, CMAS).

An additional effort ongoing in Mexico is to inform these programs through community-based water monitoring. One non-governmental organization, Global Water Watch (GWW)–Mexico, was established in Coatepec in 2005 to train members of the public to examine water quality and quantity for public policy engagement. Researchers posit that integrating collaborative conservation through such programs as community-based water monitoring allows people to learn about community impacts on nature and places resource management decisions more fully into the hands of people affected by changes to the landscape (Dickinson et al., 2012; Bonney et al., 2014).

Localizing the issue within southern Mexico, I conducted research in four municipalities surrounding El Triunfo Biosphere Reserve (ETBR) in Chiapas (i.e. Pijijapan, Villa Corzo, La Concordia, and Mapastepec) and two municipalities surrounding the Cofre de Perote National Park (CPNP) in Veracruz (i.e. Xalapa and Coatepec). Within both study areas, the regions experience humid and sub-humid climates with bimodal rainfall patterns and temperatures ranging from 16.5 to 27.5 degrees Celsius (SMN, 2017). Both study areas are characterized by steep mountainous landscapes. In Chiapas, the communities surrounding ETRB live between 664 meters above sea level (MASL) and 1,788 MASL. In Veracruz, the cities of Xalapa and Coatepec are located between 1,250 and 1,425 MASL.

Although the biophysical context of the two regions are similar, their social context differs dramatically. For example, despite the richness in natural resources in the state of Chiapas, it has lagged behind the rest of the country in terms of most socio-economic indicators (INEGI, 2010). The average household in our study region in Chiapas is exceptionally poor, undereducated, and engages in market-oriented farming. Chiapas is also home to many indigenous peoples; about 28% of its population speak an indigenous language (CONAPO, 2015). On the other hand, Veracruzanos typically speak Spanish, with only 9.2% of its population speaking an indigenous language (CONAPO, 2015). Additionally, Veracruzanos within our study area characteristically have more than primary level of education (INEGI 2010) and come from a range of professions typified in urban setting.

1.3.3 Research questions

Within this research context I examined the following research questions:

1. How do vulnerability context and livelihood assets, including climate change perceptions, influence smallholder farmer adoption of adaptation strategies?

2. Who participates in citizen science, and can novel training influence perceptions of project relevance and level of participation in the research?

3. How does citizen science influence social outcomes of conservation knowledge, attitudes, and stewardship behaviors, and can novel training influence these social outcomes?

1.4 DISSERTATION STRUCTURE

The following dissertation is comprised of three main chapters, with an introduction and conclusion to frame the research. The three main chapters follow a manuscript format and are intended to be stand-alone peer-reviewed journal articles, though the chapters are topically related.

In Chapter 2, I examine determinants for smallholder farmer adoption of adaptation strategies in Chiapas, Mexico. I use the Sustainable Livelihoods Approach to understand what capitals – human, natural, economic, physical, and social capitals, in additional to climate perceptions as a new capital – influence adoption of adaptation strategies within five categories: migration, storage, land use diversification, community investment, and market exchange. Theoretically, this research advances the Sustainable Livelihoods Approach by explicitly including climate perceptions as an important but previously overlooked capital for adaptation to climate change.

In Chapter 3, I address the second research question. In a water flow monitoring citizen science project, I examine why volunteers sign up (i.e. recruitment) and continue to volunteer (i.e. retention), as well as what their major challenges are to participation. I use surveys and interviews to understand volunteer motivations to participate in citizen science, and compare these volunteers to the nature-oriented public. A contribution of this chapter is the evaluation of motivational theories, in addition to demographic characteristics, on the decisions to participate and continue volunteering. Additionally, in one of two water flow trainings, I introduced conservation decision-makers from the PWS program to the traditional training to improve perceptions of project relevancy for long term retention. This design element relies on, and contributes to, the CRELE framework. There is a paucity of empirical research examining the efficacy of the CRELE framework (Dunn & Laing, 2017), and so far as I am aware no research has been conducted using the CRELE framework in citizen science. Therefore, in collaboration with local organizations, namely GWW-Mexico I tested whether including conservation decision-makers in training would improve perceptions of project relevancy as well as participation in citizen science. The research provides important information about how members of the public differ from citizen scientists, that citizen scientists have different motivations and barriers than drop outs, and that the novel training can influence short term perceptions of project relevancy.

In Chapter 4, I address the third research question. I examine how citizen scientists differ from the nature-oriented public in terms of social outcomes, specifically conservation knowledge, attitudes, and stewardship behaviors; how participation in citizen science changes social outcomes; and how training can be designed to improve these same social outcomes, specifically by introducing conservation decision-makers to one of two traditional water monitoring trainings. Conservation decision makers discussed: (1) threats to forests in the region to influence knowledge; (2) the importance of the conservation program, PWS, for addressing those threats to influence attitudes; and (3) specific actions citizen scientists can enact to support PWS, reduce threats to forests, and preserve water in the region. Our findings suggest that participation in citizen science improves social outcomes, and that training can improve some social outcomes, specifically attitudes. This research provides empirical evidence to support the CRELE framework, while emphasizing the need to focus on all three elements, credibility, relevancy, and legitimacy, for effective changes beyond attitudes to stewardship behaviors.

REFERENCES

Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes*, *50*(2), 179-211.

Ajzen, I., & Fishbein, M. (1972). Attitudes and normative beliefs as factors influencing behavioral intentions. *Journal of Personality and Social Psychology*, *21*(1), 1.

Allcott, H. (2011). Social norms and energy conservation. *Journal of Public Economics*, *95*(9-10), 1082-1095.

Armitage, C. J., Armitage, C. J., Conner, M., Loach, J., & Willetts, D. (1999). Different perceptions of control: Applying an extended theory of planned behavior to legal and illegal drug use. *Basic and Applied Social Psychology*, *21*(4), 301-316.

Asah, S. T., & Blahna, D. J. (2012). Motivational functionalism and urban conservation stewardship: implications for volunteer involvement. *Conservation Letters*, *5*(6), 470-477.

Barlow, J., Lennox, G. D., Ferreira, J., Berenguer, E., Lees, A. C., Mac Nally, R., ... & Parry, L. (2016). Anthropogenic disturbance in tropical forests can double biodiversity loss from deforestation. *Nature*, *535*(7610), 144.

Bebbington, A. (1999). Capitals and capabilities: a framework for analyzing peasant viability, rural livelihoods and poverty. *World Development*, *27*(12), 2021-2044.

Beer, C. T. (2014). Climate justice, the Global South, and policy preferences of Kenyan environmental NGOs. *The Global South*, *8*(2), 84-100.

Bennett, N. J. (2016). Using perceptions as evidence to improve conservation and environmental management. *Conservation Biology*, *30*(3), 582-592.

Berger, L., Bleichrodt, H., & Eeckhoudt, L. (2013). Treatment decisions under ambiguity. *Journal of Health Economics*, *32*(3), 559-569.

Bonney, R., Shirk, J. L., Phillips, T. B., Wiggins, A., Ballard, H. L., Miller-Rushing, A. J., & Parrish, J. K. (2014). Next steps for citizen science. *Science*, *343*(6178), 1436-1437.

Bruyere, B., & Rappe, S. (2007). Identifying the motivations of environmental volunteers. *Journal of Environmental Planning and Management*, *50*(4), 503-516.

Cayuela, L., Benayas, J. M. R., & Echeverría, C. (2006). Clearance and fragmentation of tropical montane forests in the Highlands of Chiapas, Mexico (1975–2000). *Forest Ecology and Management*, *226*(1-3), 208-218.

Clary, E. G., Snyder, M., Ridge, R. D., Copeland, J., Stukas, A. A., Haugen, J., & Miene, P. (1998). Understanding and assessing the motivations of volunteers: a functional approach. *Journal of Personality and Social Psychology*, *74*(6), 1516.

Cline, H. (1944). Lore and Deities of the Lacandon Indians, Chiapas, Mexico. *The Journal of American Folklore*, *57*(224), 107-115.

Coghlan, D., & Shani, A. R. (2005). Roles, politics, and ethics in action research design. *Systemic Practice and Action Research*, *18*(6), 533-546.

Comim, F. (2008). Climate Injustice and Development: A capability perspective. *Development*, *51*(3), 344-349.

Conner, M., & Abraham, C. (2001). Conscientiousness and the theory of planned behavior: Toward a more complete model of the antecedents of intentions and behavior. *Personality and Social Psychology Bulletin*, *27*(11), 1547-1561.

Conner, M., Norman, P., & Bell, R. (2002). The theory of planned behavior and healthy eating. *Health Psychology*, *21*(2), 194.

Consejo Nacional de Pobalción (CONAPO). 2015. Infografía: Población indígena. Available at: https://www.gob.mx/cms/uploads/attachment/file/121653/Infografia_INDI_FINAL_08082016.pdf

Darke, P. R., Chaiken, S., Bohner, G., Einwiller, S., Erb, H. P., & Hazlewood, J. D. (1998). Accuracy motivation, consensus information, and the law of large numbers: Effects on attitude judgment in the absence of argumentation. *Personality and Social Psychology Bulletin*, *24*(11), 1205-1215.

Dickinson, J. L., Shirk, J., Bonter, D., Bonney, R., Crain, R. L., Martin, J., ... & Purcell, K. (2012). The current state of citizen science as a tool for ecological research and public engagement. *Frontiers in Ecology and the Environment*, *10*(6), 291-297.

Dunn, G., & Laing, M. (2017). Policy-makers perspectives on credibility, relevance and legitimacy (CRELE). *Environmental Science & Policy*, *76*, 146-152.

Eakin, H. (2005). Institutional change, climate risk, and rural vulnerability: Cases from Central Mexico. *World Development*, *33*(11), 1923-1938.

Easley, D., & O'Hara, M. (2009). Ambiguity and nonparticipation: The role of regulation. *The Review of Financial Studies*, *22*(5), 1817-1843.

Fearnside, P. M., & Laurance, W. F. (2004). Tropical deforestation and greenhouse-gas emissions. *Ecological Applications*, *14*(4), 982-986.

Fehr, E., & Gächter, S. (2000). Fairness and retaliation: The economics of reciprocity. *Journal of economic perspectives*, *14*(3), 159-181.

Fernandez, R., & Rodrik, D. (1991). Resistance to reform: Status quo bias in the presence of individual-specific uncertainty. *The American Economic Review*, 1146-1155.

Ferraro, P. J., & Kiss, A. (2002). Direct payments to conserve biodiversity. *Science, 298* (559), 1718-1719.

Füssel, H. M. (2010). How inequitable is the global distribution of responsibility, capability, and vulnerability to climate change: A comprehensive indicator-based assessment. *Global Environmental Change*, *20*(4), 597-611.

Garrick, R. C. (2011). Montane refuges and topographic complexity generate and maintain invertebrate biodiversity: recurring themes across space and time. *Journal of Insect Conservation*, *15*(3), 469-478.

Giles, M., Mcclenahan, C., Cairns, E., & Mallet, J. (2004). An application of the theory of planned behaviour to blood donation: the importance of self-efficacy. *Health Education Research*, *19*(4), 380-391.

Goldstein, N. J., & Cialdini, R. B. (2007). Using social norms as a lever of social influence. *The Science of Social Influence: Advances and future progress*, 167-192.

Gómez-Díaz, J. A., Brast, K., Degener, J., Krömer, T., Ellis, E., Heitkamp, F., & Gerold, G. (2018). Long-Term Changes in Forest Cover in Central Veracruz, Mexico (1993–2014). *Tropical Conservation Science*, *11*, 1940082918771089.

González-Espinosa, M., Meave, J.A., Lorea-Hernández, F.G., Ibarra-Manríquez, G. & Newton, A. (Eds). (2011). The red list of Mexican cloud forest trees. Fauna & Flora International: Cambridge, UK.

Han, H., Hsu, L. T. J., & Sheu, C. (2010). Application of the theory of planned behavior to green hotel choice: Testing the effect of environmental friendly activities. *Tourism Management*, *31*(3), 325-334.

Heath, Y., & Gifford, R. (2002). Extending the theory of planned behavior: Predicting the use of public transportation 1. *Journal of Applied Social Psychology*, *32*(10), 2154-2189.

Heink, U., Marquard, E., Heubach, K., Jax, K., Kugel, C., Nesshoever, C., ... & Vandewalle, M. (2015). Conceptualizing credibility, relevance and legitimacy for evaluating the effectiveness of science–policy interfaces: challenges and opportunities. *Science and Public Policy*, *42*(5), 676-689.

Henrich, J., Boyd, R., Bowles, S., Camerer, C., Fehr, E., Gintis, H., & McElreath, R. (2001). In search of homo economicus: behavioral experiments in 15 small-scale societies. *American Economic Review*, *91*(2), 73-78.

Heyward, M. (2007). Equity and international climate change negotiations: a matter of perspective. *Climate Policy*, *7*(6), 518-534.

Higgins, O., & Shackleton, C. M. The benefits from and barriers to participation in civic environmental organisations in South Africa. *Biodiversity and Conservation*, 1-16.

Intergovernmental Panel on Climate Change (IPCC). (2018) Summary for policy makers of the IPCC Special Report on global warming of 1.5C. Available at: https://www.ipcc.ch/2018/10/08/summary-for-policymakers-of-ipcc-special-report-on-global-warming-of-1-5c-approved-by-governments/

Karppinen, H. (2005). Forest owners' choice of reforestation method: an application of the theory of planned behavior. *Forest Policy and Economics*, *7*(3), 393-409.

Katz, D. (1960). The functional approach to the study of attitudes. *Public Opinion Quarterly*, *24*(2), 163-204.

Kelman, H. C. (1965). Manipulation of human behavior: An ethical dilemma for the social scientist. *Journal of Social Issues*, *21*(2), 31-46.

Klöckner, C. A. (2013). A comprehensive model of the psychology of environmental behaviour—A meta-analysis. *Global Environmental Change*, *23*(5), 1028-1038.

Klöckner, C. A., & Blöbaum, A. (2010). A comprehensive action determination model: Toward a broader understanding of ecological behaviour using the example of travel mode choice. *Journal of Environmental Psychology*, *30*(4), 574-586.

Kubler, G. (1990). *The Art and Architecture of Ancient America: The Mexican, Mayan, and Andean Peoples.* Yale University Press: New Haven, CT.

Langley, P., & Leaver, A. (2012). Remaking retirement investors: behavioural economics and defined-contribution occupational pensions. *Journal of Cultural Economy*, *5*(4), 473-488.

Laurance, W. F. (2004). Forest-climate interactions in fragmented tropical landscapes. *Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences*, *359*(1443), 345-352.

Lee, T. K., Crowston, K., Harandi, M., Østerlund, C., & Miller, G. (2018). Appealing to different motivations in a message to recruit citizen scientists: results of a field experiment. *Journal of Science Communication*, *17*(1), A02.

Leichenko, R., & Silva, J. A. (2014). Climate change and poverty: vulnerability, impacts, and alleviation strategies. *Wiley Interdisciplinary Reviews: Climate Change*, *5*(4), 539-556.

Lewis, S. L., & Maslin, M. A. (2015). Defining the anthropocene. *Nature*, *519*(7542), 171.

López-Barrera, F., Manson, R. H., & Landgrave, R. (2014). Identifying deforestation attractors and patterns of fragmentation for seasonally dry tropical forest in central Veracruz, Mexico. *Land Use Policy*, *41*, 274-283.

Martínez, M. L., Manson, R. H., Balvanera, P., Dirzo, R., Soberón, J., García-Barrios, L., ... & Sarukhán, J. (2006). The evolution of ecology in Mexico: facing challenges and preparing for the future. *Frontiers in Ecology and the Environment*, *4*(5), 259-267.

Martínez-Meléndez, N., Pérez-Farrera, M., & MartÍnez-Camilo, R. (2009). The Vascular Epiphyte Flora of El Triunfo Biosphere Reserve, Chiapas, México. *Rhodora*, *111*(948), 503-536.

Mendelsohn, R., Dinar, A., & Williams, L. (2006). The distributional impact of climate change on rich and poor countries. *Environment and Development Economics*, *11*(2), 159-178.

Mittermeier, R. A., Myers, N., Thomsen, J. B., Da Fonseca, G. A., & Olivieri, S. (1998). Biodiversity hotspots and major tropical wilderness areas: approaches to setting conservation priorities. *Conservation biology*, *12*(3), 516-520.

Morrison-Saunders, A., & Fischer, T. B. (2010). What is wrong with EIA and SEA anyway? A sceptic's perspective on sustainability assessment. In *Tools, Techniques and Approaches for Sustainability: Collected Writings in Environmental Assessment Policy and Management* (pp. 221-241).

Muradian, R., Arsel, M., Pellegrini, L., Adaman, F., Aguilar, B., Agarwal, B., ... & Garcia-Frapolli, E. (2013). Payments for ecosystem services and the fatal attraction of win-win solutions. *Conservation letters*, *6*(4), 274-279.

Netemeyer, R. G., & Burton, S. (1990). Examining the relationships between voting behavior, intention, perceived behavioral control, and expectation. *Journal of Applied Social Psychology*, *20*(8), 661-680.

O'Brien, K. L., & Leichenko, R. M. (2000). Double exposure: assessing the impacts of climate change within the context of economic globalization. *Global environmental change*, *10*(3), 221-232.

Ochoa-Gaona, S., & González-Espinosa, M. (2000). Land use and deforestation in the highlands of Chiapas, Mexico. *Applied Geography*, *20*(1), 17-42.

Panagopoulos, C., & Harrison, B. (2016). Consensus Cues, Issue Salience and Policy Preferences: An Experimental Investigation. *North American Journal of Psychology*, *18*(2), 405.

Pattanayak, S. K., Wunder, S., & Ferraro, P. J. (2010). Show me the money: do payments supply environmental services in developing countries?. *Review of Environmental Economics and Policy*, *4*(2), 254-274.

Penner, L. A. (2002). Dispositional and Organizational Influences on Sustained Volunteerism: An Interactionist Perspective. *Journal of Social Issues*, *58*(3), 447–467. https://doi.org/10.1111/1540-4560.00270

Rollnick, S., Heather, N., & Bell, A. (1992). Negotiating behaviour change in medical settings: the development of brief motivational interviewing. *Journal of Mental Health*, *1*(1), 25-37.

Roth, A. E., Prasnikar, V., Okuno-Fujiwara, M., & Zamir, S. (1991). Bargaining and market behavior in Jerusalem, Ljubljana, Pittsburgh, and Tokyo: An experimental study. *The American Economic Review*, 1068-1095.

Ryan, R. L., Kaplan, R., & Grese, R. E. (2001). Predicting volunteer commitment in environmental stewardship programmes. *Journal of Environmental Planning and Management*, *44*(5), 629-648.

Saldaña-Herrera, Joaquín David. 2013. *Sistematización Y Documentación de Mecanismos Locales de Pago Por Servicios Ambientales En México*. México.: Comisión Nacional Forestal (CONAFOR), United States Agency for International Development (USAID), Fondo Mexicano para la Conservación de la Naturaleza, A.C.

Sarkki, S., Tinch, R., Niemelä, J., Heink, U., Waylen, K., Timaeus, J., ... & van den Hove, S. (2015). Adding 'iterativity'to the credibility, relevance, legitimacy: a novel scheme to highlight dynamic aspects of science–policy interfaces. *Environmental Science & Policy*, *54*, 505-512.

Schneider, B., Broda, M., Judy, J., & Burkander, K. (2013). Pathways to college and STEM careers: Enhancing the high school experience. *New Directions for Youth Development*, *2013*(140), 9-29.

Sen, A. (2005). Human rights and capabilities. *Journal of human development*, *6*(2), 151-166.

Servicio Meteorológico Nacional (SMN) (2017) Resumen mensual de temperaturas y lluvia. Servicio Metereologico Nacional, Mexico City https://smn.cna.gob.mx/es/climatologia/temperaturasy lluvias/resumenesmensualesde720temperaturasylluvias. [online] Available at [accessed 11 Mar 2019]

Sniehotta, F. F., Presseau, J., & Araújo-Soares, V. (2014). Time to retire the theory of planned behaviour. *Health Psychology Review*, *8*(1): 1-7.

Svenning, J. C., Eiserhardt, W. L., Normand, S., Ordonez, A., & Sandel, B. (2015). The influence of paleoclimate on present-day patterns in biodiversity and ecosystems. *Annual Review of Ecology, Evolution, and Systematics*, *46*, 551-572.

Thaler, R. (1980). Toward a positive theory of consumer choice. *Journal of Economic Behavior & Organization*, *1*(1), 39-60.

Thaler, R. H. (2000). From homo economicus to homo sapiens. *Journal of Economic Perspectives*, *14*(1), 133-141.

Trejo, I., & Dirzo, R. (2000). Deforestation of seasonally dry tropical forest: a national and local analysis in Mexico. *Biological Conservation*, *94*(2), 133-142.

Tversky, A., & Kahneman, D. (1974). Judgment under uncertainty: Heuristics and biases. *Science*, *185*(4157), 1124-1131.

Toledo-Aceves, T., García-Franco, J. G., Williams-Linera, G., MacMillan, K., & Gallardo-Hernández, C. (2014). Significance of remnant cloud forest fragments as reservoirs of tree and epiphytic bromeliad diversity. *Tropical Conservation Science*, *7*(2), 230-243.

Tonglet, M., Phillips, P. S., & Bates, M. P. (2004). Determining the drivers for householder pro-environmental behaviour: waste minimisation compared to recycling. *Resources, Conservation and Recycling*, *42*(1), 27-48.

Toomey, A. H., & Domroese, M. C. (2013). Can citizen science lead to positive conservation attitudes and behaviors. *Human Ecology Review*, *20*(1), 50-62.

United Nations Environment Programme (UNEP). (2002). Global environment outlook – 3. London, UK: UNEP

Van Enst, W. I., Driessen, P. P., & Runhaar, H. A. (2014). Towards productive science-policy interfaces: a research agenda. *Journal of Environmental Assessment Policy and Management*, *16*(01), 1450007.

Van der Linden, S., Leiserowitz, A., Rosenthal, S., & Maibach, E. (2017). Inoculating the public against misinformation about climate change. *Global Challenges*, *1*(2), 1600008.

Vázquez-Garcia, J. A. (1995). Cloud forest archipelagos: preservation of fragmented montane ecosystems in tropical America. In *Tropical montane cloud forests* (pp. 315-332). Springer, New York, NY.

Walter, G. A., Marks, S. E., & James, J. E. (1981). Experiential learning and change: Theory design and practice. *Scandinavian Journal of Behaviour Therapy, 4*: 109-137.

Willig, M. R., Kaufman, D. M., & Stevens, R. D. (2003). Latitudinal gradients of biodiversity: pattern, process, scale, and synthesis. *Annual review of ecology, evolution, and systematics*, *34*(1), 273-309.

Wunder, S. (2007). The efficiency of payments for environmental services in tropical conservation. *Conservation biology*, *21*(1), 48-58.

--(2013). When payments for environmental services will work for conservation. *Conservation letters*, *6*(4), 230-237.

2. CHAPTER TWO. SMALLHOLDER FARMER ADOPTION OF CLIMATE-RELATED ADAPTATION STRATEGIES: THE IMPORTANCE OF VULNERABILITY CONTEXT, LIVELIHOOD ASSETS, AND CLIMATE PERCEPTIONS[1]

2.1 INTRODUCTION

How rural communities respond to climate change-related events is an area of great concern, particularly as climate events become more frequent and severe (Adger, Brown and Tompkins, 2005; Berkes, 2007; Eakin et al., 2012). There are some 475 million smallholder farmers worldwide (FAO, 2016), who contribute to global food security, yet are highly vulnerable to climate change (Graeub et al., 2017; Morton, 2007). Understanding what adaptation strategies are used to moderate, reduce, or offset the impacts of climate change for these farmer households can help inform future management and policy strategies (IPCC, 2007). In this research, we examine why smallholder coffee farmers, who face multiple stressors, including volatile market prices and climate change, adopt costly adaptation strategies in Chiapas, Mexico.

Coffee farmers exemplify vulnerability to multiple stressors. Between 2008 and 2013, Latin American coffee-producing countries had historically low production, driven by the emergence of coffee rust, caused by the fungus *Hermileia vastrix* (Avelino et al., 2015). Coffee rust decimated crops, caused many coffee-producing nations to issue a state of emergency, and forced nations to reconsider how coffee is managed especially under imminent changes to climate (Vandermeer, Jackson and Perfecto, 2014). Top coffee producing nations like Mexico saw massive declines to production, with one agricultural agency reporting that coffee production had declined by 30% in one year alone due to coffee rust and adverse weather conditions like frost (USDA Foreign Agricultural Service, 2014). Climate trends for Mexico have already shown an increase in maximum and minimum temperature, and future climate scenarios show

[1] This has been published in Environmental Management, with co-authors Kelly Jones, Andrómeda Rivera, Walter López-Baez, and Dennis Ojima

stronger drought events (Schroth et al., 2009). Smallholder producers in Mexico who rely on coffee as their main source of income face impoverishment, malnutrition, and even forced migration if they are not able to adapt to these changing conditions (Lin, Perfecto and Vandermeer, 2008).

Although there has been a significant increase in research on household and community characteristics that are indicative of adaptive capacity (Brooks, Adger and Kelly 2005; Eakin and Lemos, 2006; Yohe and Tol, 2002), there remains a gap in empirical studies testing what determines whether farmers actually implement adaptive strategies (Smit and Pilifosova, 2003). Farm-level research suggests that households adopt adaptive strategies such as: shifting planting/harvesting dates and locations; changing land use and land use management practices; diversifying livelihood strategies; and investing in new technology such as irrigation or crop insurance (Bryan et al., 2013). However, farmers' ability and interest in adopting these strategies depends on the social and geographic context within which farmers live (Harvey et al., 2017). As climate change threatens food security and farmer well-being across Latin America (Bacon et al., 2017; Harvey et al., 2017; Hertel, Burke and Lobell, 2010), and in southern Mexico particularly (Saldaña-Zorrilla, 2008), there is a need to focus research in these regions. Understanding what adaptation strategies farmers adopt, and why, can guide policy-making to increase smallholder resiliency to future climate changes (Eakin, Lemos, and Nelson, 2014).

To understand why coffee farmers adopt climate adaptation strategies in Chiapas, Mexico we conducted 291 household surveys in eight communities in the buffer zone of El Triunfo Biosphere Reserve (ETBR), located in the mountains of the Sierra Madre de Chiapas, Mexico. This region is known for its high levels of biodiversity, as well as its susceptibility to flooding, landslides, and hurricanes (Gay et al., 2006; Saldaña-Zorrilla, 2008; Schroth et al., 2009). The specific objectives of this work were: (1) to document the prevalence of adaptation strategies for smallholder *ejido* farmers; (2) to explore which vulnerability and livelihood assets were determining factors for adoption of adaptation strategies; and (3) to characterize climate change perceptions and their influence on adoption of adaptation strategies. Within each community, governmental and non-governmental organizations have promoted climate adaptive strategies via trainings and workshops, but with different levels of efforts and success across communities. There is a critical need to identify options for adapting to climate change and to support farmers in adopting these strategies. Accordingly, we identify how policy makers promote and encourage smallholder adaptation strategies in Mexico and similar Latin American and rural contexts.

2.2 CONCEPTUAL FRAMEWORK

Vulnerability science focuses on household and community adaptive capacity and the stock of capabilities that allow for successful response to disturbance (McCarthy et al., 2001). A related concept is adaptation, or the action of applying adaptive capacity within a system (Smit and Wandel, 2006), which is less well studied. We use the Sustainable Livelihoods Approach (SLA) as a framework which focuses on how livelihood assets are used to achieve livelihood outcomes such as improved well-being. We build on the SLA by integrating a focus on household adoption of costly adaptation strategies, with consequences for livelihood outcomes (Fig. 2.1). Households can respond or adapt to climate change through a number of strategies, including: migration, where risks are pooled across space (Mearns and Norton, 2010); storage, where resources are pooled over time (Badstue et al., 2007); land use diversification, where risks are pooled across resources; community investment, where risks are pooled across households (Doss and Meinzen-Dick, 2015); and market exchange, where specialization, trade, and income-generation allows for diversification (Agrawal, 2010).

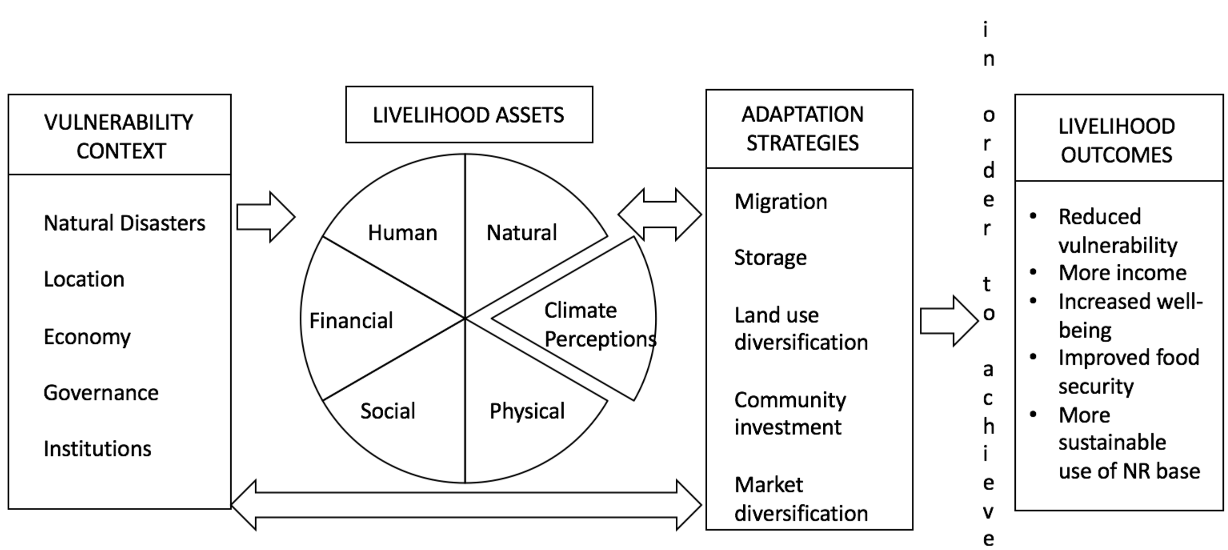


Fig. 2.1 Sustainable Livelihoods Approach modified to include adaptation strategies.

Migration, storage, land use diversification, community investment, and market exchange require a commitment of resources. Understanding when farmers will undertake costly adaptation strategies is one of the central goals for this research. We use the SLA to examine how livelihood assets enable or constrain adoption of adaptation strategies (Fig. 2.1). For example, farmers' ability to diversify crops (i.e. land use diversification) is enabled or constrained by their natural capital, the stock of natural resources, and the environmental services that are useful for livelihoods (Scoones, 1998). Thus, land-rich farmers have more flexibility in diversifying their crops (Smit and Pilifosova, 2003). Similarly, wealthy farmers with financial capital to draw on can more proactively invest in new technologies, seeds, or chemicals that improve yields (i.e. market exchange) (Tucker, Eakin and Castellanos, 2010). Closely connected to financial capital are physical capital assets (e.g. farm or household goods) that can be transformed to generate income (Moser and Felton, 2007) to invest in new agricultural technologies (Knowler and Bradshaw, 2007). The extent and strength of social networks, or social capital, can also improve household income (Narayan and Pritchet, 1999) while lowering costs of migration for individuals with strong ties to family members abroad (e.g. Garip, 2008). Finally, the household stock of labor, knowledge, and skills (i.e. human capital), specifically years of schooling, can improve engagement in off-farm activities (Yúnez-Naude and Taylor, 2001).

In addition to the traditional five livelihood assets, researchers have increasingly added other assets, like climate change perceptions, to the SLA. While climate change perceptions alone rarely drive adaptation behaviors (Mertz et al., 2009), when farmers have livelihood assets to draw on, climate change perceptions may be crucial for determining whether and to what extent farmers decide to adapt (Bryan et al., 2013). For example, researchers found that cattle ranchers in South Africa that perceived climate change to be a threat, stored fodder for cattle (storage), planted drought-resistant maize (land use diversification), invested in new businesses projects (market exchange), and went to village meetings (community investment) (Thomas et al., 2007). Additionally, climate perceptions and livelihood assets are influenced by the households' vulnerability context, specifically: the prevalence of natural disasters (Dessai et al., 2004), the community's location, economic forces like market prices (Tucker, Eakin and

Castellanos, 2010), as well as governance structures and institutions (Scoones et al. 1998). This vulnerability context may also directly influence farmers' choice of adaptation strategies.

2.3 METHODS

2.3.1 Study location

Our study focuses on eight coffee producing communities in Chiapas, Mexico, located in the buffer zone of El Triunfo Biosphere Reserve (ETRB) (Fig. 2.2). Communities hold land in common called *ejido* land. The tenure regime allows land to be managed in common as well as split into individual parcels (Assies, 2008). Land owners within the *ejido*, called *ejiditarios,* cannot sell or mortgage their individual parcels of land, and have voting rights within the *ejido* on communal land use, while *non-ejiditarios have privately owned land outside the jurisdiction of villagers within the ejido* (Assies, 2008). Surrounding the *ejidos*, the landscape of ETRB is comprised of a mosaic of lush forests, shrub, farms, and small towns. Farmers primarily cultivate cash crops like coffee, which is increasingly organic, shade-grown, and to a lesser extent bird-friendly certified (Jurjonas et al., 2016). Within our study area, the majority of land is considered non-farm land which includes forested biosphere reserve area (RAN, 2017). All communities experience humid and sub-humid climates with bimodal rainfall patterns, and temperatures ranging from 16.5 to 27.5 degrees C (Table 2.1).

Table 2.1 Characteristics of the *ejidos* and landowners selected within the region.

Ejido #	1	2	3	4	5	6	7	8	TOTAL
# of landowners surveyed	18	44	33	33	15	56	26	73	291
% of landowners surveyed†	52.9	59.5	15.9	67.3	22.1	29.6	33.3	25.1	-
# hectares owned by respondents	52	179	250	1187	138	337	192	837	3173
# hectares within the *ejido*†	104	363	681	2327	1266	3281	2265	5834	16121
% farmland*	10.2	10.2	25.4	36.6	36.6	10.2	31	31	-
% cattle land*	14.5	14.5	7.7	6.4	6.4	14.5	18.9	18.9	-

% non-farm *	75.3	75.3	66.9	57	57	75.3	50.1	50.1	-
Altitude (masl) ††	1228	1388	683	509	694	1799	813	664	-
Ave. temp (C)††	27.5	27.5	24.1	27.5	27.5	27.6	16.5	16.5	-
Ave. precipitation††	1351	1351	1613	2739	2739	1351	1351	1351	-

* Source: RAN, 2017

† Source: INEGI, (2007b)

†† Source: SMN, (2017)

2.3.2 Data collection

We conducted a household survey of 291 farmers in eight communities in Spanish in May 2016 (Appendix I, A.1.1). From each community, we solicited a list of *ejiditarios* and non-*ejiditario* landowners, which were then numbered, and selected at random using a random number generator. Before commencing the survey, respondents were asked whether they were the decision-makers on their land. Male and female heads of the household had an equal chance of being surveyed, where our sample was representative of municipality-level gender division in land ownership (INEGI, 2007a). The survey contained themes on: (1) demographics; (2) land tenancy, quality, and crops; (3) government income; (4) climate change resilience and adaptation strategies; (6) community and group participation; and (7) wealth. Average survey time was 78 minutes.

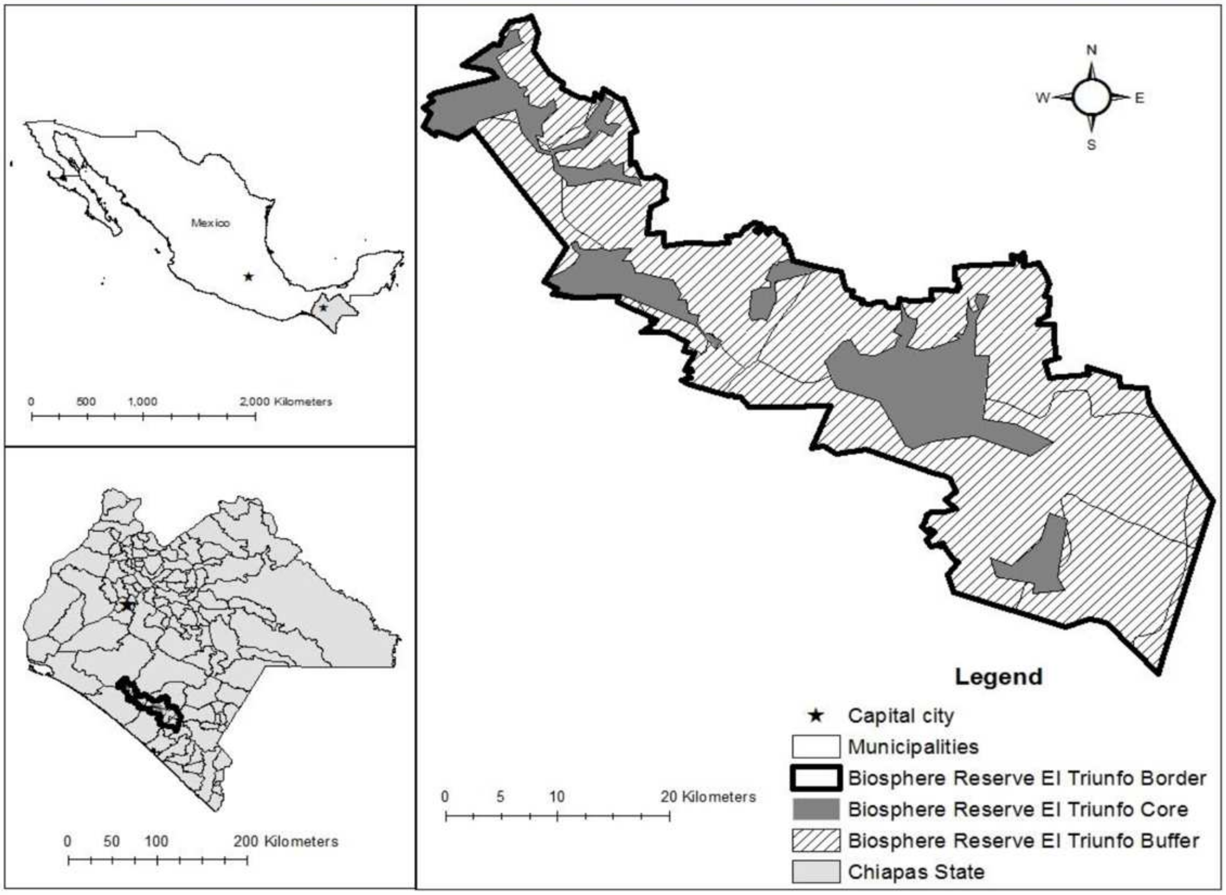


Fig. 2.2 Map of Chiapas, Mexico, the biosphere reserve, and study sites.

2.3.2.1 Adaptation strategies

To measure adaptive strategies, we examined: migration, storage, land use diversification, community investment, and market exchange. We used the 21 indicators outlined by the World Bank on adaptive strategies to climate change (Agrawal, 2010). Because adaptation strategies are location-specific (O'Brien et al., 2007), we also added five indicators identified by local partners. These included soil conservation strategies, living wall construction, building filtration dams, planting shade coffee, and planting fruit trees. In total, respondents were asked whether they had or had not taken 26 different actions to reduce their vulnerability to natural disasters. Each action was asked as a yes/no question; we summed across the five categories to create an overall adaptation index (Below et al., 2012) and also used the sum of each category independently in analysis.

2.3.2.2 Independent variables

To capture factors related to a household's vulnerability context, we collected data on experience with: natural disasters within the last ten years, asking whether and what type of disaster they had experienced; and distance to markets to capture remoteness of the household. Market access influences a number of factors, such as ability to migrate for work, livelihood strategy, wealth, and access to information, that would influence a household's vulnerability context (Gray et al., 2008). To measure market access, participants were asked how much time in minutes it took for farmers to travel from their field to sell their goods.

To capture information about household capabilities, we collected data on the livelihood assets based on the SLA – social, human, physical, financial, and natural assets – and climate perceptions as a separate asset. Financial capital is particularly difficult to measure accurately in developing nations (World Bank, 2005), therefore, we restricted our questions on financial capital to government subsidies received as they represent a significant source of off-farm income for almost all coffee farmers in the region (Barham et al. 2011). Social capital included questions about whether the household participates in formal or informal organizations including: agricultural cooperatives, community organizations, governmental organizations, or community-based water monitoring. Research shows that groups like coffee cooperatives are important venues for information-sharing about farming practices, shaping farmers adaptations to climate risks (Frank, Eakin and López-Carr, 2011). We measured human capital with questions related to sex, age, level of education, and number of family members. Studies show that education improves household farm incomes and ability to engage in off-farm activities (Yúnez-Naude and Taylor, 2001). We measured physical capital with questions related to ownership of household assets, including cars, motorcycles, bicycles, horses, chickens, pigs, chainsaws, cell phones, and televisions. Household services were also included such as plumbing and electricity. Research shows that physical capital is closely related to financial capital, allowing "poor to accumulate and consolidate their assets in a sustainable way" (Moser, 2007, p 11). Finally, we measured natural capital with a question on the number of hectares farmers owned and the percent of their land that was considered productive. The majority of coffee producers in Mexico are smallholders, with 90% cultivating less than five hectares (Gonzalez-Jacome, 2004). Smallholder farmers are more likely to intermix coffee production with beans, corn, and fruit trees for personal consumption (Gonzalez-Jacome, 2004). Intermixing of crops is a key adaptation strategy since it diversifies crops, reducing risks when pests and diseases occur.

We measured household perceptions of weather and climate change using 12 questions on a 5-point Likert scale. These questions focused on perceptions of frequency and intensity of six climate-related phenomenon including temperature, rainfall, landslides, hurricanes, crop plagues, and pests. Of the 12 questions: three were on temperature, three on rainfall, two on climate change generally, one on landslides, one on hurricanes, one on crop plague, and one on crop pests.

2.3.3 Data analysis

2.3.3.1 Variable creation and accuracy tests

For the 5-point Likert scale questions on climate perceptions, the scale was summed and averaged to calculate separate composite scores (Boone & Boone, 2012). Likert scale questions were also analyzed for internal reliability using Cronbach's alpha, using a lower bound of 0.60 (Nunnally & Bernstein, 1994). For climate change perceptions, all questions were included in the composite variable based on the Cronbach's alpha score, with a standardized coefficient of 0.64.

In summing across the adaptive strategies, dropping some indicators improved the Cronbach's alpha. Specifically, strategies that were not culturally relevant (i.e. crop insurance) or likely misinterpreted (i.e. water storage) were dropped. A literature review and personal communication with partners in the region confirmed that crop insurance is not considered culturally relevant (Harvey et al., 2017; Saldaña-Zorrilla, 2008). Water storage may have been misinterpreted since *post-facto* researchers found that most farmers had water storage tanks for daily use rather than for storage in case of disaster. The final adaptation index consisted of 18 strategies. We worked under the basic assumption that farmers who adopt a higher number of adaptation practices would be better able to respond to climate change (Below et al., 2012).

A household wealth index was created using principal component analysis (Vyas and Kumaranayake, 2006). Ten assets (variables) were included in the principal component analysis. Researchers used varimax rotational factors to ensure the variables were loaded maximally to one factor, which included the household assets of cars, motorcycles, and gas stove. Because factors two, three and four only explained a sub-group of variables researchers concluded that the first principal component provided an adequate measure of wealth for the study area (Appendix I, A.1.2).

2.3.3.2 T-tests and multiple linear regression

To understand how climate perceptions related to adaptation strategies, we first took our overall adaptation index (sum of all 18 adaptation strategies) and split it between high scores (between 18-12) and low scores (between 11-0), with a median score of 12 and mean of 11.5. A two-sample t-test was then conducted between high and low adaptive households to analyze whether climate perceptions and the other five capital assets varied across low and high adopters.

To understand the combined determinants of farmer adoption of adaptive strategies, we used multiple linear regression analysis. Prior to regression, we checked for multicollinearity between independent variables using a correlation test and the Variance Inflation Factor (VIF) (Peng, 2009). We also examined Cook's Distance to determine outliers. Only one outlier for number of hectares owned was identified as having a Cook's Distance greater than 0.10, which is regarded as unusual (Heiberger and Holland, 2004); this observation was excluded.

We used linear ordinary least squares regression to test the correlation between independent variables and our index of adaptation strategies (Peng, 2009). The final set of independent variables was determined based on the conceptual model (Fig. 2.1) and Best Subset Selection, a method which selects variables based on the global chi-square to help triangulate the base model and stepwise variable selection (using Kaiser's Rule to select AIC values less than 1) (Marasinghe and Kennedy, 2008). We estimated robust standard errors. Residual diagnostic plots were used to assess model assumptions of normality and equality of variances.

First, we present results from the following regression model:

$$Y_i = \beta_0 + \beta_1 HC_i + \beta_2 NC_i + \beta_3 PC_i + \beta_4 FC_i + \beta_5 SC_i + \beta_6 CC_i + \beta_7 VC_i + \beta_8 Ejido_j + \varepsilon_i, \quad (1)$$

where: Y_i is the adaptation index for household i; $\beta_1 - \beta_5$ include independent variables measuring the five livelihood assets; β_6 captures climate change perceptions; and β_7 includes variables measuring vulnerability context. Equation 1 also includes an ejido-level dummy variable, measured by β_8, for each j ejido, to control for community-level variation. Differences across ejidos that could influence household-level adaptation might include: the location of the *ejido*; the quality of public services like roads, schools, and health centers; the quality and type of goods that are available like technologies; the flow of information; or even social norms. Thus, the community-level dummy variable captures contextual factors within the community, as well as the vulnerability context. We present a second regression model that excludes human capital variables, β_1, based on our Best Subset Model results. Finally, in addition to using the sum of all adaptive strategies as the dependent variable, we also conducted multiple regression analysis with the sum of each individual adaptive strategy category (i.e., migration, storage, land use diversification, community investment and market exchange) and the full set of independent variables in Equation 1.

2.4 RESULTS

2.4.1 Descriptive statistics

Within our sample, about 19% of respondents were female (Appendix I, A.1.1). The average respondent was around 52 years old, with a relatively low level of education, had a family of five, and participated in one group. Households received on average 13,487 Mexican pesos from government subsidies in 2015 (899 USD). Households owned an average of 10.9 hectares, although more than 54 percent of land was reported as uncultivatable. Most fields were located far from where farmers sell their crops on the market, at almost 118 minutes away.

Farmers strongly perceived the impacts of climate change: on a Likert scale of 1 to 5, households had an average score of 4. More than 80% of respondents had experienced a disaster in the last ten years, of those 59% mentioned experiencing a hurricane, 10% mentioned earthquakes and landslides (each), 7%

mentioned drought, 5.7% mentioned coffee rust, and 3.7% mentioned flooding. However, on the 5-point Likert scale, coffee rust and higher temperatures were considered most highly concerning, reflecting that while farmers expect short-term extreme shocks (e.g. hurricanes) they are far more concerned about long-term risks such as coffee rust or temperature, that require costly investment into new adaptations strategies.

2.4.2 Adaptation strategies

In terms of individual adaptation strategies, farmers reported most frequently growing shade coffee (82%), planting different varieties of crops (75%) and changing the date of sowing (70%) (Fig. 2.3). Other frequently implemented practices included building living walls (69%), reforesting (63%), and using soil conservation strategies like cover crops (63%). Strategies like building filtration dams to confront landslides and floods (34%), changing where crops were planted (26%) and changing the crops themselves (20%), were less likely to be implemented.

Farmers frequently adopted community investment adaptation strategies (86%), specifically building community infrastructure (e.g. roads, waterways, and electricity). Many farmers also established connections to information sources regarding natural disasters (63%), and prepared a way to get in touch with friends and family in case of an emergency (60%).

Farmers frequently stored seeds in case of a natural disaster (64%). However, fewer farmers stored livestock or small animals for times of need (47%). For frequency of adoption of market strategies, farmers were almost equally likely to invest in fertilizers as not (48%). Some farmers have developed direct access to markets to cut out the middlemen (46%); however, few have more than one income source besides farming (30%). Few invested in machines like depulpers for coffee fruits (23%), or irrigation (20%), and almost none were making new sales (13%). Farmers did not frequently migrate to either a rural (16%) or urban area (11%).

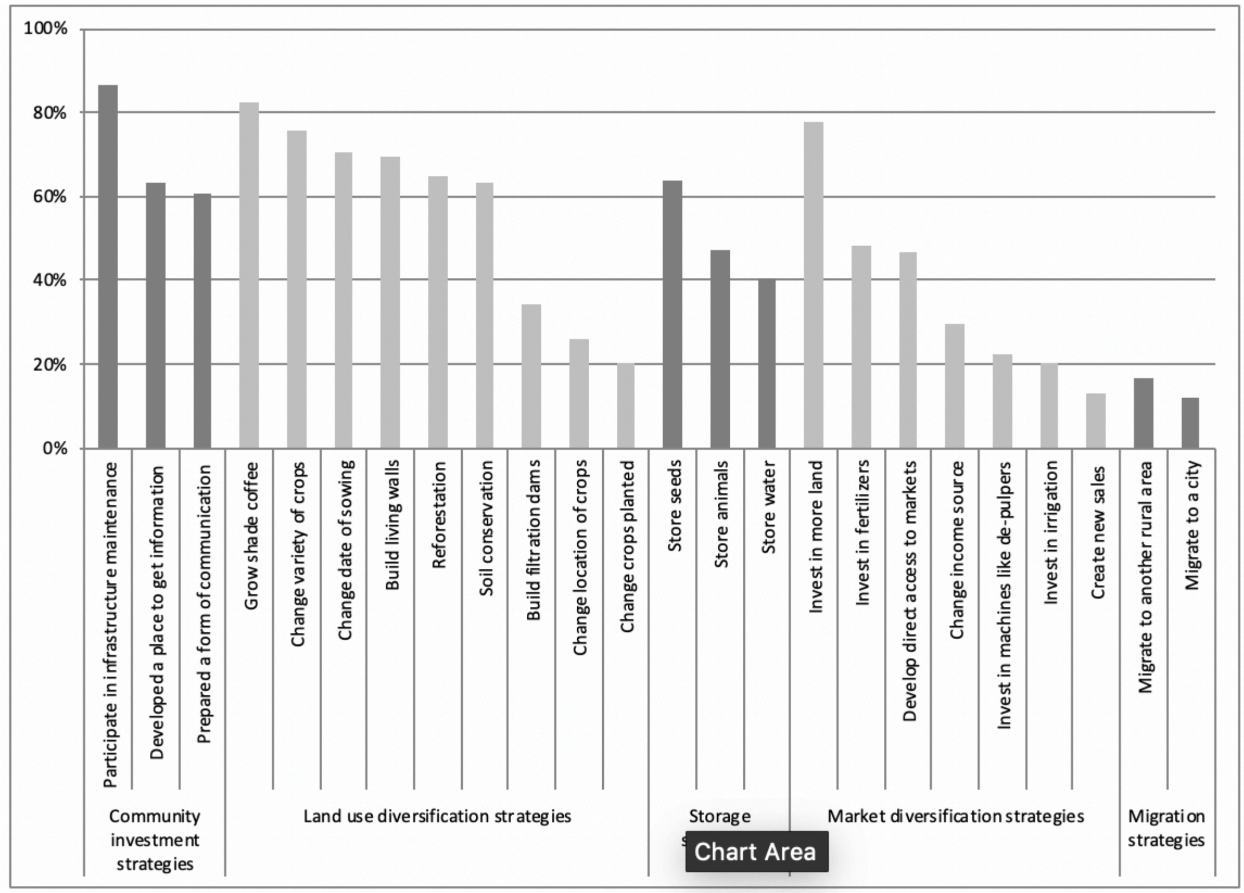


Fig. 2.3 Frequency of adaptation strategies adopted, split by category.

2.4.3 T-tests and multiple linear regression

The t-tests comparing high and low adaptive households showed statistically significant differences between their climate perceptions of higher temperatures ($p=0.1003$), drought ($p<0.05$), as well as their average climate perceptions ($p<0.10$) (Appendix I, A.1.3). However, we find no statistically significant differences for high and low adaptive households in terms of perceptions of hurricanes, erosion, crop plagues like coffee rust, and insects.

There were statistically significant differences for government subsidies received ($p<0.05$), land holdings owned ($p<0.001$), group membership ($p<0.05$), and market distance ($p<0.01$), where highly adaptive households had more subsidies, more land, engaged in more groups, and had higher market distance than low adaptive households. For human capital, the only statistically significant differences between high and low adaptive households was sex of the head of household ($p<0.10$), where highly adaptive households were more likely to be male.

The first regression model includes variables from all five capital assets, climate change perceptions, and vulnerability context (Table 2.2). The first model has an R^2 of 0.21. None of the human or financial capital variables are statistically significant in the model. The second regression model includes only the variables selected using the Best Subset Selection methods and excludes the human and financial capital variables. The second model has an R^2 of 0.20.

Across both regression models, the same five factors are predictive of adopting adaptive strategies (Table 2.2). The indicators are land holdings, group participation, market distance, disaster experience, and climate perceptions. Although it was not considered significant at the 0.10 level, physical capital was included in the final model as it explains 2.3% of the variation. Natural capital is statistically significant, explaining 3.3% of the variation, where a one hectare increase in landholdings increases the adaptation index by 0.04, all else being equal. Social capital is statistically significant, explaining 3.9% of the variation, where one additional group membership has an expected increase of 0.66 in the adaptation index. Climate perceptions are statistically significant, explaining 1.8% of the variation, where a one unit increase in the composite Likert scale of perceptions of climate has an expected increase of 0.81 in the adaptation index. Market distance is statistically significant, explaining 1.5% of the variation, where increasing the distance by one-minute from their field to markets corresponds to an 0.01 expected increase in the adaptation index. Disaster experience is statistically significant, explaining 2.3% of the variation, where a one unit increase in whether they experienced disasters or not results in a 1.06 expected increase in the adaptation index. There are two *ejido* locations which are statistically significant in the regression models.

Table 2.2 Regression analysis of factors that explain adoption of adaptive strategies.

		Full Model		***Best Model***	
Capitals	***Parameter***	***Estimate***	***Standard Error***	***Estimate***	***Standard Error***
	Intercept	5.047	1.885	4.943	1.549
Human	Sex	-0.624	0.479	-	-
	Age	-0.005	0.015	-	-
	Education	-0.212	0.212	-	-
	Family size	0.092	0.085	-	-
Financial	Subsidies	<0.001	<0.001	-	-
Natural	Land holdings	0.038**	0.021	0.043**	0.017
Physical	Assets	0.481*	0.305	0.442	0.291
Social	Group membership	0.654***	0.206	0.658***	0.202
Climate	Climate perceptions	0.824**	0.356	0.861**	0.352
Vulnerability context	Market distance	0.005**	0.002	0.005**	0.002
	Disaster experience	1.074**	0.463	1.068**	0.454
	Ejido 1	-0.079	0.814	-0.196	0.790
	Ejido 2	0.442	0.612	0.523	0.594
	Ejido 3	1.381**	0.696	1.574**	0.676
	Ejido 4	0.942	0.832	0.718	0.779
	Ejido 5	2.620***	0.868	2.352**	0.854
	Ejido 6	0.443	0.562	0.528	0.558
	Ejido 7	-0.013	0.678	0.232	0.656
	Ejido 8				
R^2		0.21		0.20	
Observations		291		291	

**p≤0.10, **p≤0.05, ***p≤0.001*

We analyzed the impact of the all independent variables, including human capitals, individually on each of the five adaptation types (Appendix I, A.1.4). Market exchange and community investment were characterized by similar variables, specifically land holdings, assets, group participation, and experiencing a natural disaster, where large landowners, with more assets, in more groups, that have experienced a natural disaster are more likely to invest in their community and diversify market investment. Community investment was also determined by family size. Land use diversification was strongly determined by market distance, in addition to land holdings, assets, group participation, and climate perceptions. Storage strategies were only determined by climate perceptions. Finally, migration was predominantly determined sex of the head of household and land holdings.

2.5 DISCUSSION

2.5.1 Vulnerability context: Natural disasters, location, and markets

The SLA recognizes that household ability to call on their livelihood assets is influenced by the vulnerability context in which they are situated (Scoones, 1998). This research supports that foundational cornerstone, highlighting the role of natural disasters, *ejido* location, and market distance in explaining farmer adaptations. Specifically, whether or not farmers experience disasters strongly determines their investment of time, labor, and resources within the community and for market exchange. Research shows that disaster experience underlines the immediate and pressing need to pool resources, for example, by developing communication strategies with friends and family in case of disaster and ensuring that the community has well developed infrastructure to confront such disasters (Adger, 2003).

However, individuals, households, and communities do not experience disasters equally, in part because of their basic differences in distribution across space. We found that two *ejidos* were predictive of farmer adaptation: in one town, residents were close to a well-equipped healthcare clinic which provided an important service and a source of employment for market diversification; in another, the *ejido* was located near a town center so employment ranged from store ownership, to taxi driving and logging. A community's connections to markets influences their access to technologies, employment, and information to improve productivity (Van de Walle, 2002). Interestingly, our research shows that longer market distances may slightly improve adaptive strategies, specifically land use diversification, suggesting that farmers are more likely to diversify for food security or risk aversion rather than for commercial reasons. Households who are further away incur greater transaction costs in selling and buying goods at markets (Ibrahim et al., 2009), so more remote households will tend to invest more in cultivation of diverse food crops to meet subsistence needs and reduce costs (Rehima et al., 2013). Therefore, in opposition to research that suggests proximity to market may increase diversification by improving market integration (Gray et al. 2008), this research shows households far from the market were slightly more likely to engage in land use diversification.

2.5.2 Livelihood assets: Natural, physical, social, and climate perception capitals

In rural Chiapas, Mexico, smallholder farmers are almost completely reliant on coffee as their sole source of income, so climate adaptation strategies will be key to protect them from impoverishment. The reliance on a single crop for income makes the rural poor generally (Skoufias, 2012), and coffee farmers specifically, extremely susceptible to shocks, whether that be from climate variation, biological shocks (e.g. coffee rust), or market shocks (e.g. volatility in prices) (Eakin et al., 2007). Diversification of crops and livelihoods is widely accepted as a way for farmers to adapt to economic and environmental shocks (Steward, 2007). In our study, almost three quarters of farmers responded that half of their income came from their crops, and all responded that they cultivated coffee. Exacerbating their vulnerability to climate and market shocks are Mexican agricultural policies and subsidies that focus on ramping up production of export-oriented cash crops (Assies, 2008). However, large land owners may be better able to overcome these vulnerabilities as they can more quickly expand their landholdings than small landowners and may more readily know how to take advantage of government resources (Christman et al., 2015). Our findings support this conclusion. We find large landowners engage in more market diversification strategies, land use diversification strategies, community investment and migration strategies. Meanwhile, small landowners must either diversify income sources outside of agriculture or expand into already marginal lands. Our study shows that most farmers own marginal lands with poor soils or steep slopes; more than half had some part of their land that could not be used productively for agriculture. Thus, research that shows Mexican households respond to climate shocks in two ways, by diversifying agricultural practices and drawing on assets to ensure income generation (Skoufias and Vinha, 2012), applies primarily to farmers that are land rich or asset wealthy.

Developing a physical asset base can greatly improve farmer adaptations (Hallegatte and Rozenberg, 2017; Moser, 2008; Patankar, 2015; Skoufias, 2012). Our results also suggest that asset accumulation improves land use diversification, market diversification, and community investment.

However, not all assets are created equally; Mensah (2011) argues that the availability and utility of key assets are paramount, as some assets can contribute to, rather than mediate, household vulnerability (Parizeau, 2015). Our results contribute to established research that accumulation of key assets is essential as they can be transformed to generate income, invested in agricultural technologies, used to reduce vulnerability and are a foundation of resources in case of a disaster (Deressa et al., 2009; Knowler and Bradshaw, 2007; Moser and Felton, 2007; Smit and Pilifosova, 2003).

However, neither physical assets nor natural capital, are sufficient to ensure that adaptive strategies are adopted. Researchers have long agreed upon the importance of social capital as a determining factor for adaptive capacity (Folke et al., 2002; Smit and Pilifosova, 2003; Yohe and Tol, 2002). Social capital can provide knowledge, skills, and networks to improve livelihoods (Pelling and High 2005). This study supports evidence that social capital via participation in organizations, can provide technologies, knowledge, and skills that facilitate adoption of adaptive strategies. Producer organizations are particularly well-recognized for their role in providing information on novel land use technologies, developing knowledge on technical skills, and mobilizing resources in land use management (Smit and Pilifosova, 2003). In Mexico, coffee farmers that are linked to coffee cooperatives are more likely to adapt, a result attributed to greater farmer access to regional, national, and global networks of information and technology (Frank, Eakin and Lopez-Carr, 2011). Simply put, since producer groups focus on the management of specific land use types, as well as the production and sale of products, they can be essential for economic well-being, improving social cohesion, and developing local decision-making (Speelman et al., 2011). Farmers themselves recognize the importance of participating in diverse social organizations to deal with climate change (Rogé et al., 2014). Particularly in regions like Chiapas, Mexico where much of the property is held in common, community and landscape resilience to change is dependent on collective action generated through social capital (García-Amado et al., 2012).

Finally, climate change perceptions are important for farmer adaptive strategies, although they may be heavily dependent on whether a major event has occurred in recent memory (Tucker, Eakin and Castellanos, 2010). Farmers frequently brought up hurricanes Mitch (1998) and Stan (2010) as major disasters devastating coffee crops; however, their perceptions of hurricane risk—specifically frequency—were low. This reflects how perceptions of risk are largely determined by "the probability or likelihood that an event will cause harm" (Tucker, Eakin and Castellanos 2010, p. 5). In other words, while farmers expect short-term extreme shocks like hurricanes, they are far more concerned about long-term risks such as coffee rust, that require expensive adaptations strategies like investment in coffee-rust resistant varietals or diversification to new crops. Coffee rust is a relatively new phenomenon with which farmers have little experience but is rampant in the region. Brought from Southeast Asia, coffee rust has devastated coffee production in the region starting in the early 2010s (Cressey, 2013).

2.5.3 Policy recommendations

The Mexican government explicitly promotes coffee cultivar diversification, and during the coffee rust epidemic they developed and distributed rust-resistant coffee varietals to farmers around the nation (SAGARPA, 2016). We found 75% of farmers used different varieties of coffee crops, but only 20% of farmers reported planting crops aside from those they already grow (i.e. Fig. 2.3). Policy makers should consider subsidizing the production of other crops to reduce vulnerabilities to extreme weather and markets. Farmers are extremely concerned about coffee rust and temperature, an indicator of the anticipated costly long-term adaptation strategies smallholder farmers need to implement to deal with climate issues, issues that policy makers can help address. The climate in our study area is suitable to a number of fruit trees, orchids, and cacao, all of which have market potential (Saldaña-Zorrilla, 2008; Schroth et al., 2009). Additionally, *Chamaedorea* palm production has had demonstrable benefits in terms of income generation in certain communities in Chiapas (García-Amado et al., 2013), although land grabs and forest degradation need to be considered prior to implementation (Castellanos-Navarrete and Jansen, 2016).

Policy makers should also build on established programs in the region to develop spaces for farmers to discuss shared understanding of weather and climate. We found that farmers who feel strongly that temperatures are changing, and rains are becoming less predictable, are more likely to adopt land use diversification and storage strategies. Thus, perceptions of climate change strongly influence what activities farmers engage in (Bryan et al., 2013), and can be a place where policy makers can directly influence adoption of adaptation strategies. The National Institute for Forestry, Agriculture and Livestock (INIFAP in Spanish) already provides technical assistance, including trainings on reforestation, soil conservation, and agricultural techniques (INIFAP, 2014). Many of the communities also receive information on climate change impacts, capacity building workshops, and trainings on building living walls and filtration dams (INIFAP, 2014). Building in climate perception workshops into these programs is a clear way to promote adaptive strategies.

Finally, strong community groups can provide important networks to exchange information, facilitate group learning, and improve social capital to implement decision making on farmers' land (Adger, 2003). Farmers who participated in more groups were more likely to diversify land use strategies in this study. Strong farmer organizations have been shown to be well-equipped to engage with various levels of government to reduce vulnerability and improve adaptive capacity of farmers in this region (Speelman et al. 2014). Other studies have shown organizations influence livelihood diversification, crop diversification, disaster resilience, and best management practices (Schroth et al., 2009). By strengthening the organizations that already exist within these communities, as well as incentivizing farmer participation in these organizations, farmers may be more likely to adopt adaptation strategies.

2.6 CONCLUSION

This research sheds light on the factors underlying coffee farmers' adaptive strategies, contributing to a growing body of literature emphasizing the importance of livelihood assets and vulnerability context for adapting to climate change. We find that human capital variables such as age, sex, family size, and education are not predictive of whether farmers adapt. Instead, the vulnerability context—specifically, natural disasters, *ejido* location, distance to markets—along with other livelihood assets—specifically, climate perceptions, natural, physical, and social capitals—work together to shape farmers' decisions on adaptation strategies. Highly adaptive households have stronger climate perceptions, more natural, physical, financial, and social capital than low adaptive households. Our results suggest some crucial areas that policy makers can have an influence for households that are not predisposed to adapt, such as investing more in crop diversification and income diversification programs, increased outreach and trainings on weather and climate, as well as strengthening of producer organizations.

REFERENCES

Adger, W.N., Brown, K. and Tompkins, E.L. (2005). The political economy of cross-scale networks in resource co-management. *Ecology and Society*, 10(2). pp. 9-23.

Adger, W.N. (2003). Social capital, collective action, and adaptation to climate change. *Economic geography*, 79(4), pp.387-404.

Agrawal, A. (2010). Local institutions and adaptation to climate change. *Social dimensions of climate change: Equity and Vulnerability in a Warming World*, 2, pp.173-178.

Assies, W. (2008). Land tenure and tenure regimes in Mexico: An overview. *Journal of Agrarian Change,* 8 (1): pp. 33-63.

Avelino, J., Cristancho, M., Georgiou, S., Imbach, P., Aguilar, L., Bornemann, G., Läderach, P., Anzueto, F., Hruska, A.J. and Morales, C. (2015). The coffee rust crises in Colombia and Central America (2008–2013): impacts, plausible causes and proposed solutions. *Food Security*, 7(2), pp.303-321.

Bacon, C.M., Sundstrom, W.A., Stewart, I.T. and Beezer, D. (2017). Vulnerability to cumulative hazards: Coping with the coffee leaf rust outbreak, drought, and food insecurity in Nicaragua. *World Development*, 93, pp.136-152.

Badstue, L.B., Bellon, M.R., Berthaud, J., Ramírez, A., Flores, D. and Juarez, X. (2007). The dynamics of farmers' maize seed supply practices in the Central Valleys of Oaxaca, Mexico. *World Development*, 35(9), pp.1579-1593.

Barham, B. L., Callenes, M., Gitter, S., Lewis, J., & Weber, J. (2011). Fair trade/organic coffee, rural livelihoods, and the "agrarian question": Southern Mexican coffee families in transition. *World Development*, *39*(1), 134-145.

Below, T.B., Mutabazi, K.D., Kirschke, D., Franke, C., Sieber, S., Siebert, R. and Tscherning, K. (2012). Can farmers' adaptation to climate change be explained by socio-economic household-level variables?. *Global Environmental Change*, 22(1), pp. 223-235.

Berkes, F. (2007). Understanding uncertainty and reducing vulnerability: lessons from resilience thinking. *Natural Hazards*, 41(2), pp.283-295.

Boone, H. N., & Boone, D. A. (2012). Analyzing likert data. *Journal of Extension*, 50(2), pp. 1-5.

Brooks, N., Adger, W.N. and Kelly, P.M. (2005). The determinants of vulnerability and adaptive capacity at the national level and the implications for adaptation. *Global Environmental Change*, 15(2), pp.151-163.

Bryan, E., Ringler, C., Okoba, B., Koo, J., Herrero, M. and Silvestri, S. (2013). Can agriculture support climate change adaptation, greenhouse gas mitigation and rural livelihoods? Insights from Kenya. *Climatic Change*, 118(2), pp.151-165.

Castellanos-Navarrete, A. and Jansen, K., (2015). Oil palm expansion without enclosure: Smallholders and environmental narratives. *Journal of Peasant Studies*, 42(3-4), pp.791-816.

Christman, Z., Pearsall, H., Schmook, B., & Mardero, S. (2015). Diversification and adaptive capacity across scales in an emerging post-frontier landscape of the Usumacinta Valley, Chiapas, Mexico. *International Forestry Review*, *17*(1), 111-123.

Cressey, D. (2013). Coffee rust regains foothold: researchers marshal technology in bid to thwart fungal outbreak in Central America. *Nature*, 493(7434), pp.587-588.

Deressa, T.T., Hassan, R.M., Ringler, C., Alemu, T. and Yesuf, M. (2009). Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. *Global Environmental Change*, 19(2), pp.248-255.

Dessai, S., Adger, W.N., Hulme, M., Turnpenny, J., Köhler, J. and Warren, R. (2004). Defining and experiencing dangerous climate change. *Climatic Change*, *64*(1-2), pp.11-25.

Doss, C.R. and Meinzen-Dick, R. (2015). Collective action within the household: Insights from natural resource management. *World Development*, *74*, pp.171-183.

Eakin, H., Benessaiah, K., Barrera, J.F., Cruz-Bello, G.M. and Morales, H. (2012). Livelihoods and landscapes at the threshold of change: disaster and resilience in a Chiapas coffee community. *Regional Environmental Change*, 12(3), pp.475-488.

Eakin, H. and Lemos, M.C. (2006). Adaptation and the state: Latin America and the challenge of capacity-building under globalization. *Global Environmental Change*, 16(1), pp.7-18.

Eakin, H.C., Lemos, M.C. and Nelson, D.R. (2014). Differentiating capacities as a means to sustainable climate change adaptation. *Global Environmental Change*, *27*, pp.1-8.

Eakin, H., Wehbe, M., Ávila, C., Torres, G.S. and Bojórquez-Tapia, L.A. (2007). Social vulnerability of farmers in Mexico and Argentina. *Climate Change and Vulnerability*, pp.257-278.

FAO. (2016). *The state of food and agriculture 2016: Climate change, agriculture, and food security.* Rome: FAO, pp. 1-173.

Folke, C., Carpenter, S., Elmqvist, T., Gunderson, L., Holling, C.S. and Walker, B. (2002). Resilience and sustainable development: building adaptive capacity in a world of transformations. *AMBIO: A Journal of the Human Environment*, 31(5), pp.437-440.

Frank, E., Eakin, H. and López-Carr, D. (2011). Social identity, perception and motivation in adaptation to climate risk in the coffee sector of Chiapas, Mexico. *Global Environmental Change*, *21*(1), pp.66-76.

Gay, C., Estrada, F., Conde, C., Eakin, H. and Villers, L. (2006). Potential impacts of climate change on agriculture: a case of study of coffee production in Veracruz, Mexico. *Climatic Change*, *79*(3-4), pp.259-288.

García-Amado, L., Ruiz Pérez, M., Iniesta-Arandia, I., Dahringer, G., Reyes, F. and Barrasa, S. (2012). Building ties: social capital network analysis of a forest community in a biosphere reserve in Chiapas, Mexico. *Ecology and Society*, 17(3): pp. 3-23.

García-Amado, L.R., Pérez, M.R., Dahringer, G., Escutia, F.R., García, S.B. and Mejía, E.C. (2013). From wild harvesting to agroforest cultivation: A Chamaedorea palm case study from Chiapas, Mexico. *Forest policy and economics*, *28*, pp.44-51.

Garip, F., (2008). Social capital and migration: How do similar resources lead to divergent outcomes?. *Demography*, *45*(3), pp.591-617.

Gertler, P.J., Martinez, S., Premand, P., Rawlings, L.B. and Vermeersch, C.M. (2016). *Impact evaluation in practice*. Washington, D.C.: World Bank Publications, pp. 1-244.

Gonzalez-Jacome, A. (2004). Dealing with risk: small scale coffee production systems in Mexico. *Perspectivas Latinoamericanas* 1, p.1.

Graeub, B.E., Chappell, M.J., Wittman, H., Ledermann, S., Kerr, R.B. and Gemmill-Herren, B. (2016). The state of family farms in the world. *World Development*, 87, pp.1-15.

Gray, C.L., Bilsborrow, R.E., Bremner, J.L. and Lu, F., (2008). Indigenous land use in the Ecuadorian Amazon: a cross-cultural and multilevel analysis. *Human Ecology*, 36(1), pp.97-109.

Hallegatte, S. and Rozenberg, J. (2017). Climate change through a poverty lens. *Nature Climate Change*, 7(4), p.250.

Harvey, C.A., Martínez-Rodríguez, M.R., Cárdenas, J.M., Avelino, J., Rapidel, B., Vignola, R., Donatti, C.I. and Vilchez-Mendoza, S. (2017). The use of Ecosystem-based Adaptation practices by smallholder farmers in Central America. *Agriculture, Ecosystems & Environment*, 246, pp.279-290.

Heiberger, R.M. and Holland, B. (2004). *Statistical analysis and data display: An intermediate course with examples in R*. Berlin: Springer.

Hertel, T.W., Burke, M.B. and Lobell, D.B. (2010). The poverty implications of climate-induced crop yield changes by 2030. *Global Environmental Change*, *20*(4), pp.577-585.

Holling, C.S. (1986). The resilience of terrestrial ecosystems: local surprise and global change. *Sustainable development of the biosphere*, *14*, pp.292-317.

Ibrahim, H., Rahman, S. A., Envulus, E. E., & Oyewole, S. O. (2009). Income and crop diversification among farming households in a rural area of north central Nigeria. *Journal of Tropical Agriculture, Food, Environment and Extension*, *8*(2), 84-89.

INEGI. (2007a). *Censo Agricola, Ganadero y Forestal. Mexico DF: Institucion Nacional de Estatistica, Geografia e Informatica*. Mexico City: INEGI.

INEGI. (2007b). *Núcleos Agrarios: Tabulados Básicos por Municipio 1992–2006. Programa de Certificacíon de Derechos Ejidales y Titulación de Solares*. Mexico City: INEGI.

INIFAP. (2014). *Propuesta integrada de adaptacion al cambio climatico en la Sierra Madre de Chiapas, Mexico*. Ocozocooautla de Espinosa, Mexico: Centro de Investigacion Regional del Pacifico Sur.

IPCC. (2007). Climate change 2007: the physical science basis. In: S. Solomon, D. Qin, M. Manning, Z. Chen, M. C. Marquis, K. Avery, M. Tignor, and H. L. J. Miller, ed., *Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge, UK: Cambridge University.

Jurjonas, M., Crossman, K., Solomon, J. and Baez, W.L. (2016). Potential links between certified organic coffee and deforestation in a protected area in Chiapas, Mexico. *World Development*, *78*, pp.13-21.

Knowler, D. and Bradshaw, B. (2007). Farmers' adoption of conservation agriculture: A review and synthesis of recent research. *Food Policy*, 32(1), pp.25-48.

Lin, B.B., Perfecto, I. and Vandermeer, J. (2008). Synergies between agricultural intensification and climate change could create surprising vulnerabilities for crops. *AIBS Bulletin*, *58*(9), pp.847-854.

Marasinghe, M.G. and Kennedy, W.J. (2008) Introduction to the SAS Language. In *SAS for Data Analysis*. New York, NY: Springer, pp. 1-54.

McCarthy, J. J., Canziani, O. K., Leary, N. A., Dokken, D. J., and White, K. S. (2001). Impacts, Adaptation and vulnerability. *Third Assessment Report of the Intergovernmental panel on climate change, working Group*, *2*. Cambridge, UK: Cambridge University Press.

Mearns, R. and Norton, A. eds. (2009). *Social dimensions of climate change: equity and vulnerability in a warming world*. Washington, D.C.: World Bank Publications.

Mensah, E.J. (2011) The sustainable livelihood framework: A reconstruction. *The Development Review – Beyond Research,*1 (1).

Mertz, O., Mbow, C., Reenberg, A. and Diouf, A. (2009). Farmers' perceptions of climate change and agricultural adaptation strategies in rural Sahel. *Environmental Management*, 43(5), pp.804-816.

Morton, J.F. (2007) The impact of climate change on smallholder and subsistence agriculture. *Proceedings of the national academy of sciences*, *104*(50), pp.19680-19685.

Moser, C.O (2007). Asset-based approaches to poverty reduction in a globalized context. *Global Economy and Development Working Paper No 01*. [online] Available at: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=1011176 [accessed 12 Nov 2018].

Moser, C.O. (2008). *Reducing global poverty: The case for asset accumulation*. Washington, D.C.: Brookings Institution Press.

Moser, C. and Felton, A. (2007). *The Construction of an Asset Index Measuring Asset Accumulation in Ecuador CPRC*. Vol. Working Paper 87). Washington DC: The Brookings Institution.

Narayan, D. and Pritchett, L. (1999). Cents and sociability: Household income and social capital in rural Tanzania. *Economic Development and Cultural Change*, 47(4), pp.871-897.

Nunnally, J. and Bernstein, I. (1994). Psychometric Theory. 3rd edition. New York: MacGraw-Hill.

O'Brien, K.L, Eriksen, S., Nygaard, L.P. and Schjolden, A. (2007).. Why different interpretations of vulnerability matter in climate change discourses. *Climate Policy*, 7(1), pp.73-88.

Parizeau, K. (2015). When assets are vulnerabilities: an assessment of informal recyclers' livelihood strategies in Buenos Aires, Argentina. *World Development*, 67, pp.161-173.

Patankar, A.M. (2015). The exposure, vulnerability, and ability to respond of poor households to recurrent floods in Mumbai. Washington, D.C.: *World Bank Policy Research Working Paper*, p. 7481.

Pelling, M. and High, C. (2005). Understanding adaptation: what can social capital offer assessments of adaptive capacity?. *Global Environmental Change*, 15(4), pp.308-319.

Peng, J.Y.C. (2009). *Data analysis using SAS*. Thousand Oaks: Sage Publications Inc.

RAN. (2017). *Registro Agrario Nacional: Ejido o Comunidades*. Mexico City: RAN. [online] Available at: http://www.ran.gob.mx/ran/index.php/sistemas-de-consulta/phina [accessed 8 Aug 2017].

Rehima, M., Belay, K., Dawit, A., & Rashid, S. (2013). Factors affecting farmers' crops diversification: Evidence from SNNPR, Ethiopia. *International Journal of Agricultural Sciences*, *3*(6), 558-565.

Rogé, P., Friedman, A.R., Astier, M. and Altieri, M.A. (2014). Farmer strategies for dealing with climatic variability: a case study from the Mixteca Alta region of Oaxaca, Mexico. *Agroecology and Sustainable Food Systems*, 38(7), pp.786-811.

SAGARPA. (2016). *Inicia SAGARPA entrega de 150 millones de plantas de café mejoradas*. [online] Available at: http://sagarpa.gob.mx/Delegaciones/bajacalifornia/Boletines /Paginas/2016B253.aspx [accessed 8 Aug 2017].

Saldaña-Zorrilla, S.O. (2008). Stakeholders' views in reducing rural vulnerability to natural disasters in Southern Mexico: Hazard exposure and coping and adaptive capacity. *Global Environmental Change*, 18(4), pp.583-597.

Schroth, G., Laderach, P., Dempewolf, J., Philpott, S., Haggar, J., Eakin, H., Castillejos, T., Moreno, J.G., Pinto, L.S., Hernandez, R. and Eitzinger, A. (2009). Towards a climate change adaptation strategy for coffee communities and ecosystems in the Sierra Madre de Chiapas, Mexico. *Mitigation and Adaptation Strategies for Global Change*, 14(7), pp.605-625.

Scoones, I. (1998). Sustainable Rural Livelihoods: A Framework for Analysis, IDS Working Paper 72, Brighton: IDS.

Skoufias, E. (2012). *The poverty and welfare impacts of climate change: quantifying the effects, identifying the adaptation strategies*. Washington, D.C.: World Bank Publications.

Skoufias, E. and Vinha, K. (2012). Timing Is Everything: How Weather Shocks Affect Household Welfare in Rural Mexico. *The Poverty and Welfare Impacts of Climate Change*, p.77.

Smit, B. and Pilifosova, O. (2003). Adaptation to climate change in the context of sustainable development and equity. *Sustainable Development*, 8(9), p.879-906.

Smit, B. and Wandel, J. (2006). Adaptation, adaptive capacity and vulnerability. *Global Environmental Change*, 16(3), pp.282-292.

SMN. (2017). Resumen mensual de temperaturas y lluvia. Mexico City: Servicio Metereologico Nacional. [online] Available at: https://smn.cna.gob.mx/es/climatologia/temperaturas-y-lluvias/resumenes-mensuales-de-temperaturas-y-lluvias [accessed 1 Nov 2017].

Speelman, E.N., Groot, J.C., García-Barrios, L.E., Kok, K., Van Keulen, H. and Tittonell, P. (2014). From coping to adaptation to economic and institutional change–trajectories of change in land-use management and social organization in a Biosphere Reserve community, Mexico. *Land Use Policy*, 41, pp.31-44.

Steward, C. (2007). From colonization to "environmental soy": a case study of environmental and socio-economic valuation in the Amazon soy frontier. *Agriculture and Human Values*, 24(1), pp.107-122.

Thomas, D.S., Twyman, C., Osbahr, H. and Hewitson, B. (2007). Adaptation to climate change and variability: farmer responses to intra-seasonal precipitation trends in South Africa. *Climatic Change*, 83(3), pp.301-322.

Tucker, C.M., Eakin, H. and Castellanos, E.J. (2010). Perceptions of risk and adaptation: coffee producers, market shocks, and extreme weather in Central America and Mexico. *Global Environmental Change*, 20(1), pp.23-32.

USDA Foreign Agricultural Service. (2014). *Mexico: Coffee Annual.* Global Agricultural Information Network Report # MX4038. Washington, D.C.: USDA.

Vandermeer, J., Jackson, D. and Perfecto, I. (2014). Qualitative dynamics of the coffee rust epidemic: educating intuition with theoretical ecology. *BioScience*, *64*(3), pp.210-218.

Van de Walle, D. (2002). Choosing rural road investments to help reduce poverty. *World Development*, 30(4), pp.575-589.

Vyas, S. and Kumaranayake, L. (2006). Constructing socio-economic status indices: how to use principal components analysis. *Health Policy and Planning*, 21(6), pp.459-468.

World Bank. (2005). *Chapter 2: Measuring Poverty*. Washington, D.C.: World Bank. [online] Available at: http://siteresources.worldbank.org/PGLP/Resources/PMch2.pdf [accessed 10 Mar 2018].

Yohe, G. and Tol, R.S. (2002). Indicators for social and economic coping capacity—moving toward a working definition of adaptive capacity. *Global Environmental Change*, 12(1), pp.25-40.

Yúnez-Naude, A. and Taylor, J.E. (2001). The determinants of nonfarm activities and incomes of rural households in Mexico, with emphasis on education. *World Development*, 29(3), pp. 561-572.

3. CHAPTER THREE: WHY CITIZEN SCIENTIST VOLUNTEER: MOTIVATIONS FOR AND BARRIERS TO PARTICIPATION[2]

3.1 INTRODUCTION

Citizen science, the partnership of scientific researchers with members of the general public, has grown significantly over the past twenty years, with more than a million projects worldwide (Kullenberg & Kasperowski, 2016). Citizen scientists can gather large volumes of data over wide geographical areas (Silvertown 2009). The success of citizen science projects relies on the recruitment and retention of volunteers who devote their unpaid time for such prosocial activities (Penner, 2002). Studies have increasingly begun to examine motivations of citizen scientists to sign up and continue to participate (Domroese & Johnson, 2017; Land-Zandstra et al., 2016; Lee et al., 2018; Rotman et al., 2014). However, motivations still remains understudied as a field, representing only 4 percent of all articles on citizen science for research published before 2015 (Follet & Strezov, 2015). Additionally, the majority of research is conducted in the global North with a bias towards the United States (e.g. Domroese & Johnson, 2017), the United Kingdom (e.g. Reed et al., 2012), where income and education levels vary substantially from the global South. Relatively few are conducted in the global South, with the exception of southern and eastern Africa (Dolrenry, Hazzah, & Frank, 2016; Higgins & Shackleton, 2015; Wright et al., 2015). To our knowledge, none have been published in English on citizen scientists' motivations in Mexico, where this study takes place. Mexico has recently begun integrating citizen science programs into community development and environmental policy making. For example, the Mexican national commission on biodiversity (in Spanish, *Comision Nacional para el Conocimiento y Uso de la Biodiversidad, CONABIO)* has created *AverAves* as a platform for citizen scientists to record bird

[2] This research is in preparation for the journal Citizen Science Theory and Practice, with co-authors Kelly Jones, Greg Newman, and Miriam Ramos-Escobedo

migration patterns and the platform *Naturalista* to identify plant and animal species (Biodiversidad Mexicana, n.d.).

In many other contexts around the world, citizen science motivational research has been framed under the umbrella of environmental volunteering, and have found that internal and external factors impact retention and recruitment. Classical psychological theories that inform the foundations of environmental volunteerism often hold that: (1) People volunteer as a means to express their *values* such as their desire to contribute to the community; (2) Those who volunteer are interested in *learning* about the world, understanding an issue, or discovering new ideas; (3) Volunteers have a desire to grow psychologically through a process of *enhancement*, e.g., to improve self-esteem; (4) The process of volunteering allows people to develop *new skills* for their careers; and (5) Volunteering provides a venue to build and strengthen *social* relationships (Clary et al., 1998).

A more recent study by Ryan et al. (2001) on environmental volunteers found five distinct motivations, including the desire to: (1) Help the environment (i.e. other-oriented *responsibility*); (2) Learn about their surroundings (i.e. *learning*); (3) Connect socially with others (i.e. *social*); (4) Experience opportunities for personal reflection (i.e. *escape*); and (5) Enjoy the organizational structure of the team (i.e. *to be part of something*). Research more specific to citizen scientists has found that volunteers are often motivated by the desire to learn and their values to help the environment (Crall et al., 2013; Wright et al., 2015). However, the influence of any one of these motivations in the decision to volunteer varies. For example, although some studies show that 'helping the environment' is the germane factor in environmental volunteer participation (Bruyere & Rappe, 2007), others found it had no influence on the duration of their involvement (Asah & Blahna, 2012). In general, while citizen scientists have a high level of concern for the environment (Johnson et al., 2014), the motivations to participate in citizen science projects are inherently complex (Rotman et al., 2014), shift through time (Ferster et al., 2013), and conservation motivations may be relatively minor in comparison to personal motivations (Higgins & Shackleton, 2015).

While motivations influence retention in citizen science programs, other factors such as overall experience in the program and having volunteers recognize the external effects of their data collection (i.e., project relevance) are also important (Rotman et al., 2014). In one framework, Cash et al. (2003) argue that information must be Credible (i.e. trustworthy), Relevant (i.e. important and timely), and Legitimate (i.e. with the perspectives of all relevant actors), for appropriate action to take place. The inclusion of these three elements—often called the CRELE framework—in research and policy suggests that policy makers prioritize research when it aligns with their specific and timely needs (Cook et al., 2013). Similarly, we hypothesize that volunteers may stay involved in citizen science projects when they view the goals of the research as useful, timely, and important. However, researchers in citizen science often exclusively focus on establishing the addressing concerns of credibility of volunteer data (Conrad & Hilchey, 2011; Henderson, 2012; Wiggins, 2013), at the expense of communicating the relevance of the research, which may be essential for retaining motivated volunteers in citizen science. Although scholars are increasing citing and adopting the CRELE model (Dunn & Laing 2017; Heink et al., 2015; Sarki et al., 2014, Sarki et al., 2015, van Enst et al., 2014), there are few (if any) empirical studies that use the CRELE framework in citizen science. More rigorous research on how citizen science programs can be designed to incorporate these principles in order to shape participation over the long term is needed.

In this study we examine what influences participation and retention of volunteers in a Global Water Watch (GWW)-Mexico project in Veracruz State, Mexico, providing important empirical information on how citizen science projects can be designed and implemented to improve recruitment and long-term participation. We recruited and trained citizen scientists to collect water flow data around two urban areas over a 12-month period. We recruited 35 volunteers and used an experimental design where one group of volunteers received a training that included an hour-long presentation by two regional decision-makers on the importance of this project for informing a local Payment for Hydrological Services (PHS) program in addition to water flow training, while the other group only received water flow training. Thus, we targeted citizen scientists' perceptions of project relevance within one of the trainings, allowing us to test the role of perceptions of project relevance on data collection and participation. We collected pre (n=35) and post surveys (n=27) with volunteers and interviewed 12 volunteers. Additionally, we collected 84 surveys from the general public about motivations. Using this dataset, we examine the following four research questions: (1) What effects initial participation in citizen science? (2) What effects retention in citizen science? (3) Does our experimental training influence perceptions of project relevance and level of participation in data collection? (4) What are the major challenges to participation in citizen science?

3.2 METHODS

3.1.2 Study area and programs

This research is situated within two urban areas in the state of Veracruz, Mexico, Xalapa and Coatepec (Fig 3.1). The city of Xalapa is the larger of the two cities, with a population of 480,841 (INEGI, 2015a). Issues of unemployment or underemployment is a concern in the region as only 91,626 were fully employed in 2008. Some (33.3%) of the residents have attained more than secondary education. In terms of age, the majority (31.8%) are children or young adults (ages 0 to 19), 32.8% are adults (ages 20 to 39), 24.4% are middle aged (ages 40 to 59), and 11.2% are elderly (ages 60 or older). The city of Coatepec has a population of 92,127 (INEGI, 2015b). Again, unemployment or underemployment is an issue as only 11,874 are fully employed. 21.8% of the population has more than secondary education. In terms of age, the majority (33.2%) are young adults or children (ages 0 to 19), 31.7% are adults (ages 20 to 39), 23.8% are middle aged (ages 40 to 59), and 11.3% are elderly (ages 60 or older).

Xalapa and Coatepec are located in the lower watersheds of the lush forested Pixquiac and Gavilanes watersheds. Both municipalities rely on rivers in these watersheds as their major sources of drinking water: the Gavilanes river provides residents of Coatepec with 90% of its drinking water, while the Pixquiac river provides residents of Xalapa with 40% of their drinking water (García-Coll et al., 2004; Paré & Gerez, 2012). Drinking water, however, is imperiled due to deforestation in the upper watershed; the state of Veracruz is one of the most deforested in Mexico (López-Rodríguez & Acevedo-Rosas 2005), with some of the poorest drinking water quality nation-wide (Yáñez-Arancibia & Day, 2004). To address this health and ecosystem crisis, Mexico implemented a national financial mechanism to pay upstream landowners to protect forests and their hydrological services, which they call the Payment for Hydrological Services (PHS) program (Muñoz-Piña et al., 2008). The efficacy of the PHS program depends on its ability to incentivize conservation behaviors to achieve hydrologic goals (Engel, Pagiola, & Wunder, 2008). However, few evaluations have been conducted to examine their effectiveness in achieving such goals (Asbjornsen et al., 2017), and continuous data collection is needed to understand the efficacy of the PHS program.

Citizen science is one low-cost method to help inform policy-makers about the efficacy of the PHS program. Therefore, we worked collaboratively with one of the largest water-related citizen science organizations in Mexico, GWW-Mexico, to determine data collection design, recruitment, and training of water monitors in these two watersheds. In our study area, GWW-Mexico plays a potentially crucial role in providing publicly available data on water quantity and quality to inform policy-making for the PHS program. As part of a larger collaborative project based in Veracruz examining the influence of PHS on environmental outcomes, we designed a citizen science project to study water flow specifically within the two watersheds in which PHS operates (Asbjornsen et al., 2018).

To incentivize data use by decision-makers as well as retention of citizen scientists in the program, we invited representatives from two organizations, one NGO and one quasi-governmental organization, who implement and support the PHS program, to speak at one of the two citizen science trainings. In the experimental design, one training group was informed of the relevance of their research for PHS decision makers in addition to water flow training, while another simply received the regular GWW water flow training. In the standard GWW-Mexico training for water flow, the float method is used to measure surface velocity, in this method two variables are measured, velocity and the area of the stream's cross section where the velocity is measured. Velocity is estimated by the time it takes to float an object a specified distance – in this case 10m – downstream. It requires measurements between the start and end point of the reach, then dividing distance by time (m/sec). The area of the cross section is measured by placing a leveled rope from each of the streambanks, the total width of the stream is measured and divided to obtain 20 subsections. In each subsection depth is measured in the beginning (D_x) and end (D_{x+1}), for each subsection the area is calculated by multiplying the subsection width by the average of D_x and D_{x+1}. The total area of the cross section is estimated by adding all the subsection areas. A minimum team of four volunteers is recommended to conduct the fieldwork

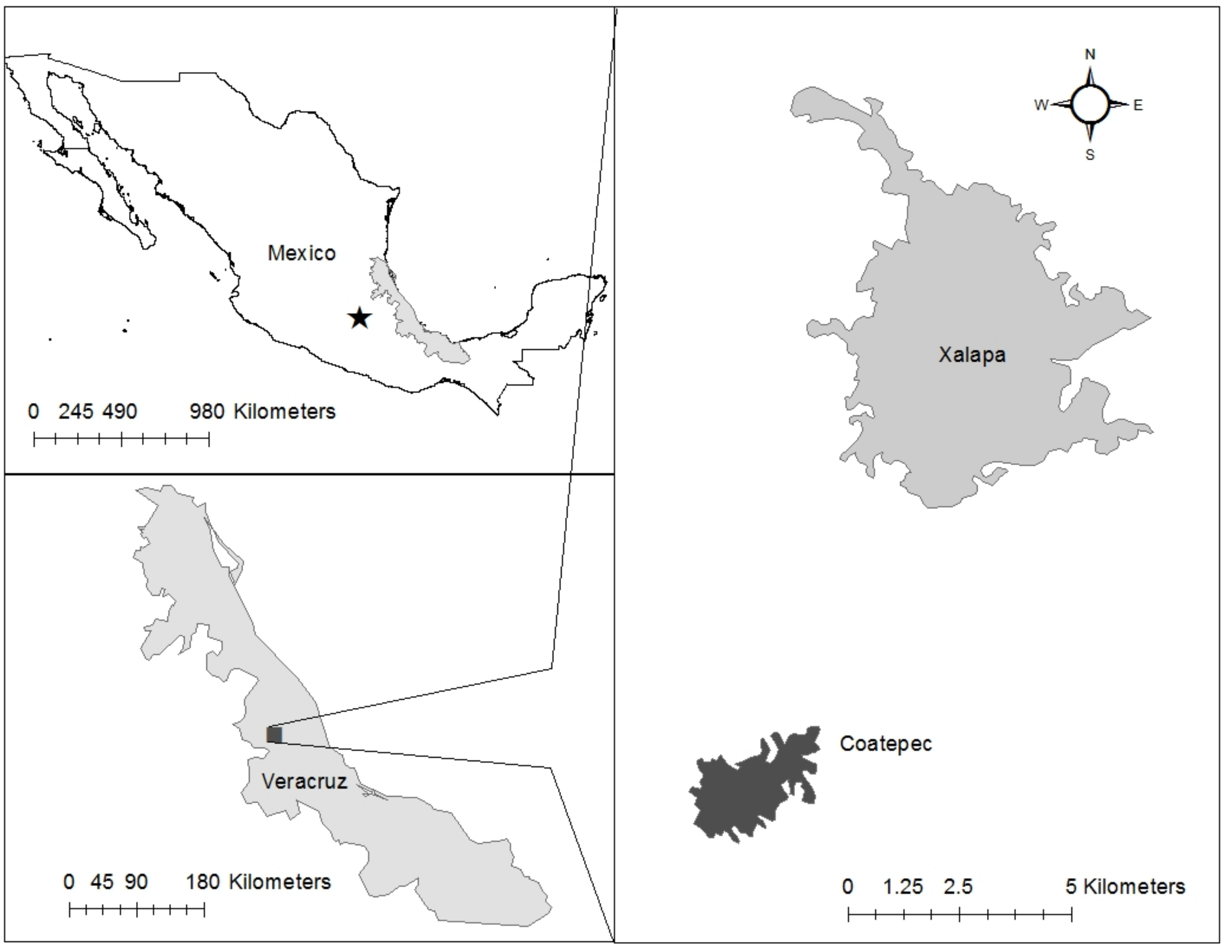


Fig. 3.1 Map of the Mexican state of Veracruz (top left), the boxed location where the two urban areas lie in Veracruz (bottom left), and the study areas of Xalapa and Coatepec (right).

3.2.2 Data collection

3.2.2.1 Survey data

We recruited, trained, and surveyed 35 citizen scientists in February and May of 2016. Recruitment was accomplished through use of the GWW-Mexico Facebook page, the Fidecoagua website, and the SENDAS website; posters at two high schools and one university; and oral presentations at a Coatepec townhall meeting and on the radio announcements, and posters at the University of

Veracruz in Xalapa. Recruitment was conducted between January and March 2017. Trainings occurred in February and May of 2017. We surveyed citizen scientists prior to training, two weeks after the training, and six months after the original survey to understand changes over time (Appendix II, A.2.1). Nineteen volunteers had stopped collecting data by the six month mark but were still included in data collection. The surveys were self-administered and in Spanish. We received a response rate of 94.2% after two weeks, and 80.0% after six months.

All three surveys contained a section on (1) motivations, focusing on the five motivations identified in Ryan et al. (2001): responsibility, learning, social, to be part of something, and escape (Appendix II, A.2.1, Section B); and (2) perceptions of project relevance (Appendix II, A.2.1, Section F). Only the pre-survey collected information on (3) demographics and (4) personal attributes (Appendix II, A.2.1, Section A), as well as (5) Income (Appendix II, A.2.1, Section H). Finally, all three surveys contained open-ended questions on motivations and challenges to participation in the citizen science project. The survey contained multiple choice, fill in the blank, five-point Likert scale questions, and an open-ended motivations question to triangulate survey research and reveal unforeseen motivations. Project relevance was measured with one five-point Likert scale question on whether they thought the data generated by GWW monitors to be useful and important for decision-making. Motivations questions were measured with five-point Likert scales. Motivations Likert scale constructs had a minimum of three related questions to ensure reliability, validity, and generalizability (Carifio & Perla, 2007).

Additionally, we surveyed 84 members of the nature-oriented public who were in the same two urban areas as citizen scientists, who could have been recruited for the citizen science project, and who we expected to have similar motivations to citizen scientists because of time spent in natural areas, but that had not volunteered for our project. Members of the nature-oriented public were surveyed from five natural areas in the region, Parque Macuiltepetl (n=20), Parque los Tecajetes (n=20), Parque de la Culebra (n=21), Trianon (n=21), and Cascada Bola de Oro (n=2). Sample selection was determined based on their entrance into the natural area and their agreement to participate in the survey. The survey collected information on: (1) demographics, including age, sex, education, children, family members, and income;

(2) personal attributes, such as distance to water bodies, past and current volunteering, and water knowledge; and (3) motivations.

We used the sample of the nature-oriented public and all volunteers to answer our question on recruitment and initial participation (research question 1). We used the sample of volunteers that dropped out versus those that continued monitoring to test our questions on retention and challenges to participation (research questions 2 and 4). We used the sample of volunteers that received the experimental training with decision-makers and those that did not receive the additional training to test our question on project relevance (research question 3).

3.2.2.2 Qualitative data

We conducted a total of 12 interviews with citizen science volunteers six months after the training. We selected interviewees on the basis of their level of participation in monitoring and collected six interviews with volunteers that dropped out and six with volunteers that continued monitoring throughout the duration of the project. Interviews ranged between 15 minutes and an hour and 15 minutes, with interviews running an average length of 35 minutes. The interviews were conducted in Spanish.

The interview protocol consisted of open-ended questions focused on similar themes to the survey including motivations, perceptions of the research relevance, perceptions of threats to water, and challenges to water monitoring. We also asked interviewees for stories about how their lives and work are connected to water, i.e., about their 'identity'. Follow up questions were used to acquire missing information and resolve ambiguities.

3.2.3 Data analysis

3.2.3.1 Quantitative data analysis

For all five-point Likert scale questions, the scale was summed and averaged to calculate separate composite scores (Boone & Boone, 2012). Likert scale questions were also analyzed for internal reliability using Cronbach's alpha. We accepted a Cronbach's alpha greater than 0.5, since all other means to improve Cronbach's alpha to 0.75 were unsuccessful (Hinton et al., 2004). We also checked for multicollinearity between independent variables using a correlation test (Peng, 2009). Dependent variables were also checked for normal distribution using visual examination of histograms.

We first conducted descriptive statistics on demographic data for the nature-oriented public and citizen scientists and for the Likert scale questions on motivations. We then examined differences in means using t-tests and examining pooled and Saitherworth's results to ensure for equal variances. To understand differences in what leads to recruitment (question 1) we tested differences in means between the nature-oriented public and citizen scientist volunteers for all demographic, motivations, and attributional questions. Using the results from t-tests and theory we developed a logistic regression to explain participation. We selected five independent variables: two demographic (i.e. age and education), two motivational (i.e. learning and escape) and one attributional (i.e. knowledge of the source of water). The dependent variable of participation in citizen science was coded as "0" for the nature-oriented public and "1" for citizen scientists. We report odds rations from the logistic regression. Nagelkerke R^2 was used as the pseudo-R^2 to measure the explained variance of the logistic regression model.

To understand what determines retention in citizen science (question 2) we conducted t-tests between two-weeks after and six months after training for demographics, motivations, and attributes variables. T-tests and theory informed development of a multiple linear regression to explain retention, using self-reported number of times monitored as the dependent variable. We conducted variance inflation factors to ensure no multicollinearity among variables. We also checked scatter plots to determine whether the residuals were equally distributed across the regression line. We included the following independent variables based on our t-tests and theory: age, social motivations, and the motivation to be part of something.

Finally, to understand how our experimental training affected retention (question 4), we first conducted paired t-tests between citizen scientists that received the novel training and those that did not for measures of perceptions of project relevance two weeks and six months after the training. Next, we constructed a mixed effects model, with time and intervention as the fixed effects and participant as the random effect, to examine whether changes in perceptions of project relevance were due to the intervention. Additionally, we tested whether the novel training influenced volunteer participation in data collection, i.e. the number of times a volunteer monitored six months after the training, by conducting a t-test between the intervention and non-intervention citizen scientists. Then we conducted a mixed effects model, constructed with time and intervention as the fixed effects and participant as the random effect, to examine whether changes participation were due to the intervention.

3.2.3.2 Qualitative data analysis

To address the research questions on participation (question 1) and retention (question 2), the pre-survey and post-surveys contained one open-ended question on motivations. To address the research question on challenges to participation (question 4), the pre-survey and post-surveys contained one-open ended question about the greatest challenges faced. Interviews also asked questions about experiences in nature, motivations to sign up, challenges to participation, as well as on perceptions of project relevance (question 3). Interviews were transcribed in Spanish, and two bilingual researchers used an iterative process of content and thematic analysis, for intercoder reliability. Researchers first used a directed content analysis approach, reading theoretical and applied research on the research questions to inform the initial codebook. Then using the open coding technique for thematic analysis, we allowed themes and codes to emerge from the transcripts. Researchers generally followed a six-step process detailed in Mann (2016): familiarization with the data, coding, searching for themes, reviewing themes, defining and naming themes, and write up. These codes were then entered into the qualitative software NVivo 12 Pro to analyze results, and to create comparison diagrams. To report back results, the first author translated relevant quotes from Spanish to English. The initial codes for motivations were created based on a literature review, while all other codes for motivations, challenges, and project relevance, were created from *in vivo* text, i.e. word for word. These were then examined by volunteer type: continuing volunteers and drop outs, as well as by the two citizen science training groups.

3.3 RESULTS

3.3.1 Who participates in citizen science?

3.3.1.1 Descriptive statistics

Descriptive statistics of citizen scientists and members of the nature-oriented public demonstrate that citizen scientists in our study tend to be more highly educated (88%), older ($\bar{x}$=58 years of age), and have more family members who live with them ($\bar{x}$=4) (Supplementary Materials, Table 5). In terms of occupation, most citizen scientists tend to be students (34%), teachers (20%), or unemployed (20%), which may reflect our recruitment strategy at schools and via Facebook. The vast majority of volunteers (89%) know where their water comes from but are located relatively farther from any body of water (23 minutes away) than the nature-oriented public. Citizen science volunteers are just as likely to volunteer as the nature-oriented public, but when citizen scientists volunteer, they are more likely to volunteer for an environmental organization than at a socially-related organization like the Red Cross or the church.

Testing for differences in motivations between the nature-oriented public and citizen scientists using t-tests, we found all five motivations to be statistically different across the groups (Table 3.1). Specifically, citizen scientists are more highly motivated in terms of feelings of responsibility toward the environment (t-value=3.13), in terms of learning about nature (t-value=5.15), in terms of social motivations to spend time with others (t-value=2.66), and in their desire to be a part of something (t-value=4.06). There were also statistically significant differences for escape motivations, however, members of the nature-oriented public were more highly motivated to get into nature than citizen scientists (t-value= -3.19). Because we selected people who were spending time in nature as our control, their higher motivations for escape is likely an artefact of the research design.

Table 3.1 Summary statistics of differences in motivations for citizen science volunteers and members of the nature-oriented public.

Motivation	*Definition*	*Volunteers Mean (StdDev)*	*Public Mean (StdDev)*	*t-value*
Responsibility	Feeling responsible for the environment.	4.585 (0.383)	4.301 (0.588)	3.13***
Learning	Desire to learn about nature.	4.850 (0.244)	4.396 (0.654)	5.51***
Social	Desire to spend time with others.	3.942 (0.662)	3.566 (0.798)	2.66**
To be part of something	Desire to be part of something.	4.629 (0.573)	4.077 (0.873)	4.06***

Escape	Desire to escape daily routine in nature.	4.324 (0.527)	4.643 (0.485)	-3.19**
Observations		*35*	*84*	
p-value <0.10, 0.05**, 0.001****				

3.3.1.2 Logistic regression

Table 3.2 presents the summary of the logistic model of participation in citizen science, where five variables were statistically significant in explaining recruitment as a citizen scientist: two demographic, two motivational, and one attributional variable. The model has a pseudo-R^2 of 0. 6905. In terms of demographics, we found age and education to be statistically significant in the model. An increase by one educational unit (e.g. completing secondary school instead of primary school) increases the likelihood estimate of recruitment by 1.2. An increase in age by one year decreases the likelihood estimate of recruitment by 0.07. In terms of motivations, learning and escape were statistically significant in the model. An increase in motivation for learning by one Likert scale point increases the likelihood estimate of recruitment by 4.7. We found an increase in the motivation for escape by one Likert scale point decreases the likelihood estimate of recruitment by 4.1. Finally, in terms of personal attributes, knowing where their water source is located was statistically significant in the model. An increase in knowledge increases the likelihood estimate of recruitment by 2.5.

Table 3.2 Results from the logistic regression for predictors of recruitment.

Theme	*Variables*	*Odds Ratio (standard error)*
Demographics	1. Age	-0.072 (0.028)**
	2. Education	1.212 (0.392)**
Motivations	3. Learning	4.661 (1.339)***
	4. Escape	-4.196 (1.176)***
Attributes	5. Knows location of water source	2.537 (0.925)**
AIC		143.029
Likelihood ratio		77.338
Observations		117
Pseudo-R^2		0.6905

3.3.2 What effects retention in citizen science?

After two weeks, only three volunteers had dropped out (n=3), but after six months, more volunteers had dropped out (n=19), than continued to monitor (n=16). Examining the pre-survey for volunteers and drop outs, we found no statistically significant differences in the summed average Likert scale for any motivational factor (Appendix II, A.2.3). However, six months after the training, continuing volunteers had statistically significant differences in stated motivations as compared to drop outs in terms of higher social motivations (t-value=2.14) and higher motivations to be a part of something (t-value=2.68) (Appendix II, A.2.4). Examining demographic differences between volunteers and drop outs we found that age was statistically significant (t-value=1.80), where pair profiles show that drop outs tend to be younger ($\bar{x}$= 27, SD= 8.345) than continuing volunteers ($\bar{x}$=34.375, SD=14.390). Examining differences between volunteers and drop outs for other attributes we found no differences between drop outs and volunteers. Based on the results from the t-tests, we examined age, social motivations, and motivations to be part of something in a linear regression model of number of times a volunteer participated (i.e. retention). The model shows that the only factor that is statistically significant and predictive of retention is age. The model had an R^2 of 0.1897. The model shows that a one year increase in age increased number of times monitoring by 0.062 (Appendix II, A.2.5).

Triangulating survey data with qualitative research, the open-ended survey question on motivations to continued participate in citizen science revealed 11 codes were important for participation, including the five motivations asked about in the survey: responsibility, learning, social, to be part of something, and escape. However, the qualitative results also demonstrate several important emergent themes including valuing nature, identity, sense of place, seeking career skills, helping research, disseminating information, and helping others (Table 3.3). Prior to training, learning was more than twice as likely to be mentioned by drop outs than by continuing volunteers, in the open-ended survey question as a motivation. However, six months after the training drops out were less likely to say learning was a major motivation, suggesting a decline over time in learning motivations for drop outs. Prior to the training as well as six months after the training continuing volunteers were twice as likely to mention valuing nature as a major motivation (n=10; n=5). Other motivations that were more frequent before the training than after for continuing volunteers was the desire to be part of something and seeking career skills. Citizen scientists' sense of identity, for example as an environmentalist, was equally important for drop outs and continuing volunteers six months after the training (n=4; n=4).

Table 3.3 Six months post-training open-ended survey question, demonstrating frequency of emerging and established themes by volunteers and drop outs.

Motivational code	*Continuing Volunteers*	*Drop outs*	*Examples*
1.Valuing nature	10	5	"To conserve and prevent the deterioration of our planet."
2. Learning	5	4	"I'm interested in understanding water quality of rivers in the region."
3. Identity	4	4	"To understand my environment and as such, understand myself better through it."
4. Responsibility	2	1	"The disinterest of the population in general and their lack of involvement in the environment."
5. To be part of something	2	1	"To be part of a community committed to the improvement of the environment."
6. Social	0	1	"Meeting people with more experience than me and getting to know them."
7. Escape	1	0	"I like getting away and into nature."
8. Sense of place	2	1	"The state of the environment, where I normally spend a great part of my time with my family, is very important to me"
9. Seeking career skills	0	2	"To get knowledge for my career."
10. Helping research	1	1	"To help programs that can serve as a reference for management and improvement of water quality."
11. Disseminating information	1	1	"Because the building conscientiousness on our globe is important for taking care of water on our planet."
12. Helping others	1	0	"A better understanding of how to monitor the river can help humanity."

Interview data six months after the training also suggests that continuing volunteers have higher motivations to be part of something. One volunteer said of drop outs, "They need to drink more of the [GWW] punch!" They also suggest that volunteers have higher social motivations, for example, one volunteer said, "When my girlfriend commented to me about this place, Global Water Watch, the truth is it made me interested!" Some volunteers also stated higher motivations to escape to nature, similar to survey data. For example, one citizen scientist that works as a teacher with disabled students said, "[Monitoring] has helped provide me an escape from what I'm living with…Because it's not so easy to work with children with disabilities, and the problems they also have with their families. So above everything it serves as an escape and I do especially enjoy it."

Interviews with volunteers and drop outs revealed that environmental values were more related to retention. For example, one volunteer said, "It's cool and enjoyable to work knowing that you're doing something for the environment. But sometimes it's sad when you meet people that don't know anything or don't care. So, it's nice to feel satisfaction for doing something." Drop outs, on the other hand, had weaker stated environmental values, for example, "If I were closer, or if I had more of a connection or experience with water resources, I would say 'Now, I'd like to do monitoring.' And so, I feel in some way it's very personal… I see it as a theme that is very unrelated to what I'm doing right now."

3.3.3 Does the novel training influence perceptions of project relevance and participation in data collection?

On average, perceptions of project relevance were higher for the intervention group than the non-intervention group at all time points, before, two weeks after, and six months after the training. Testing for short-term changes in perceptions of project relevance before the training and two weeks after the training using t-tests within each group, we found that the intervention training group had statistically significant differences (t-value=2.45, p-value=0.0917), increasing from a Likert scale of 4.000 to 4.500. The control training group did not have any differences in the short term. However, testing for longer-term changes in perceptions of project relevance before the training and six months after the training using t-tests within each group, we found that neither group showed statistically significant differences from before training (Fig. 3.2).

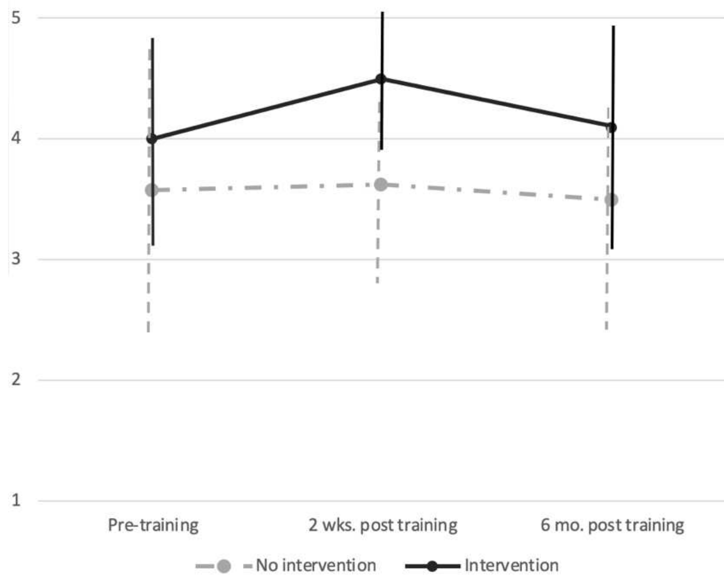


Fig 3.2 Illustrating short term changes in citizen scientists' perceptions of project relevance, on a 5-point Likert scale, due to the intervention.

To test whether these differences in perceptions of project relevance were due to the intervention, we used a mixed effects model with intervention and time as fixed effects and participants as the random effect. We found that participants showed statistically significant differences due to the intervention over time, with a positive influence (f-value=5.17; p=0.014) (Table 3.4).

Table 3.4 Results of the mixed effects model of time and intervention on saliency.

Variable	*f-value*	*p-value*
Time	0.08	0.782
Intervention	0.68	0.518
Time*Intervention	5.17	0.014
AIC	*113.6*	
Likelihood Ratio	*7.22*	
Observations	*52*	

Triangulation using interview data on perceptions of project relevance show that drop outs who had monitored only once tended to question the importance of the research (n=4), while continuing volunteers tended to understand and accept its importance (n=3) (Table 3.5). Both volunteers (n=5) and drop outs (n=4) were more concerned with pollution as a major threat to water supply than issues with water flow, suggesting that including a dimension on water pollution in addition to water supply could have improved perceptions of project relevance. For example, one drop out said "All of the drainages go into the river, so it smells horrible. It comes in with contaminants from fertilizers, from a range of sources, but in the end there's a lot of contamination." Similarly, one volunteer said, "on the weekends people come and bring food, bring whatever, and leave their trash [in the river]. You walk around and there's all types of trash, things you couldn't even imagine." These results demonstrate that water quality is much more visible in many ways that incremental changes in water flow.

Table 3.5 Perceptions of project relevance of research of drop outs and continuing volunteers

Drop outs question project relevance	"I don't know if the data are used by the government, I doubt it. I hope that it will get to them but it's probably in a limited way."
	"This has worried me a lot, and actually it's something that I'm still not clear on: is it important to measure the flow or quantity of water?"
	"It's cool, I like it, but at this point I don't see its functionality in how it can be useful. If I wasn't dedicated to studying or working in the environmental sector this wouldn't serve me at all! Not even from the spiritual environmental part, because monitoring water doesn't help the river get clean, or for reforestation… it's theoretical!"
	"It continues to be difficult for me to talk about the utility of the data, except maybe directly for you all, for the organization. But for the public I don't think it tells you much. As a tool to get excited about, building conscientiousness, I don't think it tells you much."
Continuing monitors confirm project relevance	"The results help precisely to determine some environmental solutions in the long, medium, and short term."
	"I think that we should collect better information. The volume of information is good but we need to know more about what is affecting the river."
	"I do think the data is useful, at least as a reference."

Turning to the participation of volunteers in collecting water monitoring data, we found on average that participants in the intervention training group collected similar levels of data ($\bar{x}$=2.056, SD=1.626) as those within the non-intervention training group ($\bar{x}$=2.235, SD=1.437) six months after the training. We found no statistically significant differences between these values using t-tests (t=0.71, p=0.478). To test whether there were changes in data collection over time due to the intervention, we used a mixed effects model with intervention and time as fixed effects and participants as the random effect.

We found the interaction of intervention and time was not statistically significant (f-value=0.10; p-value=0.906).

3.3.4 What are the challenges to participation in citizen science?

Split by volunteers and drop outs, the open-ended survey question six months after the training showed that drop outs were more likely to say they had insufficient time (n=10), than continuing volunteers (n=0) (Table 3.6). Interviews confirm that drop outs are likely to say they have insufficient time (n=10), while none of the continuing volunteers had this challenge. There were also major challenges with traveling to the site that was mentioned both by drop outs (n=4) and by continuing volunteers (n=8) in the open-ended survey question, which was re-affirmed in interviews of three of the six drop outs and two of the six volunteers we examined.

Table 3.6. Perceived challenges to participation in citizen science by continuing volunteers, drop outs and the total.

Challenge	*Continuing Volunteers*	*Drop outs*	*Total*
Difficulty organizing others	12	4	16
Traveling to the site	8	4	12
Insufficient time	0	10	10
Inputting data	3	0	3
Family obligations	2	0	2
Costs	0	2	2
Afraid of getting in water	1	1	2
Understanding the data	1	0	1
None	1	0	1

Note: Multiple themes could have been mentioned which is why the totals add up to more than the number of volunteers and drop outs.

3.4. DISCUSSION

3.4.1 The role of age and education in citizen scientist recruitment and retention

Research shows that education is a consistent predictor for the participation of volunteers (McPherson & Rotolo, 1996; Penner, 2004), as well as of citizen scientists (Brossard et al., 2005, Evans et al., 2005; Jordan et al., 2011; Land-Zandstra et al., 2015; Overdevest, Orr, & Stepenuck, 2004; Price & Lee, 2013; Trumbull et al., 2007). Our research confirms these patterns. Because citizen scientists are inherently interested in contributing to science it is perhaps unsurprising that they are highly educated, are already knowledgeable about the topic, interested in learning, and have a propensity to look up information. Education is often a strong predictor of volunteering for various reasons, specifically highly educated people have higher levels of self-efficacy, cognitive ability to fulfill the task, and are employed in jobs where volunteering can be an advantage (McPherson & Rotolo, 1996). In our study we find that education is a strong predictor of recruitment, but also acknowledge that our recruitment strategy (i.e. some of which occurred at schools) may have influenced our results.

In our study, age also proved to be an important variable for recruitment and retention, where middle aged individuals were more likely to sign up and continue volunteering. These results are widespread in citizen science (Crall et al., 2012; Jordan et al., 2011; Land-Zandstra et al., 2015). Research shows that age generally has a non-linear relationship with volunteering, gradually increasing from young adulthood to middle age then declining with the elderly due to health issues (Einolf, 2009; Herzog, Kahn, & Morgan 1989; Wilson, 2000). Offsetting declines in health, however, is the increased availability in time for volunteering for those that retire (Chambré, 1987). Indeed, although those that are retired do not necessarily volunteer in greater numbers than individuals who still work, retired individuals do tend to volunteer more time than those that are still in the workforce (Chambre, 1993; Choi, 2003). Research shows that simply asking individuals to volunteer with a personalized invitation increases likelihood of volunteering (Martinez et al., 2006; Tang, 2008; Brown et al., 2011), and is a best-practice for recruiting volunteers (Sellon, 2014).

3.4.2 Citizen scientists' motivations for learning and valuing the environment

Alongside demographic factors, motivations are an important determinant of participation in citizen science. Unlike demographic factors which are relatively static, understanding dynamic motivations can be useful for tailoring recruitment and retention strategies. We found that the most important reason for respondents to sign up were because of their interest in learning. Motivations to learn new things coincides with other citizen science research that volunteers are interested in the project topics (Dickinson et al., 2012; Newman et al., 2012) and to learn (Brossard et al., 2005; Crall et al., 2013; Land-

Zandstra et al., 2015). Additionally, framing of recruitment materials to consider the importance of learning may be influential for getting citizen scientists to sign up.

Although survey data did not identify any motivational factors as important for continued participation, interview data adds to these narratives showing that values and learning were extremely important motivations, a finding that coincides with other citizen science research (Domroese & Johnson, 2017). Indeed, the interviews showed pro-environmental values were the most important motivations for volunteering in citizen science. This adds to previous research confirming the importance of values for environmental volunteers and citizen scientists (Bramston, Pretty, & Zammit, 2011; Bruyere & Rappe, 2007; Stern & Dietz, 1994). Specifically, continuing volunteers indicated a stronger desire to conserve nature.

We also had a number of intrinsic motivations emerge in our qualitative data. These motives fall into role identity theory (Finkelstein & Brannick, 2007; Grube & Allyn Piliavin, 2000; Piliavin, Grube, & Callero, 2002), e.g. 'identity' and 'sense of place' (Evans et al., 2005; Haywood, 2014; Newman et al., 2017), as well as prosocial personality behavior (Penner, 2002), including 'helping research', 'disseminating research', and 'helping others'. Although in our research prosocial behavior was relatively minor, there is much research indicating that volunteers are often motivated to help others and the environment (Bruyere & Rappe, 2007; Jacobson, Carlton, & Monroe, 2012) and that citizen science projects that incorporate facets of sense of place into project materials increase likelihood of affecting conservation decision making (Newman et al., 2017). The diversity of responses, however, attests to the need for research to test and integrate multiple social-psychology frameworks, and to gain a fuller understanding of these more nuanced motivations (Finkelstien, 2009).

3.4.3 Novel training's influence on short-term perceptions of project relevance

We sought to improve perceptions of project relevance of the research by inviting local decision makers to discuss the importance of citizen science for decision making in the local PHS program. We found that a one-time presentation in the training was sufficient for influencing perceptions of project relevance in the short term. Indeed, many volunteers from the intervention were convinced of the importance of this research while drop outs within the control group questioned the importance of monitoring as being nothing more than 'theoretical'. However, these results were short-lived, and we found no long-term improvements to their perceptions. The training had no influence on the level of effort in data collection.

Theoretical research in the field of political action strongly suggests that targeting perceptions of relevance, i.e. importance and timeliness, is important for action (Cash et al., 2002). While we do not find a connection between perceptions of project relevance and data collection in our experimental design, there are many reasons why this might be. First, the training itself was not designed to influence perceptions of project relevance of the research *for the citizen scientists,* the training was designed to incentivize participation because the data is important *for the policy maker* in making decisions related to the PHS conservation program. For changes in perceptions of project relevance to affect data collection, they may need to address the importance and timeliness of the data to the target audience (i.e. the citizen science volunteers). Second, information on relevance is often defined as being both important and timely, however, our survey instrument only measured one facet (i.e. how important the data is). We did not measure whether citizen scientists found the information to also be timely, which may be more important for action (i.e. participation in citizen science). Third, long-term perceptions of project relevance may be unaffected by a one-time training intervention; continuous interventions may be needed to see sustained changes. Finally, committed volunteers and drop outs alike expressed concerns about water pollution but *not* water supply. A citizen science project for water quality monitoring (e.g. testing for E. coli, fecal matter, and total coliform) may have been more effective at recruiting and retaining citizen scientists in this study area. In the CRELE framework the three components are tightly coupled, where legitimacy of the project (i.e. taking in the voice of all participants) is often inextricable from the perceived relevancy of the project (Dunn & Laing, 2017; Sarkki et al., 2014). This research suggests that future efforts to improve participation should focus on integrating all three elements –credibility, relevancy and legitimacy—into citizen science project design.

3.4.4 Addressing challenges to participation for citizen scientists

Citizen scientists measuring water flow faced many challenges some of which were inherent within the design of the data collection method. As discussed in the methods, data collection on water flow required a team of four, so it is perhaps unsurprising that one of the major challenges that volunteers faced was organizing others to conduct the research. We anticipate that retention could have been improved if the tasks could be completed individually rather than in a group. Other challenges included issues with traveling long distances and having difficulty finding the water flow sites. In the future, researchers should consider selecting sites that are closer to volunteers' residences and helping coordinate monitoring efforts among multiple volunteers (via web- or phone-based applications) to reduce the number of drop outs.

3.4.5 Study limitations

The generalizability of this study is limited by the small study area, sample size, and limited time frame within which our research was conducted. The results should therefore be interpreted with caution and be considered descriptive in nature, signaling additional areas of research on the topic of citizen science participation and retention in a global South context. Despite these limitations, our use of mixed methods, and a novel training intervention, contribute new understanding on what drives initial participation and retention in water flow monitoring citizen science projects in Mexico, an important and expanding area of citizen science development for Mexico's national and local PHS programs.

3.5 CONCLUSION

Citizen science has irreversibly changed the scientific landscape, improving the resolution and scale at which research can be conducted. However, it requires a motivated base of volunteers that sign up and continue to collect high quality data. This research contributes knowledge on who participates (i.e. recruitment), who continues to participate (i.e. retention), how training can influence perceptions of the importance of the research (i.e. relevance) and participation in data collection, and what challenges citizen scientists face, in an understudied part of the world for this topic, Mexico. In practice, it is one of the first to our knowledge to directly link decision makers to citizen scientists within training to experimentally test its influence on perceptions of project relevance and level of participation. Both drop outs and continuing monitors were more concerned about water pollution than water supply, which is also often more visible than incremental changes in flow. This highlights the importance of including citizen scientist voices in project design to improve long-term participation. Future projects should consider integrating a more iterative dialogue between decision makers and citizen scientists improve perceptions of project relevancy, legitimacy and participation in citizen science projects.

REFERENCES

Asah, S. T., & Blahna, D. J. (2012). Motivational functionalism and urban conservation stewardship: Implications for volunteer involvement. *Conservation Letters*, *5*(6), 470–477. https://doi.org/10.1111/j.1755-263X.2012.00263.x

Asbjornsen, H., Manson, R. H., Scullion, J. J., Holwerda, F., Alvarado-barrientos, M. S., Geissert, D., … Bruijnzeel, L. A. (2018). Interactions between payments for hydrologic services , landowner decisions , and ecohydrological consequences : synergies and disconnection in the cloud forest zone of central Veracruz , Mexico. *Ecology and Society, 22*(2):25.

Biodiversidad Mexicana. *n.d.* Ciencia Ciudadana. Available at: https://www.biodiversidad.gob.mx/Difusion/cienciaCiudadana/

Bramston, P., Pretty, G., & Zammit, C. (2011). Assessing Environmental Stewardship Motivation. *Environment and Behavior* , *43*(6), 776–788.

Brossard, D., Lewenstein, B., & Bonney, R. (2005). Scientific knowledge and attitude change: The impact of a citizen science project. *International Journal of Science Education*, *27*(9), 1099–1121. https://doi.org/10.1080/09500690500069483

Brown, J. W., Chen, S. L., Mefford, L. C., Brown, A., Callen, B., & McArthur, P. (2011). Becoming an older volunteer: A grounded theory study. *Nursing Research and Practice*, 2011.

Bruyere, B., & Rappe, S. (2007). Identifying the motivations of environmental volunteers. *Journal of Environmental Planning and Management*, *50*(4), 503–516. https://doi.org/10.1080/09640560701402034

Carifio, J., & Perla, R. J. (2007). Ten Common Misunderstandings, Misconceptions, Persistent Myths and Urban Legends about Likert Scales and Likert Response Formats and their Antidotes. *Journal of Social Sciences*, *3*(3), 106–116.

Cash, D. W., Clark, W. C., Alcock, F., Dickson, N. M., Eckley, N., Guston, D. H., … Mitchell, R. B. (2003). Knowledge systems for sustainable development. *Proceedings of the National Academy of*

Sciences of the United States of America, *100*(14), 8086–8091. https://doi.org/10.1073/pnas.1231332100

Chambré, S. M. (1987). *Good deeds in old age*. Lexington, MA: D.C. Health.

Chambré, S. M. (1993). Volunteerism by elders: Past trends and future prospects. *The Gerontologist*, *33*(2), 221-229.

Choi, L. H. (2003). Factors affecting volunteerism among older adults. *Journal of Applied Gerontology*, *22*(2), 179-196.

Clary, E. G., Snyder, M., Ridge, R. D., Copeland, J., Associates, S. J., Stukas, A. A., … Miene, P. (1998). Understanding and Assessing the Motivations of Volunteers: A Functional Approach. *Journal of Personality and Social Psychology*, *24*(6), 1516–1530.

Conrad, C. C., & Hilchey, K. G. (2011). A review of citizen science and community-based environmental monitoring: issues and opportunities. *Environmental monitoring and assessment*, *176*(1-4), 273-291.

Cook, C. N., Mascia, M. B., Schwartz, M. W., Possingham, H. P., & Fuller, R. A. (2013). Achieving conservation science that bridges the knowledge-action boundary. *Conservation Biology*, *27*(4), 669–678. https://doi.org/10.1111/cobi.12050

Crall, A. W., Jordan, R., Holfelder, K., Newman, G. J., Graham, J., & Waller, D. M. (2013). The impacts of an invasive species citizen science training program on participant attitudes, behavior, and science literacy. *Public Understanding of Science (Bristol, England)*, *22*(6), 745–764. https://doi.org/10.1177/0963662511434894

Dickinson, J. L., Shirk, J., Bonter, D., Bonney, R., Crain, R. L., Martin, J., ... & Purcell, K. (2012). The current state of citizen science as a tool for ecological research and public engagement. *Frontiers in Ecology and the Environment*, *10*(6), 291-297.

Domroese, M. C., & Johnson, E. A. (2017). Why watch bees? Motivations of citizen science volunteers in the Great Pollinator Project. *Biological Conservation*, *208*, 40–47. https://doi.org/10.1016/J.BIOCON.2016.08.020

Dunn, G., & Laing, M. (2017). Policy-makers perspectives on credibility, relevance and legitimacy

(CRELE). *Environmental Science & Policy*, *76*, 146-152.

Einolf, C. J. (2009). Will the boomers volunteer during retirement? Comparing the baby boom, silent, and long civic cohorts. *Nonprofit and voluntary sector quarterly*, *38*(2), 181-199.

Engel, S., S. Pagiola, & Wunder, S. (2008). Designing payments for environmental services in theory and practice: an overview of the issues. *Ecological Economics*. 65(4):663–674.

Evans, C., Abrams, E., Reitsma, R., Roux, K., Salmonsen, L., & Marra, P. P. (2005). The Neighborhood Nestwatch Program: Participant Outcomes of a Citizen-Science Ecological Research Project. *Conservation Biology*, *19*(3), 589–594. https://doi.org/10.1111/j.1523-1739.2005.00s01.x

Follett, R., & Strezov, V. (2015). An analysis of citizen science based research: usage and publication patterns. *PloS one*, *10*(11), e0143687.

Ferster, C., Coops, N., Harshaw, H., Kozak, R., Meitner, M., Ferster, C. J., … Meitner, M. J. (2013). An Exploratory Assessment of a Smartphone Application for Public Participation in Forest Fuels Measurement in the Wildland-Urban Interface. *Forests*, *4*(4), 1199–1219. https://doi.org/10.3390/f4041199

Finkelstein, M. A., & Brannick, M. T. (2007). Applying theories of Institutional Helping to Informal Volunteering: Motives, role identity, and prosocial personality. *Social Behavior and Personality: An International Journal*, *35*(1), 101–114. https://doi.org/10.2224/sbp.2007.35.1.101

Finkelstien, M. A. (2009). Intrinsic vs. extrinsic motivational orientations and the volunteer process. *Personality and Individual Differences*, *46*(5–6), 653–658. https://doi.org/10.1016/J.PAID.2009.01.010

García-Coll, I., A. Martínez-Otero, A. Ramírez-Soto, A. NiñoCruz, A. J. Rivas, L. Domínguez-Barrada. (2004). Relación aguabosque: delimitación de zonas prioritarias para pago de servicios ambientales hidrológicos en la cuenca del río Gavilanes, Coatepec, Veracruz. Pages 99–115 in H. Cotler, editor. *Manejo integral de cuencas en México: estudios y reflexiones para orientar la política ambiental INE/SEMARNAT,* Mexico City, D.F., Mexico.

Grube, J. A., & Allyn Piliavin, J. (2000). Role identity, organizational experiences, and volunteer performance. *Personality and Social Psychology Bulletin*, *26*(9), 1108–1119.

Haywood, B. K. (2014). A “Sense of Place” in Public Participation in Scientific Research. *Science Education*, *98*(1), 64–83. https://doi.org/10.1002/sce.21087

Heink, U., Marquard, E., Heubach, K., Jax, K., Kugel, C., Nesshoever, C., ... & Vandewalle, M. (2015). Conceptualizing credibility, relevance and legitimacy for evaluating the effectiveness of science–policy interfaces: challenges and opportunities. *Science and Public Policy*, *42*(5), 676-689.

Henderson, S. (2012). Citizen science comes of age. *Frontiers in Ecology and the Environment*, *10*(6), 283-283.

Herzog, A. R., Kahn, R. L., Morgan, J. N., Jackson, J. S., & Antonucci, T. C. (1989). Age Differences in Productive Activities. *Journal of Gerontology*, *44*(4), 129–138. https://doi.org/10.1093/geronj/44.4.S129

Higgins, O., & Shackleton, C. M. (2015). The benefits from and barriers to participation in civic environmental organisations in South Africa. *Biodiversity and Conservation*, *24*(8), 2031–2046. https://doi.org/10.1007/s10531-015-0924-6

Hinton, P.R., Brownlow, C., Murray, I., & Cozens, B. (2004). SPSS Explained. New York: Routlouge.

Instituto Nacional de Estatistícas y Geographía (INEGI). (2015a). Demografía – Xalapa. Mexico City, Mexico.

Instituto Nacional de Estatistícas y Geographía (INEGI). (2015b). Demografía – Coatepec. Mexico City, Mexico.

Jacobson, S. K., Carlton, J. S., & Monroe, M. C. (2012). *Motivation and Satisfaction of Volunteers at a Florida Natural Resource Agency*. *Journal of Park and Recreation Administration Spring* (Vol. 30).

Johnson, M. F., Hannah, C., Acton, L., Popovici, R., Karanth, K. K., & Weinthal, E. (2014). Network environmentalism: Citizen scientists as agents for environmental advocacy. *Global Environmental Change*, *29*, 235–245. https://doi.org/10.1016/j.gloenvcha.2014.10.006

Jordan, R. C., Gray, S. A., Howe, D. V., Brooks, W. R., & Ehrenfeld, J. G. (2011). Knowledge gain and behavioral change in citizen-science programs. *Conservation Biology*, *25*(6), 1148-1154.

Kullenberg, C., & Kasperowski, D. (2016). What is citizen science? - A scientometric meta-analysis. *PLoS ONE*, *11*(1). https://doi.org/10.1371/journal.pone.0147152

Land-Zandstra, A. M., Devilee, J. L., Snik, F., Buurmeijer, F., & van den Broek, J. M. (2016). Citizen science on a smartphone: Participants' motivations and learning. *Public Understanding of Science*, *25*(1), 45-60.

Lee, T. K., Crowston, K., Harandi, M., Østerlund, C., & Miller, G. (2018). Appealing to different motivations in a message to recruit citizen scientists: results of a field experiment. *Journal of Science Communication*, *17*(1), A02.

Martinez, I. L., Frick, K., Glass, T. A., Carlson, M., Tanner, E., Ricks, M., et al. (2006). Engaging older adults in high impact volunteering that enhances health: recruitment and retention in the experience corps® Baltimore. *Journal of Urban Health, 83*(5), 941–953.

McPherson, J. M., & Rotolo, T. (1996). Testing a Dynamic Model of Social Composition: Diversity and Change in Voluntary Groups. *American Sociological Review*, *61*(2), 179. https://doi.org/10.2307/2096330

Newman, G., Chandler, M., Clyde, M., McGreavy, B., Haklay, M., Ballard, H., … Gallo, J. (2017). Leveraging the power of place in citizen science for effective conservation decision making. *Biological Conservation*, *208*, 55–64. https://doi.org/10.1016/J.BIOCON.2016.07.019

Newman, G., Wiggins, A., Crall, A., Graham, E., Newman, S., & Crowston, K. (2012). The future of citizen science: emerging technologies and shifting paradigms. *Frontiers in Ecology and the Environment*, *10*(6), 298-304.

Overdevest, C., Orr, C. H., & Stepenuck, K. (2004). Volunteer stream monitoring and local participation in natural resource issues. *Human Ecology Review*, *11*(2), 177–185.

Paré, L., & Gerez, P. (2012). Al filo del agua: cogestión de la subcuenca del río Pixquiac, Veracruz. *Instituto Nacional de Ecología*, Mexico City, D.F., Mexico. Paruelo, J. M. 2012. Ecosystem services

Penner, L. A. (2002). Dispositional and Organizational Influences on Sustained Volunteerism: An Interactionist Perspective. *Journal of Social Issues*, *58*(3), 447–467. https://doi.org/10.1111/1540-

4560.00270

Penner, L. A. (2004). *Volunteerism and Social Problems: Making Things Better or Worse? Journal of Social Issues* (Vol. 60).

Piliavin, J. A., Grube, J. A., & Callero, P. L. (2002). *Role as Resource for Action in Public Service. Journal of Social Issues* (Vol. 58).

Price, C. A., & Lee, H. S. (2013). Changes in participants' scientific attitudes and epistemological beliefs during an astronomical citizen science project. *Journal of Research in Science Teaching*, *50*(7), 773-801.

Rotman, D., Hammock, J., Preece, J., Hansen, D., Boston, C., Bowser, A., & He, Y. (2014). Motivations Affecting Initial and Long-Term Participation in Citizen Science Projects in Three Countries. In *iConference 2014 Proceedings* (p. 110–124). doi:10.9776/14054

Sarkki, S., Niemelä, J., Tinch, R., Van Den Hove, S., Watt, A., & Young, J. (2013). Balancing credibility, relevance and legitimacy: a critical assessment of trade-offs in science–policy interfaces. *Science and Public Policy*, *41*(2), 194-206.

Sarkki, S., Tinch, R., Niemelä, J., Heink, U., Waylen, K., Timaeus, J., ... & van den Hove, S. (2015). Adding 'iterativity'to the credibility, relevance, legitimacy: a novel scheme to highlight dynamic aspects of science–policy interfaces. *Environmental Science & Policy*, *54*, 505-512.

Sellon, A. M. (2014). Recruiting and retaining older adults in volunteer programs: Best practices and next steps. *Ageing International*, *39*(4), 421-437.

Silvertown, J. (2009). A new dawn for citizen science. *Trends in ecology & evolution*, *24*(9), 467-471.

Stern, P. C., & Dietz, T. (1994). The Value Basis of Environmental Concern. *Journal of Social Issues*, *50*(3), 65–84.

Tang, F. (2008). Socioeconomic disparities in voluntary organization involvement among older adults. *Nonprofit and Voluntary Sector Quarterly, 37*(1), 57–75.

Trumbull, D. J., Bonney, R., Bascom, D., & Cabral, A. (2000). Thinking scientifically during participation in a citizen-science project. *Science education*, *84*(2), 265-275.

Van Enst, W. I., Driessen, P. P., & Runhaar, H. A. (2014). Towards productive science-policy interfaces: a research agenda. *Journal of Environmental Assessment Policy and Management*, *16*(01), 1450007.

Wiggins, A., Bonney, R., Graham, E., Henderson, S., Kelling, S., LeBuhn, G., ... & Newman, G. (2013). Data management guide for public participation in scientific research. *DataOne Working Group*, 1-41.

Wilson, J. (2000). Volunteering. *Annual review of sociology*, *26*(1), 215-240.

Wright, D. R., Underhill, L. G., Keene, M., & Knight, A. T. (2015). Understanding the Motivations and Satisfactions of Volunteers to Improve the Effectiveness of Citizen Science Programs. *Society and Natural Resources*, *28*(9), 1013–1029. https://doi.org/10.1080/08941920.2015.1054976

Yáñez-Arancibia, A., & Day, J.W. (2004). Environmental subregions in the Gulf of Mexico coastal zone: the ecosystem approach as an integrated management tool. *Ocean & Coastal Management.* 47(11):727–757.

CHAPTER FOUR: DOES CITIZEN SCIENCE IMPROVE CONSERVATION KNOWLEDGE, ATTITUDES, AND STEWARDSHIP BEHAVIORS[3]

4.1. INTRODUCTION

The participation of the public in generation of knowledge—i.e. citizen science—is increasingly recognized and used for science and natural resource management (Bonney et al., 2009). Millions of individuals have become involved in citizen science projects and there are now hundreds of projects worldwide (Bonney et al., 2014). Citizen science is one of many terms that have similar meanings including public participation in scientific research, participatory monitoring, and community-based monitoring. Generally, although citizen science refers to various levels of involvement of the public in scientific research, the majority of projects still emphasize the importance of the public in collecting data at spatial scales and resolutions that were never before attainable by individual researchers. Citizen science has contributed to important advances in the biological sciences, conservation sciences, astronomy, medicine, and evolutionary ecology (Follett & Strezov, 2015).

Increasingly, researchers have turned to questions of whether and how citizen science projects can provide benefits beyond the natural sciences to social outcomes such as gains in knowledge, attitudes, and stewardship behaviors. The majority of research on social outcomes in citizen science has focused on improvement to learning outcomes or changes in attitudes. This includes improvements to skills and content knowledge (Crall et al., 2013), understanding of the scientific method (Brossard et al., 2005), and knowledge of context specific ecological and environmental issues (Cronje et al., 2011). However, gains in knowledge and changes in attitudes are often insufficient to determine stewardship behavior (Manfredo, 2008). While some behavioral changes are relatively simple, such as learning skills useful in identifying invasive weeds (Crall et al., 2013), others are more complex, such as developing responsible

[3] This research is in preparation for Environmental Behaviors, with co-authors Kelly Jones, Jen Solomon, and Miriam Ramos-Escobedo.

stewardship ethics and civic engagement (Overdevest, Orr, & Stepenuck, 2004). Psychological research suggests that complex behavioral changes like stewardship require three components: (1) Knowledge of the issue; (2) Knowledge of courses of action that are most effective; and (3) Desire to act, which is influenced by attitudes towards the environment (Hungerford & Volk, 1990). An additional challenge with assessing social outcomes in citizen science projects is that most people who volunteer already have higher levels of scientific knowledge and engage in more environmental stewardship behaviors than the average person (Crall et al. 2013; Shinbrot et al., in prep.).

In general, there have been few studies that rigorously test the connection of citizen science to changes in knowledge, attitudes, and stewardship behaviors (Toomey & Domroese, 2013). The few that have examined these outcomes have been inconclusive in demonstrating significant impacts. For example, one study found citizen science improved content knowledge but had no significant impact on attitudes towards the environment (Brossard et al., 2005). Another study on participant attitudes towards then environment found no difference between pre- and post-training survey scores (Crall et al., 2013). Some research has showed that participation can influence how volunteers manage their backyards for wildlife benefits (Evans et al., 2005), i.e. behaviors. However, other researchers found that despite improvements to knowledge, changes to behavior were minor (Jordan et al., 2011). These studies suggest the need for additional research on how citizen science programs can be designed to affect knowledge, attitudes, and behaviors, where internal factors like preexisting values (Schultz, 2001), self-identity (Waylen et al., 2009), and external factors like subjective norms (Ajzen 1991), may have a significant influence.

The primary goal of this research was to examine whether citizen science participation influenced social outcomes, specifically conservation knowledge, attitudes towards conservation programs, and environmental stewardship behaviors. A sub-goal of this study was to test whether including regional conservation decision-makers in the training, to increase the saliency of the work, would have greater impacts on these social outcomes. Our specific research questions include: (1) Do citizen scientists differ from the nature-oriented public in terms of conservation knowledge, attitudes, and stewardship behaviors?

(2) How does participation in citizen science programs influence conservation knowledge, attitudes, and stewardship behavior? (3) Does a novel training that involves policy makers influence conservation knowledge, attitudes, and stewardship behavior? Related to the third question, we exploited a unique opportunity to influence the design of a water flow citizen science program in Mexico and held two water flow trainings for citizen scientist volunteers: one traditional training and one novel training involving regional decision-makers that emphasized the importance of data collection for local Payment for Hydrologic Services (PHS) programs. We collected mixed methods data, surveying volunteers before and after training and conducting interviews. Our findings contribute important experimental evidence on whether citizen science projects influence social outcomes and how programs can be designed to effect changes in conservation knowledge, attitudes, and stewardship behaviors.

4.2 BACKGROUND

Our research was conducted in the cities of Xalapa and Coatepec, in the coastal state of Veracruz, Mexico. With a population of 480,841, the city of Xalapa is one of the largest cities in the state (INEGI, 2015a). Less than ten miles away is the smaller sister city of Coatepec, with a population of 92,127 (INEGI, 2015b). Situated in the lower watersheds of the forested Pixquiac and Gavilanes watersheds, Xalapa and Coatepec rely on these rivers as major sources of drinking water: the Pixquiac river provides 40% of potable water to Xalapa and the Gavilanes river provides 90% of potable water to Coatepec (García-Coll et al., 2004; Paré & Gerez, 2012). Drinking water, however, has increasingly been imperiled due to land use change and deforestation upstream (Jones et al., 2019; López-Rodríguez & Acevedo-Rosas, 2005). Over the past fifty years extensive deforestation due to agriculture and cattle ranching has increasingly fragmented and degraded landscapes (López-Barrera, Manson, & Landgrave, 2014). To address this ecological crisis, the Mexican government implemented a national financial mechanism where downstream water users pay upstream land owners to conserve their land for associated water services downstream –i.e. PHS (Muñoz-Piña et al., 2008). The success of the PHS program is dependent on its ability to incentivize conservation behaviors for downstream benefits (Engel, Pagiola, & Wunder, 2008), but few evaluations have been made and there is a need for continuous monitoring to evaluate its efficacy (Asbjornsen et al., 2017).

We collaborated with regional implementers of the PHS programs in each watershed to design a training module that emphasized the saliency of water monitoring for decision making. Within the Pixquiac watershed, we collaborated with Fidecoagua which manages the matching funds for hydrological services as part of the municipal government of Coatepec (Scullion et al., 2011). Within the Gavilanes, we collaborated with SENDAS, in Spanish *Senderos y Encuentros para un Desarrollo Autónomo Sustentable*, which is a Xalapa-based non-profit organization that advocates and promotes sustainable development through best management practices of natural resources as well as provides environmental education on the PHS program (Nava-López et al., 2018; Paré and Fuentes, 2018). Each was interested in continuous water flow data for informing their decision making on the PHS program.

To organize data collection and volunteer training, we worked closely with Global Water Watch (GWW)-Mexico, one of the largest volunteer monitoring organizations in Mexico. GWW-Mexico was established in 2005 in Veracruz state as a chapter of GWW (located at Auburn University in Alabama) to train citizen scientists in measuring biophysical, bacterial, flow, and macroinvertebrate samples (Flores-Díaz et al., 2013). GWW-Mexico seeks not only to generate data but also to amplify environmental education and to encourage environmental protection. Their conceptual framework works under the assumption that by providing rigorous training through workshops—in our study, on water flow—they will produce knowledgeable citizens who collect data and also engage in stewardship behaviors.

The GWW conceptual framework mirrors much traditional environmental education research, assuming a linear association between increased knowledge and improved skills, and changes to environmental stewardship. However, research on stewardship behavior shows that these theoretical models are more complex. One model presented by Hungerford and Volk (1990), suggests that there are several components influencing an individual's intention to act, a prerequisite to behavior change. Specifically, individuals need to have the *awareness* of the issue, *knowledge* of the course of action to mediate the problem, as well as the desire to act, which is influenced by *attitudes* towards the problem

(Hungerford & Volk, 1990). In order to try and directly affect an individual's behaviors, we introduced a novel training program to the GWW traditional training to try and amplify these outcomes. In addition to the traditional GWW-Mexico water flow training to improve knowledge and skills, we invited regional decision-makers of the PHS programs – Fidecoagua and SENDAS – to discuss: (1) major threats to their watershed to influence *awareness* of the issue and *knowledge*; (2) courses of actions to improve water quality and quantity outcomes, to influence *behaviors*; and (3) the importance of the PHS program for providing water to downstream users, to influence *attitudes*.

4.3 METHODS

4.3.1 Participants and training

We recruited 35 individuals between February and May 2016 in the two urban cities of Xalapa and Coatepec through: advertisements on the GWW-Mexico Facebook page, the Fidecoagua website, and the SENDAS website; posters at two high schools and one university; and oral presentations at a Coatepec townhall meeting and on the radio. All forms of advertisement explicitly targeted individuals who were interested in learning new skills and gaining information related to water, engaging with GWW-Mexico, and contributing to information needed by regional decision-makers with the PHS program (Fig. 4.1.a).

Fig. 4.1 (a) An example of the advertisement to recruit water monitors in Xalapa; (b) the intervention training with SENDAS; (c) the intervention training with Fidecoagua; and (d) practice in the field measuring water flow.

Participants randomly signed up to participate in one of two trainings. Seventeen participants attended the traditional GWW water flow training, and 18 participants attended the novel intervention training that included decision-makers (Fig. 4.1 b,c). Although each monitoring team is typically encouraged to decide its own objectives, here we recruited monitors to specifically measure water flow. Participants did not know they were participating in different trainings. The traditional water flow training included two hours of in-class training learning about watersheds and developing skills for water monitoring; as well as two hours in the field practicing the water flow monitoring protocol (Fig. 4.1 d). After, participants spent an hour in class to debrief data collection and analysis as well as the mechanics of uploading data to the publicly accessible GWW-Mexico website. All participants were asked to sign a commitment to their participation in the project, which was signed after the training at the same time by the president of GWW-Mexico who committed to support them in their endeavors. They were then presented with a certificate of completion.

For the novel intervention training, the only modification made was that the first hour and a half included in-class presentations from the executive directors of Fidecoagua and SENDAS (Fig. 4.1 b, c).

In their presentations, they covered ecosystem threats, the PHS program, and courses of action to improve water, specifically environmental activism, non-activist behavior like speaking to others about conservation and engaging in private sphere activities (e.g. reducing water use). Following these presentations, the training for the most part mimicked the traditional water flow training. However, slightly less time (~30 min) was allocated to the water flow training to combat volunteer fatigue during training; this was suggested by the GWW-Mexico director. No fees were required for the training.

We also surveyed 84 non-citizen scientists in five natural areas in the region: Parque Macuiltepetl (n=20), Parque los Tecajetes (n=20), Parque de la Culebra (n=21), Trianon (n=21), and Cascada Bola de Oro (n=2). We targeted natural areas that were located in the same two urban areas as citizen science project; the goal was to find members of the public that could have been recruited for the citizen science project, and we expected them to have similar pro-environmental motivations to citizen scientists because of their desire to spend time in natural areas (Guiney & Oberhauser, 2009), but had not volunteered in our project. We approached every individual who entered the park during the data collection period in February 2017 and conducted in-person surveys. Below, we refer to these individuals as members of the nature-oriented public, because they were selected for their use of natural areas.

4.3.2 Data collection

4.3.2.1 Survey data

To understand the influence of the trainings on social outcomes, we surveyed citizen scientists prior to training, two weeks after, and six months after the training for both groups of volunteers (Appendix II, A.2.1).. The surveys were created in English by a bilingual researcher and independently assessed by a multicultural team of experts consisting of the GWW-Mexico director, GWW-Mexico staff, and University of Veracruz research assistants to ensure for semantic, cultural, and normative equivalence (Behling & Law, 2000). These surveys were self-administered in Spanish, and the primary investigator was nearby to clarify questions. The response rate for the survey two weeks after the training was 94.2%, and 80.0% six months after the training. All three surveys contained a section on (1) general knowledge, including environmental knowledge and awareness of the issues; (2) attitudes towards PHS; and (3) behaviors for environmental stewardship. Only the pre-survey collected information on (4) demographic factors such as age, sex, education, children, family members, and income.

Demographic factors were measured using fill in the blank, except income which was measured with a multiple-choice question with income ranges. General knowledge was measured using binary yes/no questions, six questions were on environmental knowledge (i.e. knowledge that: deforestation impairs water flow; where there are forests there is more rain; that forests provide clean water; of where their sources of drinking water are; and of their water treatment plant is) as well as six awareness questions (i.e. aware of: the need for water regulations; the PHS program; river flow problems in the region; and the insufficient water supply for the cities of Coatepec and Xalapa). Attitudes were measured using five, five-point Likert scale questions on the PHS program (i.e., PHS reduces threats to forests; PHS improves water supply; PHS reduces soil erosion; PHS benefits me; and PHS benefits others). The Likert scale contained more than three questions to ensure reliability, validity, and generalizability (Carifio & Perla, 2007).

The survey had eight behavioral items that were split into three categories: environmental activism, non-activist behavior, and private-sphere behaviors (Stern, 2000). For environmental activism we used the following items: “attending townhall meetings on conservation”, “writing politicians on conservation”, “writing to newspapers on conservation,” and “volunteering for a conservation cause”. For non-activist behavior that support environment movements we used “speaking to others on conservation issues.” For private-sphere environmentalism, we used the following items: “reducing water use,” “saving water for reuse,” and “cleaning up trash.” Research has shown that differentiating these types of behaviors is reliable and meaningful (Dietz, Stern, & Guagnano, 1998). Each behavior question was assessed using a five-point Likert-type ordinal scale of frequency of behavior from “never or almost never” (=1), “between every year and every four months” (=2), “between every four months and every month” (=3), “between every month and every week” (=4), to “more frequently than every week” (=5).

From the nature-oriented public we collected information on: (1) demographic factors; (2) general knowledge, including environmental knowledge, and awareness of water-related issues; (3) attitudes towards PHS; and (4) behaviors for environmental stewardship. These were measured the same way as was done in the surveys for citizen scientists.

4.3.2.2 Qualitative data

We conducted a total of 12 semi-structured interviews with citizen scientists six months after the training. Six of the interviews were with participants in the intervention group and six were from the group that did not receive the novel training. Interviews ran an average length of 35 minutes and were conducted in Spanish. The interview protocol consisted of open-ended questions with requests for clarification on specific themes (Appendix III, A.3.1). Similar to survey questions, we used modified direct translation where a panel of Spanish speakers, including the GWW-Mexico director, GWW-Mexico staff, and research assistants from University of Veracruz independently assessed the original translation to ensure for semantic and conceptual equivalence of English to Spanish translation of interview questions (Behling & Law, 2000). This method is useful for detecting semantic and conceptual misunderstandings that undermine the validity of the questions (Greenfield, 1997). We focused the interview on similar themes to the survey, specifically to understand attitudes towards PHS and stewardship behaviors. General knowledge was not triangulated using interviews.

4.3.3 Data analysis

4.3.3.1 Variable creation and statistical analyses

We conducted descriptive statistics on demographic data from surveys for the nature-oriented public and citizen scientists. We also conducted descriptive statistics for the binary yes/no questions for knowledge, which included environmental knowledge and awareness of the issues. All knowledge questions were summed and averaged, and all awareness were also summed and averaged to understand the percent correct. We conducted descriptive statistics for the five-point Likert scale questions on attitudes towards the PHS program, where the scale was summed and averaged to calculate separate composite scores (Boone & Boone, 2012). Likert scale questions were also analyzed for internal reliability using Cronbach's alpha. We accepted a Cronbach's alpha greater than 0.5 as moderately reliable (Hinton et al., 2004). We conducted univariate statistics on the behavioral questions for environmental stewardship. Likert-type scales cannot be summed and averaged as it does not presume underlying continuous variables as Likert scale questions do (Boone & Boone, 2012). Each environmental stewardship behavior was therefore analyzed separately

To examine whether the citizen scientists initially differ from the nature-oriented public (research question 1), we conducted t-tests to measure differences in mean values for conservation knowledge, attitudes, and stewardship behaviors, examining results to ensure for equal variances.

To analyze how participation in citizen science influences conservation knowledge, attitudes, and stewardship behaviors over time (research question 2), we conducted t-tests before the training and two weeks after to understand short-term changes in citizen science volunteers. We also conducted t-tests before the training and six months after to understand long-term changes in citizen science volunteers.

To evaluate whether the training intervention influenced conservation knowledge, attitudes, and stewardship behaviors in citizen science volunteers (research question 3) we conducted a generalized linear mixed model approach. Participant-level random effects were partitioned from fixed effects of time and the intervention. Linear mixed models were fit by maximum likelihood in the statistical software R, as:

$$y_{ij} = X_i\beta + b_i + \varepsilon_{ij}, \qquad \text{Eq. (1)}$$

where y_{ij} is the response for the *i*th respondent at the *j*th time for each model, X_i is the design matrix, and β is the vector of coefficients for fixed effects for the pre-survey and two post survey time periods, control and intervention group, as well as the interaction between the two (i.e. time and intervention) (Fujitani et al., 2016). In the model, b_i is the vector of random-effects coefficients for participants, and ε_{ij} is the vector of residual variance terms. We did not use the Wald test of the covariance parameters as they can be unreliable in small sample sizes (ibid).

4.3.3.2 Qualitative analysis

Interviews were transcribed using Jeffersonian transcription notation to capture not just what was said but also how it was said, for example, with italics for emphasis (Jefferson, 2004). Punctuation was also used to ensure transcript readability (Mann, 2016). Following transcription, two bilingual researchers used an iterative process of content and thematic analysis, for intercoder reliability. Researchers first used a directed content analysis approach, reading theoretical and applied research on the research questions to inform the initial codebook. Then using the open coding technique for thematic analysis, we allowed themes and codes to emerge from the transcripts. Researchers generally followed a six-step process detailed in Mann (2016): familiarization with the data, coding, searching for themes, reviewing themes, defining and naming themes, and write up. To ensure reliability of codes, transcripts were analyzed by two researchers. These codes were then entered into the qualitative software NVivo 12 Pro to analyze results, and to create comparison diagrams. To report back results, the first author translated relevant quotes from Spanish to English.

4.4 RESULTS

4.4.1 Do citizen scientists differ from the nature-oriented public?

In comparison to members of the nature-oriented public, citizen scientists were typically highly educated (88%) and women (54%), who were students (34%), teachers (20%), or unemployed (20%) (Appendix II, A.2.2). Despite patterns of under- or unemployment, citizen scientists tend to be from upper-middle income households (39%). On average, citizen scientists have lived in the community most of their lives (an average of 18 years). Most knew where their water comes from (89%) but were on average located relatively far from any body of water ($\bar{x}$=23 minutes away).

In terms of general knowledge, the pooled t-test with equal variances showed statistical difference between citizen scientists and the public in terms of eight knowledge, five attitude, and three behavioral variables (Table 4.1). The comprehensive scores for environmental knowledge were statistically different between citizen scientists and the public ($p<0.10$), where citizen scientists were more knowledgeable. The comprehensive scores for awareness also showed statistically significant differences ($p<0.05$), where citizen scientists were also more aware of the issues.

Table 4.1 Differences between citizen scientists and the nature-oriented public in terms of general knowledge, attitudes, and behaviors.

Theme	*Indicator*	*Citizen scientist Mean (SD)*	*Nature-oriented public Mean (SD)*	*t-test*
General knowledge	Know that deforestation impairs water flow (% correct)	1.00 (0)	0.89 (0.31)	3.16***
	Know where there are forests there is more rain (% correct)	1.00 (0)	0.90 (0.30)	2.96***
	Know that forests provide clean water (% correct)	1.00 (0)	0.96 (0.19)	1.75*
	Know that forests provide more water downstream (% correct)	0.97 (0.17)	0.96 (0.19)	0.16
	Know the sources of drinking water (% correct)	0.54 (0.50)	0.42 (0.49)	1.26
	Know the location of the water treatment plant (% correct)	0.54 (0.51)	0.58 (0.50)	0.40
	Comprehensive environmental knowledge score (% correct)	*0.83 (0.14)*	*0.77 (0.17)*	*1.79**
	Aware of the need for regulation of rivers (% correct)	0.50 (0.51)	0.23 (0.42)	2.74***
	Aware of PHS (% correct)	0.31 (0.47)	0.11 (0.31)	2.39**
	Aware of river flow problems in the region (% correct)	0.47 (0.51)	0.25 (0.44)	2.20**
	Aware that there is insufficient water in the city of Coatepec (% correct)	0.69 (0.42)	0.58 (0.50)	1.76*
	Aware that there is insufficient water in the city of Xalapa (% correct)	0.88 (0.33)	0.89 (0.31)	0.14
	Comprehensive awareness score (% correct)	*0.36 (0.31)*	*0.24 (0.25)*	*1.99***
Attitudes	PHS reduces threats to forests	3.57 (1.27)	1.66 (1.15)	2.22*
	PHS improves water supply	4.22 (0.67)	4.86 (0.38)	-2.24**
	PHS reduces soil erosion	4.00 (0.58)	2.53 (1.84)	2.00*
	PHS benefits me	4.11 (1.05)	2.75 (1.91)	1.79*

	PHS benefits others	4.70 (0.48)	3.25 (1.49)	2.65**
	Comprehensive attitudes score (averaged 5-pt. Likert scale)	4.15 (0.57)	3.16 (1.18)	2.18**
Behaviors[†]	Talk to others about conservation	4.23 (1.14)	3.76 (1.17)	1.99**
	Search for information on conservation	3.74 (1.11)	2.41 (1.47)	5.34***
	Save water for later use	4.57 (0.85)	4.04 (1.61)	2.35**
	Clean up trash in a natural area	2.77 (1.48)	2.44 (1.64)	1.01
	Write newspapers on conservation	1.06 (0.59)	1.27 (0.83)	1.54
	Attend town hall meetings on conservation	1.57 (0.31)	1.25 (0.76)	1.36
	Write politicians on conservation	1.42 (0.94)	1.26 (0.82)	0.96
	Volunteer for a conservation cause	2.03 (1.48)	1.96 (1.56)	0.21
Observations		*35*	*84*	

p-value 0.10, 0.05**, 0.01****

[†] Frequency of engagement in each activity on a five-point Likert-like scale, where 1 is almost never and 5 is more frequently than every week.

In terms of attitudes, the comprehensive Likert-scale score for attitudes towards PHS programs were statistically different between the nature-oriented public and citizen scientists (p-value<0.05), where citizen scientists had more strongly positive attitudes. Each individual variable was significantly different, where citizen scientists had more positive attitudes for perceptions that PHS reduces threats to forests, that it reduces soil erosion, that PHS benefits them, and that PHS benefits others. Only one variable, that PHS improves water quality, was higher for members of the nature-oriented public, however both groups had strong positive attitudes with Likert-scales greater than 4.

In terms of behavior, the pooled t-test with equal variances showed a statistically significant difference between citizen scientists and the public in terms of three behaviors. Specifically, citizen scientists were more likely to: talk to others about conservation (p-value<0.05), search for information on conservation (p<0.01), and save water for later use (p<0.05).

4.4.2 How does participation in citizen science programs influence conservation knowledge, attitudes, and stewardship behaviors?

In terms of short-term changes, the paired t-tests before training and two weeks after training showed statistically significant differences in terms of the comprehensive environmental knowledge score, four individual knowledge variables, and one behavioral variable for citizen science volunteers (Appendix III, A.3.2). Differences over time for the comprehensive environmental knowledge score were statistically significant (p-value<0.01), where paired profiles demonstrate positive improvements to knowledge. Additionally, the t-tests showed statistically significant differences over time in terms of knowledge of the location of drinking water sources ($p<0.01$), knowledge of the location of the water treatment plant ($p<0.10$) and awareness of PHS ($p<0.01$), where knowledge increased after two weeks. However, the t-test showed statistically significant negative changes for awareness of the need for water regulations ($p<0.05$). The t-test showed statistically significant and positive differences for one behavioral variable after two weeks: the frequency of talking to others about environmental issues (p-value<0.05).

In terms of longer-term changes, the paired t-tests before training and six months after training showed statistically significant differences in terms of three knowledge and one behavioral variable (Table 4.2). Differences over time for knowledge of sources of water were statistically significant (p-value<0.01), where paired profiles demonstrate positive improvements to knowledge. Differences over time for awareness of the PHS programs was statistically significant (p-value<0.01), where paired profiles demonstrate positive improvements to knowledge about PHS. Differences over time for perceptions of the importance of regulation for managing water ways was statistically significant (p-value< 0.0001), where paired profiles demonstrate negative changes in views about regulation. The t-test before training and six months after training showed statistically significant differences in terms of one behavioral variable, frequency of volunteering for an environmental organization (p-value<0.0001), where paired profiles demonstrate positive improvements to the frequency of volunteering.

Table 4.2 Summary statistics of differences before and 6 months after the training.

Theme	Parameter	Before the training Mean (SD)	6 mo. after training Mean (SD)	t-value
General knowledge	Know that deforestation reduces water flow	1.00 (0)	1.00 (0)	-
	Know where there are forests there is more rain	1.00 (0)	1.00 (0)	-
	Know forests provide clean water	1.00 (0)	0.93 (0.26)	-1.00
	Know forests provide more water downstream	0.97 (0.18)	0.96 (0.19)	0.00
	Know location of drinking water sources	0.54 (0.51)	0.89 (0.31)	3.29***
	Know location of water treatment plant	0.54 (0.51)	0.68 (0.48)	0.70
	Comprehensive content knowledge score	*0.83 (0.14)*	*0.90 (0.14)*	*1.68**
	Aware of need for regulations for rivers	0.50 (0.51)	0.14 (0.36)	-3.25***
	Aware of PHS	0.31 (0.47)	0.75 (0.44)	4.50***
	Aware of river flows problems in the region	0.47 (0.51)	0.50 (0.51)	0.00
	Aware there is insufficient water in Coatepec	0.88 (0.42)	0.79 (0.42)	-1.00
	Aware there is insufficient water in Xalapa	0.89 (0.33)	0.90 (0.31)	0.00
	Comprehensive awareness score	*0.34 (0.22)*	*0.34 (0.17)*	*0.54*
Attitudes	PHS reduces threats to forests	3.57 (1.27)	3.26 (0.99)	0.00
	PHS improves water supply	4.22 (0.66)	4.28 (0.75)	1.16
	PHS reduces soil erosion	4.00 (0.58)	3.80 (0.89)	0.53
	PHS benefits me	4.70 (0.48)	3.95 (1.12)	1.67
	PHS benefits others	4.11 (1.05)	4.11 (1.05)	-
	Comprehensive attitudes score	*4.15 (0.56)*	*3.88 (0.69)*	*0.50*
Behaviors	Volunteers for an environmental cause	2.03 (1.48)	2.89 (1.26)	1.75*
	Writes politician on environmental issues	1.43 (0.94)	1.36 (0.73)	1.07
	Attends townhall meetings on environmental issues	1.57 (1.31)	1.75 (0.93)	0.67
	Looks up information on environmental issues	3.74 (1.11)	3.68 (0.77)	-1.10
	Talks with others about environmental issues	4.11 (0.95)	4.22 (1.40)	0.45
	Cleans up trash locally	2.77 (1.48)	2.96 (1.34)	0.60
	Saves water for later use	4.57 (0.85)	4.50 (1.00)	-0.55
	Reduces time using water bathing	4.57 (0.81)	4.79 (0.49)	1.07
Observations		*35*	*28*	
*p-value *<0.10, **<0.05, ***<0.01*				

4.4.3 Does the novel training influence conservation knowledge, attitudes, and stewardship behaviors?

To understand the effect of the training, we first tested whether citizen science volunteers in each group were similar before training, conducting t-tests for general knowledge, attitudes, and stewardship behaviors. We found that the two groups were generally similar, with statistically significant differences for one knowledge parameter and two attitudes parameters, and no differences for stewardship behaviors. Specifically, we found that the intervention group was less aware of the importance of regulations, these differences were statistically significant (t-value=4.30, p-value<0.001). This influenced their comprehensive awareness score which was lower than the control group's; these differences were statistically significant (t-value=3.30, p-value=0.003). We also found that the treatment group had less positive attitudes that PHS reduces threats to forests (t-value=3.04, p-value=0.029), and that PHS improves water supply (t-value=2.40, p-value=0.047).

To understand the effect of the intervention training on knowledge, we tested a mixed effect model (Eq. 1) and found improvements to knowledge of water source location (p-value<0.10) (Table 4.3), due to the intervention over time. We also found improvements to the comprehensive score of awareness (p-value<0.001) due to the intervention over time. Additionally, one individual awareness variable, the importance of water regulations, showed improvements over time due to the intervention (p-value<0.001).

To understand the effect of the intervention training on attitudes, we tested a mixed effects model and found improvements to the comprehensive attitudes score for the PHS program (p-value<0.05) over time due to the intervention. Additionally, we found improvements for three of the individual attitude questions due to the training over time, specifically that PHS reduces threats to forest (p-value <0.01), that PHS improves water supply (p-value<0.01), and that PHS reduces soil erosion (p-value<0.10).

Table 4.3 Coefficients, standard error, and p-values for interaction effects of intervention and time on knowledge, attitudes, and behaviors.

Theme	Parameter	β	Std. error	p-values

General knowledge	Know that deforestation reduces water flow	-	-	-
	Know forests provide clean water	-	-	-
	Know forests provide more water downstream	-	-	-
	Know location of drinking water sources	-	-	-
	Know where there are forests there is more rain	-0.0384	0.02817	0.181
	Know location of water treatment plant	0.1306	0.0749	0.0864*
	Comprehensive environmental knowledge score	*-0.0042*	*0.0405*	*0.9190*
	Aware of need for regulations for rivers	0.3784	0.0975	0.0003***
	Aware of PHS	0.1175	0.0827	0.1600
	Aware of river flows problems in the region	0.0826	0.0893	0.3590
	Aware there is insufficient water in the city of Coatepec	0.0328	0.0808	0.6862
	Aware there is insufficient water in the city of Xalapa	0.0310	0.0573	0.5909
	Comprehensive awareness score	*0.1424*	*0.0397*	*0.0006****
Attitudes	PHS reduces threats to forests	1.0609	0.3308	0.0033**
	PHS improves water supply	0.6086	0.2234	0.0099**
	PHS reduces soil erosion	0.4390	0.2549	0.0941*
	PHS benefits me	0.5135	0.3090	0.1050
	PHS benefits others	0.0707	0.2236	0.7540
	Comprehensive attitudes score	*0.4809*	*0.1709*	*0.0078***
Behaviors	Volunteers for an environmental cause	0.4890	0.2574	0.0621*
	Writes politician on environmental issues	0.1334	0.1229	0.2820
	Attends townhall meetings on environmental issues	-0.3574	0.2181	0.1062
	Looks up information on environmental issues	0.2137	0.1906	0.2670
	Talks with others about environmental issues	0.0877	0.2406	0.7170
	Cleans up trash locally	0.0949	0.2553	0.7113
	Saves water for later use	0.2818	0.1689	0.1004
	Reduces time using water bathing	0.0758	0.1751	0.6660

Observations	*35*
*p-value *<0.10, **<0.05, ***<0.01*	
**Note: Blanks exist for the parameters were no changes were found*	

4.4.4 Triangulation with qualitative research

From our interviews we found that citizen scientists from the intervention group tended to have more positive attitudes toward the PHS programs after the training (e.g. more optimistic about its potential to deliver conservation goals), while still noting the challenges the PHS programs faced from limited funds and reach (Appendix III, A.3.3). For example, one participant said, “I think it’s a good initiative, it is necessary to have these types of incentives. I think it works in rural zones where there is much [financial] need, and a need to protect the space where they are living.” However, he went on to say, “I think the program’s reach is still very limited in two senses: in one there isn’t very much dissemination of the program, and the other is that it can’t compete with other productive sectors.” Another participant in the intervention training underlined this issue with reach, “What is working with [PHS] is that there are still trees, maybe not the quality or quantity there should be, but they are *there*.” He went on to say that, “There needs to be much more dissemination, so that people know more, that they see the possibility that they can go and engage in PHS.”

For volunteers in the control group, interviews showed more participants held negative or neutral attitudes. For example, one participant said, “There are people that have been receiving this support for a year, I think from Fidecoagua, and they are only giving it to landowners that have larger properties. So, it’s still a little unjust.” Another said, “I do think [PHS] works, but maybe not at the moment, maybe that will be further along. Sadly, when there is a change in government everyone brings their own ideas and so there are programs already approved, and as other ideas arrive the programs decrease.”

In terms of changes to stewardship behaviors due to the intervention training, interviews revealed one new behavior change which was financial investment in the reforestation program. Indeed, two of the individuals became financial investors because of the training. One said, “After the training, I started to organize around the goals of Fidecoagua, to organize my neighbors. ‘Come on,’ I said, ‘we’re going to organize to pay for a hectare of land to keep it maintained as forest'!" Another said that after the training, "I went to see the person who came to see us [in the training]… I was interested in paying for a parcel [to be forested]. I was very interested because I have a certain economic ability since I'm retired. I thought 'well this is a good investment.'"

4.5 DISCUSSION

4.5.1 Citizen scientists differ from the nature-oriented public

In our case study, we found that people who volunteered for citizen scientist projects were in many ways very different from the nature-oriented public in their knowledge, attitudes, and behaviors. Citizen scientists were more knowledgeable, had more positive attitudes towards conservation programs like PHS, and more frequently engaged in a range of environmental stewardship behaviors. Previous research has shown that educated individuals more frequently engage in citizen science (Overdevest, Orr, & Stepenuck, 2004). Since citizen science is explicitly about knowledge generation, the people it tends to attract are those who are already highly motivated to learn (Domroese & Johnson, 2017) and to contribute to scientific knowledge (Alender, 2016).

Citizen scientists also had more positive attitudes towards conservation programs than the public. This difference could be because we explicitly advertised the citizen science program as being important for informing decision-makers in the PHS conservation program. Previous research has shown that participation in online citizen science projects can positively influence scientific attitudes, by reinforcing previously held epistemological beliefs (Price & Lee, 2013). Indeed, even in studies where changes in science attitudes due to citizen science participation were not always demonstrable, citizen scientists tended to have predominantly strong attitudes towards science and the environment (Brossard et al., 2005; Crall et al., 2012; Trumbull et al., 2000). Our results support these findings, demonstrating that that individuals who engage in conservation-related citizen science projects tend to already hold positive attitudes about conservation projects.

Finally, our research demonstrates that citizen scientists tended to engage in more stewardship behaviors than the nature-oriented public. Previous research has suggested that those that tend to join organizations and volunteer for collective goals are also more likely to engage in a wide range of collective efforts (Putnam, 1995). The importance of joining volunteer organizations is particularly influential in Mexico: in one study modeling political activism across Argentina, Chile, Mexico, and Peru, researchers found that volunteering in almost all types of nonpolitical organizations—i.e. churches, labor unions, cultural groups, etc.— was strongly predictive of political participation in Mexico (Klesner et al., 2007). Our results support these findings and demonstrate that people who tended to volunteer for citizen science projects are also more likely to engage in other stewardship behaviors.

These results have implications for citizen science researchers generally, and GWW-Mexico specifically, as citizen scientists tend to be highly educated individuals that are active in their communities in terms of environmental stewardship. It highlights the need for researchers of citizen science to construct an control group to measure the social impact of citizen science projects.

4.5.2 Conservation knowledge, attitudes, and stewardship behavior change over time

We found citizen scientists' knowledge, attitudes, and stewardship behaviors significantly changed over time due to participation in the citizen science water flow program. Most citizen science projects work towards developing citizen scientists' knowledge about the patterns and processes they observe and experience (Bonney et al., 2009). Studies that have evaluated changes in content knowledge as well as awareness and concern for the issue show improvements in understanding (Crall et al., 2013; Hartley, Thompson, & Pahl, 2015). For example, one citizen science project found that following the three-day training citizen scientists had dramatically improved their understanding of invasive species ecology as well as the effects of the invasive on the environment (Jordan et al., 2011). We found citizen scientists gained environmental knowledge and some awareness over time: they learned about the location of their drinking water source, the location of the water treatment plant, and gained awareness of the PHS conservation program, no matter what type of training they received. However, many people responded that there was less need for water regulations after participating in the program; this might have been due to the emphasis on PHS—a voluntary approach to watershed management—in this particular study.

While we found gains in knowledge and awareness about the PHS program, we did not find that citizen scientists, on average, changed their attitudes toward the conservation program, PHS, due to participation. However, we did find that within the intervention group, citizen scientists were more likely to have positive attitudes. As the other half the participants in the citizen science program did not receive the intervention training discussing the importance of PHS for reducing threats for forests, we did not expect changes to their overall attitudes simply due to participation.

Our study also shows that participation in citizen science led to changes in one behavior but only in the short term. For example, in the two weeks immediately following the training citizen scientists more frequently talked to others about environmental issues, but after six months that activity had waned. Individuals often prefer to discuss and engage in novel experiences. Indeed, research shows that people preferentially seek optimal levels of stimulation for their behavior choice, a phenomenon known as novelty-seeking behavior (Assaker, Vinzi, & O'Connor, 2010), where novelty is considered the difference between present perceptions and past experiences (Pearson, 1970). Sources of novelty can come from exploration of physical places, learning new skills, or gaining attention and communicating with others (McIntosh, Goeldner & Ritchie, 1995). This interest in novel stimuli is evident even in children in early infancy (Akhtar, Carpenter, & Tomasello, 1996). Experimental evidence has shown that children prefer to talk about what is new and egotistically interesting to them (Baker & Greenfield, 1988). They simultaneously desire to talk about things that are new and informative for the listener (Akhtar, Carpenter, & Tomasello, 1996). Perhaps as the novelty of water monitoring waned for volunteers, the familiarity reduced the frequency that citizen scientists discussed environmental issues with others.

4.5.3 Novel trainings can improve conservation knowledge, attitudes, and behaviors

Our study provides evidence that designing training to include presentations from regional conservation decision-makers can lead to knowledge gains, attitude shifts, and some environmental stewardship outcomes among citizen scientists. Knowledge gains, however, were restricted to only a few knowledge and awareness parameters. One possible explanation for this is that we allotted less time for the traditional water flow training in our treatment group to allow for the regional decision-makers to make their presentations. Because less time was allotted for the traditional in-class training time, some concepts received only cursory discussion. Psychological literature has demonstrated the importance of repetition for strengthening accuracy of recall (Hinzman & Block, 1971), where spaced repetition specifically improves learning and knowledge retention (Ullman & Lovelett, 2018). Research from conservation education camps has shown the need for repeated and reinforced education for knowledge gains (Kruse & Card, 2010).

Despite research in citizen science showing the recalcitrance of attitudes to change (Brossard et al., 2005), our study demonstrated improvements in attitudes towards the PHS conservation program, due to the intervention. Indeed, although the intervention group had less strong positive attitudes towards the program than the control group before the training began, six months after they had more positive attitudes in terms of almost every parameter. Interviews support these quantitative results while underlining the complexity of attitudes where many acknowledged that the program had limited reach beyond the few landowners it funded, and that more dissemination and funds were needed.

Finally, our quantitative data showed the intervention training had little influence on any of the measured behaviors. However, some emerging themes arose in qualitative interviews suggesting that the intervention influenced financial investment in reforestation programs in the region which were not measured in the survey. Two individuals within the intervention group mentioned that they had donated to the organizations for reforestation purposes. Since PHS program depends on its ability to incentivize forest protection and procure associated water services, during the training PHS decision makers were strongly interested in donations. The behavior then could be explained by such a need and emphasis but need to be tested empirically.

4.5.4 Reflecting on the novel training for researchers in citizen science

Our qualitative interviews provide important insight into why we may not have found more changes in knowledge, attitudes or behaviors due to our intervention. Specifically, the presentations may have had: *(1) Too much focus on one threat which reduced sense of control.* The emphasis of regional conservation decision-makers on the threat of upstream deforestation and land use change for downstream water, may have reduced the sense of control that urban citizen scientists had for improving conservation outcomes through stewardship behaviors in their own homes. Sense of control is understood as an essential factor for behavior change across contexts (Bamberg & Möser, 2007; Dresner et al., 2013; Ernst, Blood, & Bleery, 2017; Fielding & Head, 2012; Hungerford & Volk, 1990), and other citizen science projects have failed to influence stewardship behaviors because of volunteers' impaired sense of control (Jordan et al., 2011). Of the behaviors that decision-makers did emphasize, financial investment in reforestation received the most attention, which is likely why this was one of the only behaviors influenced. *(2) Too many goals aside from behaviors.* The presentations by decision-makers were quite lengthy, targeting not just stewardship behaviors but also environmental knowledge and PHS attitudes. Therefore, the importance of individual stewardship behaviors may not have received the attention needed to make the necessary impact. *(3) Too few repetitions.* This research introduced a one-time informational intervention, which may be insufficient for influencing stewardship behavior. Repetition is essential for strengthening learning and knowledge retention (Ullman & Lovelett, 2018), and behavior is significantly more complex than knowledge alone (Kollmuss & Agyeman, 2002). *(4) Presentations may be the wrong mechanism altogether.* Because behaviors are complex, information exchange may be insufficient to influence behaviors (Manfredo, 2008). Stewardship behaviors are influenced by a plethora of other factors including preexisting values (Schultz, 2001), habits (Dahlstrand & Biel, 1997) and subjective norms (Ajzen, 1991). Citizen science researchers have increasingly examined how training and research can be designed to improve one behavior: participation in citizen science. For example, in one project where citizen scientists examined historical weather observations, researchers introduced competitive mechanisms such as rewards to improve quality and quantity of citizen scientist contributions (Eveleigh et al., 2013). There is still a strong need to understand how to design citizen science projects to influence multiple behaviors, aside from participation in citizen science.

4.5.5 Recommendations for citizen science programs

Our recommendation for researchers and practitioners who are in charge of designing citizen science programs is to keep the goals simple: focus on one social outcome, i.e., choose either environmental knowledge, attitudes, or stewardship behaviors. If these citizen science project designers choose to target stewardship behaviors, emphasis should be placed on focusing on one or two behaviors. Additionally, designers should consider how many trainings to conduct; we suggest that citizen science projects should explore the possibility of hosting multiple trainings to improve memory and retention as well as consider testing novel designs to influence that behavior. Finally, the power of citizen scientists' sense of control to make a difference in conservation outcomes should not be underestimated. We recommend designers ensure their citizen science projects empower and encourage participants, to demonstrate that their stewardship behavior will have tangible conservation benefits.

4.5.6 Study limitations

The generalizability of this study is limited by the small study area, sample size, and limited time frame within which our research was conducted. The results should therefore be interpreted with caution and be considered descriptive in nature, signaling additional areas of research on the topic of citizen science participation and retention in a global South context. Despite these limitations, our use of mixed methods, and a novel training intervention, contribute new understanding on how citizen science projects and training can influence knowledge, attitudes, and stewardship behaviors in Mexico, with implications for Mexico's national and local PHS programs.

4.6 CONCLUSION

Understanding how citizen science projects can provide benefits beyond the natural sciences to social outcomes such as gains in knowledge, attitudes, and stewardship behaviors has been of increasing interest to researchers. We examined how citizen scientists differed from the nature-oriented public, how participation in citizen science programs influenced social outcomes, and whether an experimental training could influence these outcomes. Our results show that citizen scientists were more knowledgeable and aware of the issues than the nature-oriented public, that they had more positive attitudes towards PHS programs, and that they engaged in more stewardship behaviors, before they received the training. This again highlights the need for citizen science researchers to focus on designing evaluation protocols to integrate a control group. Examining citizen scientists specifically, we found that participation in the citizen science water flow program led to additional improvements in knowledge, positive attitudes towards PHS conservation programs, and had some influence on short and long-term behaviors—specifically talking to others on conservation issues in the short term and volunteering for environmental organizations in the long term. Finally, our experimental design, integrating conservation decision-makers into the traditional water flow training, had significant benefits for knowledge and attitudes towards the PHS conservation program. We also found that the intervention led to some changes in behavior (i.e. frequency of volunteering for an environmental organization). More experimental testing of citizen science intervention designs can help shed light on how to best affect social outcomes such as conservation knowledge, attitudes, and stewardship behaviors, which would have implications for longer-term conservation outcomes.

REFERENCES

Ajzen, I. (1991). The theory of planned behaviour. *Organisational Behaviour and Human Decision Processes,* 20, 179–211.

Akhtar, N., Carpenter, M., & Tomasello, M. (1996). The role of discourse novelty in early word learning. *Child Development*, *67*(2), 635-645.

Alender, B. (2016). Understanding volunteer motivations to participate in citizen science projects: a deeper look at water quality monitoring. *Journal of Science Communication*, *15*(3), A04.

Assaker, G., Vinzi, V. E., & O'Connor, P. (2011). Examining the effect of novelty seeking, satisfaction, and destination image on tourists' return pattern: A two factor, non-linear latent growth model. *Tourism Management*, *32*(4), 890-901.

Baker, N. D., & Greenfield, P. M. (1988). The development of new and old information in young children's early language. *Language Sciences*, *10*(1), 3-34.

Bamberg, S., & Möser, G. (2007). Twenty years after Hines, Hungerford, and Tomera: A new meta-analysis of psycho-social determinants of pro-environmental behaviour. *Journal of environmental psychology*, *27*(1), 14-25.

Behling, O., & Law, KS. (2000). *Translating Questionnaires and Other Research Instruments: Problems and Solutions.* Thousand Oaks, CA: Sage Publications Inc.

Bonney, R., Ballard, H., Jordan, R., McCallie, E., Phillips, T., Shirk, J., & Wilderman, C. C. (2009). Public Participation in Scientific Research: Defining the Field and Assessing Its Potential for Informal Science Education. A CAISE Inquiry Group Report. *Online Submission*.

Bonney, R., Shirk, J. L., Phillips, T. B., Wiggins, A., Ballard, H. L., Miller-Rushing, A. J., & Parrish, J. K. (2014). Next steps for citizen science. *Science*, *343*(6178), 1436-1437.

Boone, H. N., Jr., & Boone, D. A. (2012). Analyzing Likert Data. Journal of Extension, 50(2).

Brossard, D., Lewenstein, B., & Bonney, R. (2005). Scientific knowledge and attitude change: The impact of a citizen science project. *International Journal of Science Education*, *27*(9), 1099-1121.

Crall, A. W., Jordan, R., Holfelder, K., Newman, G. J., Graham, J., & Waller, D. M. (2013). The impacts of an invasive species citizen science training program on participant attitudes, behavior, and science literacy. *Public Understanding of Science*, *22*(6), 745-764.

Crall, A. W., Newman, G. J., Stohlgren, T. J., Holfelder, K. A., Graham, J., & Waller, D. M. (2011). Assessing citizen science data quality: an invasive species case study. *Conservation Letters*, *4*(6), 433-442.

Cronje, R., Rohlinger, S., Crall, A., & Newman, G. (2011). Does participation in citizen science improve scientific literacy? A study to compare assessment methods. *Applied Environmental Education & Communication*, *10*(3), 135-145.

Dahlstrand, U., & Biel, A. (1997). Pro‐Environmental Habits: Propensity Levels in Behavioral Change 1. *Journal of applied social psychology*, *27*(7), 588-601.

Danielsen, F., Burgess, N. D., Jensen, P. M., & Pirhofer‐Walzl, K. (2010). Environmental monitoring: the scale and speed of implementation varies according to the degree of peoples involvement. *Journal of Applied Ecology*, *47*(6), 1166-1168.

Dietz, T., Stern, P. C., & Guagnano, G. A. (1998). Social structural and social psychological bases of environmental concern. *Environment and behavior*, *30*(4), 450-471.

Dresner, M., Handelman, C., Braun, S., & Rollwagen-Bollens, G. (2015). Environmental identity, pro-environmental behaviors, and civic engagement of volunteer stewards in Portland area parks. *Environmental Education Research*, *21*(7), 991-1010.

Dolrenry, S., Hazzah, L., & Frank, L. G. (2016). Conservation and monitoring of a persecuted African lion population by Maasai warriors. *Conservation Biology*, *30*(3), 467-475.

Domroese, M. C., & Johnson, E. A. (2017). Why watch bees? Motivations of citizen science volunteers in the Great Pollinator Project. *Biological Conservation*, *208*, 40-47.

Engel, S., S. Pagiola, & Wunder, S. (2008). Designing payments for environmental services in theory and practice: an overview of the issues. *Ecological Economics*. 65(4):663–674.

Ernst, J., Blood, N., & Beery, T. (2017). Environmental action and student environmental leaders:

exploring the influence of environmental attitudes, locus of control, and sense of personal responsibility. *Environmental Education Research*, *23*(2), 149-175.

Evans, C., Abrams, E., Reitsma, R., Roux, K., Salmonsen, L., & Marra, P. P. (2005). The Neighborhood Nestwatch Program: Participant outcomes of a citizen-science ecological research project. *Conservation Biology*, *19*(3), 589-594.

Eveleigh, A., Jennett, C., Lynn, S., & Cox, A. L. (2013). "I want to be a Captain! I want to be a Captain!": Gamification in the Old Weather Citizen Science Project. In *Proceedings of the First International Conference on Gameful Design, Research, and Applications.* New York, NY, U.S.A.: ACM Press, pp. 79–82. DOI: 10.1145/2583008.2583019.

Fielding, K. S., & Head, B. W. (2012). Determinants of young Australians' environmental actions: The role of responsibility attributions, locus of control, knowledge and attitudes. *Environmental Education Research*, *18*(2), 171-186.

Flores-Díaz, A. C., Ramos-Escobedo, M. G., Ruiz-Córdova, S. S., Manson, R., Aranda, E., & Deutsch, W. G. (2013). Monitoreo comunitario del agua: retos y aprendizaje desde la perspectiva de Global Water Watch-México. *México, DF: GWW*

Follett, R., & Strezov, V. (2015). An analysis of citizen science based research: usage and publication patterns. *PloS one*, *10*(11), e0143687.

Fujitani, M. L., McFall, A., Randler, C., & Arlinghaus, R. (2016). Efficacy of lecture-based environmental education for biodiversity conservation: a robust controlled field experiment with recreational anglers engaged in self-organized fish stocking. *Journal of Applied Ecology*, *53*(1), 25-33.

García-Coll, I., A. Martínez-Otero, A. Ramírez-Soto, A. NiñoCruz, A. J. Rivas, L. Domínguez-Barrada. (2004). Relación aguabosque: delimitación de zonas prioritarias para pago de servicios ambientales hidrológicos en la cuenca del río Gavilanes, Coatepec, Veracruz. Pages 99–115 in H. Cotler, editor. *Manejo integral de cuencas en México: estudios y reflexiones para orientar la política ambiental INE/SEMARNAT,* Mexico City, D.F., Mexico.

Greenfield, P.M. (1997). You can't take it with you: Why ability assessments don't cross cultures. *American Psychologists, 52:* 1115-1124.

Hartley, B. L., Thompson, R. C., & Pahl, S. (2015). Marine litter education boosts children's understanding and self-reported actions. *Marine Pollution Bulletin*, *90*(1-2), 209-217.

Hinton, P.R., Brownlow, C., McMurray, I., Cozens, B. (2004) SPSS Explained. *Routledge:* New York, NY, p. 363.

Hungerford, H. R., & Volk, T. L. (1990). Changing learner behavior through environmental education. *The Journal of Environmental Education*, *21*(3), 8-21.

Instituto Nacional de Estatistica y Geographía (INEGI). (2015a). Demografía – Xalapa. Mexico City, Mexico.

Instituto Nacional de Estatistica y Geographía (INEGI). (2015b). Demografía – Coatepec. Mexico City, Mexico.

Jones, K. W., Foucat, S. A., Pischke, E. C., Salcone, J., Torrez, D., Selfa, T., & Halvorsen, K. E. (2019). Exploring the connections between participation in and benefits from payments for hydrological services programs in Veracruz State, Mexico. *Ecosystem services*, *35*, 32-42.

Jordan, R. C., Gray, S. A., Howe, D. V., Brooks, W. R., & Ehrenfeld, J. G. (2011). Knowledge gain and behavioral change in citizen-science programs. *Conservation Biology*, *25*(6), 1148-1154.

Klesner, J. L. (2007). Social capital and political participation in Latin America: evidence from Argentina, Chile, Mexico, and Peru. *Latin American Research Review*, *42*(2), 1-32.

Kollmuss, A., & Agyeman, J. (2002). Mind the gap: why do people act environmentally and what are the barriers to pro-environmental behavior?. *Environmental education research*, *8*(3), 239-260.

Kruse, C. K., & Card, J. A. (2004). Effects of a conservation education camp program on campers' self-reported knowledge, attitude, and behavior. *The Journal of Environmental Education*, *35*(4), 33-45.

López-Barrera, F., Manson, R. H., & Landgrave, R. (2014). Identifying deforestation attractors and patterns of fragmentation for seasonally dry tropical forest in central Veracruz, Mexico. *Land Use Policy*, *41*, 274-283.

López-Rodríguez, R., and F. Acevedo-Rosas. 2005. Flood risk zones within the State of Veracruz. Mexican National Water Commission, Veracruz Delegation. Xalapa, Veracruz, Mexico.

Manfredo, M. J. (2008). *Who cares about wildlife?*: *Social Science Concepts for Exploring Human-Wildlife Relationships and Conservation Issues***.** New York, NY: Springer Science.

McIntosh, R. W., Goeldner, C. R., & Ritchie, J. B. (1995). Tourism: Principles, practices, philosophies. *Willey. New York*.

Muñoz-Piña, C., Guevara, A., Torres, J. M., & Braña, J. (2008). Paying for the hydrological services of Mexico's forests: Analysis, negotiations and results. *Ecological Economics*, *65*(4), 725-736.

Nava-López, M., Selfa, T. L., Cordoba, D., Pischke, E. C., Torrez, D., Ávila-Foucat, S., ... & Maganda, C. (2018). Decentralizing Payments for Hydrological Services Programs in Veracruz, Mexico: Challenges and Implications for Long-term Sustainability. *Society & Natural Resources*, *31*(12), 1389-1399.

Oberhauser, K., & Prysby, M. D. (2008). Citizen science: creating a research army for conservation. *American Entomologist*, *54*(2), 103-104.

Overdevest, C., Orr, C. H., & Stepenuck, K. (2004). Volunteer stream monitoring and local participation in natural resource issues. *Human Ecology Review*, *11*(2), 177-185.

Paré, L., and Fuentes, T. (2018) El Comitê e Cuenca del río Pixquiac: alternativas para la cogestión de una Cuenca abestecedora de agua de Xalapa. *In* L. Paré and H.G. Campos (Eds.) *Gestión para la defense del agua y el territorio en Xalapa, Veracruz.* Universidad Nacional Autónoma de México: Mexico City, Mexico.

Pearson, P. H. (1970). Relationships between global and specified measures of novelty seeking. *Journal of Consulting and Clinical Psychology*, *34*(2), 199.

Peng, J.Y.C. (2009). *Data analysis using SAS*. Thousand Oaks: Sage Publications Inc

Price, C. A., & Lee, H. S. (2013). Changes in participants' scientific attitudes and epistemological beliefs during an astronomical citizen science project. *Journal of Research in Science Teaching*, *50*(7), 773-801.

Putnam, R. D. (1995). Tuning in, tuning out: The strange disappearance of social capital in America. *PS: Political Science & Politics*, *28*(4), 664-683.

Schultz, P. W. (2001). The structure of environmental concern: Concern for self, other people, and the biosphere. *Journal of Environmental Psychology*, *21*(4), 327-339.

Scullion, J., Thomas, C. W., Vogt, K. A., Pérez-Maqueo, O., & Logsdon, M. G. (2011). Evaluating the environmental impact of payments for ecosystem services in Coatepec (Mexico) using remote sensing and on-site interviews. *Environmental Conservation*, *38*(4), 426-434.

Stern, P. C. (2000). New environmental theories: toward a coherent theory of environmentally significant behavior. *Journal of Social Issues*, *56*(3), 407-424.

Toomey, A. H., & Domroese, M. C. (2013). Can citizen science lead to positive conservation attitudes and behaviors?. *Human Ecology Review*, *20*(1), 50.

Trumbull, D. J., Bonney, R., Bascom, D., & Cabral, A. (2000). Thinking scientifically during participation in a citizen-science project. *Science Education*, *84*(2), 265-275.

Ullman, M. T., & Lovelett, J. T. (2018). Implications of the declarative/procedural model for improving second language learning: The role of memory enhancement techniques. *Second Language Research*, *34*(1), 39-65.

Waylen, K. A., McGowan, P. J., Milner-Gulland, E. J., & Pawi Study Group. (2009). Ecotourism positively affects awareness and attitudes but not conservation behaviours: a case study at Grande Riviere, Trinidad. *Oryx*, *43*(3), 343-351.3.6

5. CHAPTER FIVE: CONCLUSIONS

This dissertation investigates the potential of multiple theoretical frameworks and contributes to empirical research and methodologies for understanding decision-making across complex systems. It integrates behavioral theories (e.g. Ajzen, 1991), volunteer motivations theories (e.g. Ryan et al., 2001), the credibility, relevancy, and legitimacy framework (Cash et al., 2002), and the sustainable livelihoods approach framework (Scoones et al., 1998), which have often been examined in isolation but rarely together. Using these frameworks, I have identified internal cognitive factors and environmental, socio-economic, and demographic factors that enable or constrain behavior change. Additionally, I have disentangled when and why people act in complex, rational, and irrational ways. This research provides foundational theoretical contributions to the fields of climate vulnerability/adaptation and citizen science. Finally, this research adds methodological contributions to the field of citizen science by utilizing a randomized design to introduce a novel training where conservation decision-makers are linked to volunteers to improve perceptions of the project relevancy as well as to improve social outcomes such as conservation knowledge, attitudes, and stewardship behaviors. In combination, these three chapters lead to insights on important future directions for research and applied implications for information-sharing programs to achieve behavior changes.

5.1 CONTRIBUTIONS TO THEORY

My research examines a range of factors that influence how individuals choose to participate in citizen science, to enact stewardship behaviors, and to adapt to climate change. While explicitly acknowledging that internal cognitive factors and external contextual factors are often tightly linked (Courtenay-Hall & Rogers, 2002), it provides a useful range of varied frameworks for understanding behavior change for social and ecological outcomes (Kollmuss & Agyeman, 2002).

5.1.1 Cognitive behavioral factors

Across the three empirical chapters in this dissertation, I found cognitive factors like motivations and perceptions of climate change to be critical for understanding why individuals make the choices they do whether in citizen science or climate-based agriculture. In citizen science, volunteers continued to monitor water because of their values and deep interest in learning. In volunteer literature, research suggests that ‘values’, ‘social’, and ‘career’ are crucial for participation (Clary et al., 1996), while ‘learning, ‘helping the environment,’ ‘project organization,’ and ‘social’ reasons are important for environmental volunteers (Ryan et al., 2001). These findings contribute to a growing body of research suggesting that internal motivations influence environmental volunteer behavior (Bruyere & Rappe, 2007; Domroese & Johnson, 2017; Measham & Barnett, 2008; Ryan et al., 2001). Simultaneously, it underlines the importance of understanding and fulfilling volunteers’ motivations for influencing their decision to sign up and continue to volunteer.

In climate-adapted agriculture, understanding decision-making around whether and how small holder farmers adapt to climate change is important for wellbeing and livelihood strategies (Eakin, 2005). This research shows that internal cognitive factors, specifically perceptions of climate change, were influential in what adaptation strategies farmers enact. Perceptions play an important role in choices surrounding conservation and environmental management (Bennett, 2016), and this research confirms that climate change perceptions particularly are critical to adaptation behaviors. Farmers necessarily operate within a certain degree of climatic variability for agricultural production, already enacting coping strategies to deal with this variability (Smit, McNabb, & Smithers, 1996). However, because climate change increasingly produces erratic and anomalous conditions, ensuring that farmers are perceiving these changes and threats may be essential for motivating them to take more drastic adaptive measures (Tucker, Eakin, & Castellanos, 2010). Although farmer perceptions of climate change have been shown as important agricultural and non-agricultural adaptation strategies (Deressa, Hassan, & Ringler, 2011; Fosu-Mensah, Vlek & MacCarthy 2012; Mertz, Mbow, & Reenberg, 2009; Tucker, Eakin, & Castellanos, 2010), most sustainable development frameworks do not consider climate perceptions as an essential factor for welfare and livelihoods (Bebbington, 1999). Thus, this research contributes to the Sustainable Livelihoods Approach framework, by explicitly integrating climate perceptions as an essential internal factor for adaptation to climate change.

5.1.2 Environmental, socio-economic, and demographic factors of behaviors

Across this research, I identified environmental, socio-economic, and demographic factors that can be as important as cognitive factors for enabling or constraining behaviors. For example, although citizen scientists tended to have strong motivations to participate initially, they faced a number of environmental challenges that led to dropping out, specifically: having to travel long distances to their water monitoring site, difficulty organizing other volunteers to help with monitoring water, and insufficient time. Research on constraints to volunteering faced by non-volunteers has shown that lack of time, lack of interest, and ill health are the most commonly cited barriers (Sundeen, Raskoff, & Garcia, 2007). Time commitments were also frequently cited as the most important barrier for non-volunteers for the Appalachian Trail Conference (Martinez & Mullen, 2004). Similarly, research has shown that the most important barriers for environmental volunteers are structural constraints such as lack of time to volunteer and distance (O'Brien et al., 2010; Gage & Thapa, 2012; Weaver, 2015). These lessons learned on constraints to environmental volunteering have increasingly been applied to citizen science (West & Pateman, 2016). This work contributes by suggesting that structural constraints such as lack of time and distance, as well as interpersonal constraints, such as organizing others, were strongly constraining participation.

Contextual factors such as environmental, geographic, and socio-economic factors also play a role for smallholder farmer adaptation to climate change. I found that experiencing a natural disaster, distance to markets, and the town farmers lived in, were enabling (or constraining) factors for adoption of adaptation strategies. These factors are tightly linked, as the town location strongly influences their exposure to natural disasters as well as the distance to markets. Counter to some research, however, we found that farmers that were located farther from markets were more likely to adapt to climate change, specifically through land use diversification. These results suggest that isolated farmers are more likely to diversify for food security or risk aversion rather than for commercial reasons. Indeed, because of higher transaction costs for buying and selling crops at markets (Ibrahim et al., 2009), remote households will invest more heavily in cultivation of diverse food crops to reduce costs (Rehima et al., 2013). Therefore, contrary to research that shows proximity to markets increases diversification by improving market integration (Gray et al., 2008), I find that households far from markets are more self-reliant, enacting land-use diversification strategies.

Farmer adaptations to climate change were also influenced by demographic factors: I found that men are more likely to migrate from rural to urban areas in search of work than women. Migration provides unique new opportunities to earn income, which are often unavailable in predominantly agricultural communities. Whether and why people move, however, depends on several factors including education, family obligations, social and economic status, social networks, and opportunities outside their local context (Kanaiaupuni, 2000). These factors require consideration through a gendered lens to understand determinants of migration. Gender discrimination, traditional norms of women as caretakers, and expectation that women stay at home, often constrain women from engaging in rural to urban migration (Kanaiaupuni, 2000). On the other hand, women in Mexico still have insecure land tenure as they have largely been excluded from land redistribution programs, are not voting members in their local townships (*ejidos)*, and therefore do not have ties to the land that men often do (USAID, 2011). Cognitive differences between men and women in terms of perceptions of risk may influence decision-making like migration choice. Some research has shown, for example, that in situations that are perceived as risky women are likely to respond differently (and in less risky ways) than men (Charness, Gneezy, & Imas, 2013). Investment games show that men tend to be more willing to take financial risks than women, a finding that applies in contexts around the world (Charness & Gneezy, 2012). Emerging evidence suggests that risk perceptions may also play an important role in determining individual likelihoods for migration (Dustmann et al., 2017), but more research is needed on how internal factors like gender influence adaptation strategies.

Demographic factors like education also influenced likelihood of signing up for citizen science projects. Much research shows that education is a consistent predictor of participation for volunteers (McPherson & Rotolo, 1996; Penner, 2004), and citizen scientists specifically (Overdevest & Orr, 2004). Education is often linked to rates of volunteering because the highly educated are more empowered, have sufficient cognitive ability, and often see volunteering as an advantage and status symbol (McPherson & Rotolo, 1996). However, these demographic, environmental, and socio-economic factors only partially account for explaining decision-making.

5.1.3 (Ir)rational decision making

Individual decision making has historically been characterized in traditional economic and behavioral theories as purely rational (Simon, 1955; Becker, 1967), where individuals seek to maximize utility, act completely independently of others, deciding on the optimal option based on an objective understanding of the costs and benefits (Thaler, 2000). However, there is considerable evidence today to suggest that decision-making deviates from rational choice models, and behavior is not easily predicted by what is the best or right thing to do.

More often than not, the choices we make are complex, non-linear, and informed by hidden heuristics, leading to knowledge-action gaps (Courtenay-Hall & Rogers, 2000; Kennedy et al., 2004; Sligo & Jameson, 2000) and attitude-action gaps (Kollmuss & Agyeman, 2002). For example, the novel informational training that was designed in this research to influence stewardship behaviors for citizen scientists—where conservation decision-makers detailed an extensive list of how volunteers could address threats to water—was successful for influencing attitudes towards conservation, but it only moderately influenced behaviors. Other factors such as social norms may play a role in what actions people take. For example, research on water conservation has shown that social comparison messages—i.e. comparing an individual to others—are more influential than technical information alone (Ferraro et al., 2011; Ferraro & Miranda 2013; Ferraro & Price, 2013). Similarly, households who received normative information consume less water than a randomized control group (Schultz et al., 2016). While we did not test these outcomes in the citizen science study, we did examine the influence of social factors for rural smallholder farmers.

This research showed that social capital—i.e. farmer membership to multiple agricultural, religious, and community groups—was a critical factor for farmer adoption of climate adaptation strategies like land use diversification, income diversification, and community investment. Groups can be essential for knowledge, skills and technological exchange (Smit & Pilifosova, 2003), providing the impetus to enact a certain behavior. In situations that are highly complex, risky, and with uncertain outcomes—e.g. decision making under long-term uncertainty due to climate change (Polasky et al., 2011)—these decision-making biases (like relying on social networks for information) may more likely influence choice (Tversky & Kahneman, 1974). These biases will prove to be an important topic for behavior change researchers in the future.

5.2. METHODOLOGICAL CONTRIBUTIONS

Because of the inherent complexity within individual decision-making, there is a need to test novel methodological and theoretical frontiers to better explain and influence choice. Underlining such a need, the European Commission released a report concluding that "systematic application of BIs [behavioral insights] throughout the policy cycle can advance evidence-based policy making (Lourenço et al., 2016, p. 2). Indeed, researchers have also increasingly called for the inclusion of behavior change research in conservation, specifically using experimental or quasi-experimental approaches to identify causal relationships (Akerlof & Kennedy, 2013; Czap et al., 2019; Reimer et al., 2014). Following this, I conducted an experimental design to investigate how including conservation decision-makers in citizen science training could influence perceptions of project relevance as well as improve participation, and influence social outcomes like conservation knowledge, attitudes, and stewardship behaviors.

In this design, I applied a novel science-policy framework which holds research must be credible (i.e. trustworthy), relevant (i.e. important and timely), and legitimate (i.e. with the perspectives of all relevant actors) for appropriate action to take place (Cash et al., 2002). The inclusion of these three elements—often called the CRELE framework—suggests that policy makers prioritize research when it aligns with their specific and timely needs (Cook et al., 2013), and that volunteers may similarly prioritize citizen science when they see the goals as relevant. However, research in citizen science often exclusively focuses on addressing concerns about credibility of volunteer data (Conrad & Hilchey, 2011; Henderson, 2012; Wiggins et al., 2013), at the expense of communicating why the research is relevant to policymakers. Therefore, through an experimental study I applied the CRELE framework through a citizen science training, which to my knowledge has not yet been conducted in this field. Despite trying to influence perception of project relevance, citizen scientists' perceptions were only influenced in the short term, and training did not influence the level of participation. Interviews suggest that many citizen scientists were strongly interested in analyzing local water quality (rather than water flow), suggesting that future research applying the CRELE framework in citizen science needs to take into account the interests of volunteers (i.e. project legitimacy) for long-lasting changes to participation.

5.3 IMPLICATIONS FOR RESEARCH AND APPLIED CONTRIBUTIONS

This dissertation confirms that a range of internal cognitive factors as well as environmental, socio-economic, and demographic factors work together to enable and constrain individual choice, and that rational and irrational psychological biases are at play in how people make decisions. A focal area across all three chapters was how information sharing influenced decision-making for citizen science participation, environmental stewardship behaviors, and adoption of climate adaptation strategies. I found that novel trainings were successful in influencing conservation knowledge, attitudes, and stewardship behaviors to varying degrees. However, trainings were ineffective for incentivizing adoption of climate change adaptation strategies by smallholder farmers. Understanding how the content and process of information-sharing influences decision making (or not) is essential for the development of effective behavior change research.

Information-sharing content: Focusing on critical thinking rather than behaviors. Environmental education has been criticized for placing undue focus on the pro-environmental behavior, rather than developing individual skills and critical thinking, which circumvents and undermines an individual's ability to make their own decisions about what constitutes a significant environmental behavior (Courtenay-Hall & Rogers, 2002). Knowledge itself is not a value-free commodity, possessed by teachers and transmissible to students (Courtenay-Hall & Rogers, 2000; Kennedy et al., 2004; Sligo & Jameson, 2000). Instead, knowledge is positional, value-laden, and collaboratively produced by students and teachers (Freire, 1970; Longino, 1990; Lipman, 1991). To overcome these challenges in knowledge-production and knowledge-sharing researchers have turned to participatory action research with a focus on outcomes and processes to increase relevant research, improve livelihoods and ecological outcomes. In practice, attaining multiple goals has been successful through strategies like community-based co-management of natural resources.

Information-sharing process: Focusing on an iterative, collaborative, and co-created process. Launched in the 1990s, community-based natural resource management programs (CBNRM) built on the legacy of Integrated Conservation and Development Projects (ICDPs) designed to link conservation with sustainable livelihoods. In its day, CBNRM was understood as a panacea to amplify the benefits of conservation while alleviating poverty. Recently, however, researchers have recognized many constraints and conditions: "[t]he shimmer has worn off" (Reid et al., 2014, pg. 15). Indeed, many CBNRM projects have institutional barriers to implementation and fail to overcome power dynamics. In order for strong CBNRM researchers have recognized the need to: integrate different ways of knowledge, share knowledge with multiple stakeholders, and create an iterative process of learning-by-doing.

Successful local CBNRM programs have provided a framework for international policy makers. For example, The United Nations Development Programs have developed a number of programs through its Equator Initiative (EI) to reduce poverty through conservation by strengthening community partnerships (Berkes & Adhikari, 2006; Brown, 2002; EI, 2019). These Initiatives have been largely successful for reducing threats to biodiversity, while providing economic opportunities for community members (Berkes & Adhikari, 2006). Such success is attributed to the involvement of diverse partners—ranging between 10 to 15 partners per project—and multiple linkages across organizations—ranging from 4 to 5 levels of organizations (Berkes, 2007). By including a variety of partners, the Initiatives were able to fill various roles including: networking, empowerment, innovation, and knowledge production.

Certain organizations, such as bridging institutions, are particularly well suited for building trust, reducing conflict, improving knowledge coproduction, and facilitating vertical and horizontal organizational collaboration (Berkes, 2009). However, "The challenge is to build a fully communicative, deliberative, multilevel system that deals with tradeoffs between social and ecological objectives in an optimum fashion, without being skewed by disciplinary biases or the political economic of power relations" (Berkes 2007, pg. 15191). My research has focused on including high level decision makers—governmental (e.g. INIFAP), non-governmental (e.g. FONCET), and non-profit organizations (e.g. GWW-Mexico)— in research decision making to facilitate collaboration and improve knowledge sharing. The challenge will be to bring in knowledge from communities and participants too, for a more iterative process of learning-by-doing in complex systems (Sarkki et al., 2015).

Indeed, integrating multiple knowledge systems is a key attribute of CBNRM programs. Rangeland ecologists Reid et al. (2014), found that network development, cooperation, and knowledge sharing were essential for East African pastoralists to adapt to quickly changing ecological (e.g. increased drought) and social (e.g. population growth) landscapes. By integrating traditional ecological knowledge with scientific knowledge into discourse, both scientists and locals deepened their understanding and learning through knowledge sharing at various scales (Berkes 2009). "When local people help identify locally salient indicators and carry out assessments, monitoring is more likely to lead to prompt action" (Reid et al. 2014, pg. 17).

In citizen science, there are a growing number of projects using and promoting collaboration and even co-creation of research (Bonney et al., 2009; Danielsen et al., 2009; Shirk et al., 2012), rather than the traditional contributory systems where citizen scientists simply collect the data (Wiggins & Crowston, 2015). Ensuring full participation of stakeholders not only promotes innovative thinking for complex problems (Woolley et al., 2010) it can improve relationships between stakeholders (Ridder & Pahl Wostl, 2005), while developing trust, distributing power, integrating knowledge, and promoting longevity of conservation goals (Tengö et al., 2014; Reid et al., 2016). My dissertation has made collaboration a primary feature of the study design and data collection, and I look forward to conducting critical action-based research while testing novel techniques for understanding decision making. Collaborative research to ensure projects are developed by and with practitioners, community-members, and decision-makers is essential for a common understanding of the problem and solutions (Greenwood & Levin, 1998; Selener, 1997).

Novel mechanisms for behavior change. Because many information campaigns have fallen short of achieving behavioral outcomes, there is a need to test novel mechanisms that have been successful in other fields—such as external incentives/rewards and social norm messaging—to improve participation in citizen science, pro-environmental behavior, and climate adaptation strategies.

In citizen science, positive incentives in the form of rewards (e.g. points, badges, stars, or thumbs ups) have increasingly been used to motivate and retain volunteers (Bowser et al., 2013; Restivo & van de Rijt, 2014; Eveleigh et al., 2013). Rewards provide feedback for volunteers which is not only important for engagement (Csikszentmihalyi, 1990), but can also be a social marker of prestige, or demonstration of achievement (Gibson et al., 2013). Positive feedback loops using rewards may mean individuals are more likely to engage in similar behavior when they see others acting in a certain way (Cialdini, 2001), and stimulate desire to outcompete others for points (Eveleigh et al. 2013; Jennett et al., 2016). However, the influence of rewards varies. For example, one study examined effect of rewards on citizen science participation in the project Old Weather, where participants transcribe written weather logs online, and their efforts are rewarded with scoring that leads to promotion from "Private", to "Lieutenant", and finally to "Captain". Scoring, however, demotivated citizen scientists with fewer contributions (and farther from "Captain") from participating (Eveleigh et al., 2013). Indeed, researchers found that the project was not only stressful for participants trying to maintain (or attain) the rank of Captain, but many felt that quantity was rewarded over quality, and the game trivialized their experience. Therefore, understanding when and why external incentives are successful (or fail) will be important for motivating volunteers as well as social and ecological outcomes.

Another novel technique within choice literature is social norm messaging, a tool that has been underutilized for changing stewardship behaviors (Griskevicius, Cialdini, & Goldstein, 2008). As unwritten rules or guidelines, norms are considered commonly accepted behavior in a particular situation (Cialdini, 2003). In the environmental sector, normative messaging—especially through social comparison—has been popularized to encourage basic behaviors, such as reducing water use during droughts (Bernedo et al., 2014), persuading homeowners to conserve energy (Allcott et al., 2011), or discouraging natural resource degradation in National Parks (Cialdini, 2003). These social norm messages give credence to social comparison theory, which suggests that individuals judge the validity of their own behaviors by comparing themselves to others (Festinger, 1958). Indeed, several studies on behavioral impacts of social comparison have demonstrated normative messaging to be highly effective (e.g. Goldstein et al., 2008), more effective in fact than traditional pro-environmental messages (Nolan et al., 2008). Normative messaging can also be long lived, one study found that the impacts of a single nudge aimed at reducing water use were still detectable six years later (Bernedo et al., 2014).

Citizen science has only begun to explore the implications of social norms. Several studies have demonstrated the importance of norms in motivating individuals to contribute (Nov et al., 2011; Nov et al., 2014). However, empirical studies on the influence of social norms on volunteer participation have been somewhat mixed (Houle et al., 2005). Some researchers have hypothesized that while social pressure is important for encouraging citizen science contributions that it is "less likely to induce the kind of commitment, enthusiasm and sustained effort that are necessary for making high-quality contributions" (Nov et al. 2014, p. 4). Indeed, their findings support the idea that social norms could increase quantity but not quality of data.

In the field of climate adaptation, there is significant empirical and theoretical research to suggest that farmers are influenced by social norms (Adger, 2003; Frank, Eakin, & López-Carr, 2011; Hu et al., 2006; Truelove, Carrico, & Thabrew, 2015). For management of common-pool resources, research shows that individuals are more likely to make decisions that favor the group when they identify positively with that group (Brewer & Kramer, 1986; Kramer & Brewer 1984; Van Vugt, 2001) and trust group members (Brann & Foddy, 1987; Messick, 1983). Farmers then that strongly identify with a group and perceive their group's social norm for adaptation, are more likely to choose similar behaviors (Truelove et al., 2015). Despite such studies, research is conspicuously lacking on how social norm messaging could be used to elicit adaptation strategies. Research that has been conducted using social norm messaging has been restricted to farmers the Global North to improve conservation outcomes. For example, one study used social norm messaging to encourage farmers to join the Conservation Stewardship Program (CSP), a federal agri-environmental scheme in the United States designed to improve crop yields or cattle gains, while improving wildlife populations, ecological resilience, and reducing chemical inputs (Wallander et al., 2017; Czar et al., 2019). Researchers found that social norm messaging dramatically improved enrollment in the CSP, but handwritten letters were significantly more effective for farmer enrollment than photocopied letters (Czap et al., 2019), suggesting the importance of form *and* content for messaging (Garner, 2005). More research, however, is needed in the Global South on how social norm messaging could improve adaptation strategies like land use or market diversification.

5.4 FUTURE DIRECTIONS

In his work on pedagogy, Brazilian educator and philosopher Paulo Freire made a call to all teachers: "*The role of the educator is not simply to transmit knowledge to the student, but to seek alongside them the means to transform the world".* To achieve this goal, he committed himself to a philosophy that guides my own teaching and research, specifically that education requires a commitment to: the co-development of research goals by academics and non-academics for conservation; the establishment of inclusive spaces for diverse knowledge-sharing; as well as an iterative process of learning-by-doing. I strive to implement these core values derived from my doctoral research.

All three core chapters of my dissertation have been developed in collaboration with local stakeholders – in Veracruz, I worked with a non-governmental organization (Global Water Watch-Mexico), a conservation trust fund (Fidecoagua), and a sustainable development advocacy group (SENDAS); in Chiapas, I worked with a governmental institution for farmers (*Inistituto Nacional de Investigaciones Forestales, Agrícolas, y Pecuarios, INIFAP*) and a non-governmental organization for conservation (*Fondo para la Conservación El Triunfo, FONCET*). I am proud that this research was co-developed research with key organizational stakeholders, and recognize that without their help this research could not have been realized.

Learning from these experiences, I commit to integrating stakeholders that were previously excluded from the decision-making processes into the co-development of research goals. For example, I was not able to include smallholder farmers in Chiapas into the goal setting stage of my research. Because of this, I found farmers were often reluctant to speak to me, or even angry about the colonialist style of extractive research that in the past had done little to benefit them. However, through my commitment to report the results back, as well as the foundational relationships built between farmers and host organizations, farmers increasingly opened their doors to me to allow my research to continue. To improve inclusivity and co-development of research requires a commitment of time and resources, frequently lacking, but these I believe are required for successful conservation and livelihood outcomes.

In the long run, I am interested in combining my interests in information-campaigns, adaptation to climate change, and public participation in science with the goal of improving individual livelihoods, science production, and policy making for conservation. One area that is ripe for investigation, is the use of publicly collected information on natural hazards for public service announcements. Research shows that situational factors like natural hazard types—chronic slow-onset hazards like sea level rise or drought, as opposed to acute-onset hazards like hurricanes and fire (Ludwig et al., 2018)— influences perceptions of risk as well as what measures people make (Ho et al., 2008). Cognitive factors like perceptions of risk are also influenced by the type of natural disaster (Tobin et al., 2011), where perceptions of risk interact with the type of behavior that is required. For example, drastic measures like evacuation (Eisenman et al., 2007) or incremental measures like creating defensible spaces (Hall et al., 2009). Social norms may influence whether and what behaviors are adopted. Currently, there are a number of crowdsourced weather stations like WeatherUnderground, (Muller et al., 2013) which provide information on a range of weather-related phenomenon – e.g. rain, snow, hail, and temperature – as well as health related factors – e.g. ozone, pollen, and particulate matter – which can be enabled to provide public warnings. Integrating social norms into crowdsourced weather station data could provide an impetus for individuals on how to respond. For example, crowdsourcing could encourage users to log whether they have created defensible spaces around their homes. At large enough scales, these could be used to generate messages for social comparison – e.g. “90% of households within your neighborhood have created defensible spaces.” Understanding what cognitive factors are at play – e.g. climate risk perceptions or social norms – that encourage patterns of adaptive and anti-adaptive responses to these events will be crucial for improving livelihoods, as well as social and ecological outcomes.

REFERENCES

Adger, W.N. (2003). Social capital, collective action, and adaptation to climate change. *Economic geography*, *79*(4), 387-404.

Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes*, *50*(2), 179-211.

Akerlof, K., & Kennedy, C. (2013). Nudging toward a healthy environment: How behavioral change research can inform conservation. *White paper for the Gordon and Betty Moore Foundation. George Mason University, Fairfax, VA*.

Allcott, H. (2011). Social norms and energy conservation. *Journal of public Economics*, *95*(9-10), 1082-1095.

Bebbington, A. (1999). Capitals and capabilities: a framework for analyzing peasant viability, rural livelihoods and poverty. *World development*, *27*(12), 2021-2044.

Becker, G.S. (1962) Irrational Behaviour and economic theory. *Journal of Political Economy,* 70: 1-13.

Bennett, N. J. (2016). Using perceptions as evidence to improve conservation and environmental management. *Conservation Biology*, *30*(3), 582-592.

Berkes, F. (2007). Community-based conservation in a globalized world. *Proceedings of the National academy of sciences*, *104*(39), 15188-15193.

Berkes, F. (2009). Evolution of co-management: role of knowledge generation, bridging organizations and social learning. *Journal of environmental management*, *90*(5), 1692-1702.

Berkes, F., & Adhikari, T. (2006). Development and conservation: indigenous businesses and the UNDP Equator Initiative. *International journal of entrepreneurship and small business*, *3*(6), 671-690.

Bernedo, M., Ferraro, P. J., & Price, M. (2014). The persistent impacts of norm-based messaging and their implications for water conservation. *Journal of Consumer Policy*, *37*(3), 437-452.

Bonney, R., Ballard, H., Jordan, R., McCallie, E., Phillips, T., Shirk, J., & Wilderman, C. C. (2009). Public Participation in Scientific Research: Defining the Field and Assessing Its Potential for Informal Science Education. A CAISE Inquiry Group Report. *Online Submission*.

Bowser, A., Hansen, D., He, Y., Boston, C., Reid, M., Gunnell, L., & Preece, J. (2013, October). Using gamification to inspire new citizen science volunteers. In *Proceedings of the first international conference on gameful design, research, and applications* (pp. 18-25). ACM.

Brann, P., & Foddy, M. (1987). Trust and the consumption of a deteriorating common resource. *Journal of conflict resolution*, *31*(4), 615-630.

Brewer, M. B., & Kramer, R. M. (1986). Choice behavior in social dilemmas: Effects of social identity, group size, and decision framing. *Journal of personality and social psychology*, *50*(3), 543.

Brown, K. (2002). Innovations for conservation and development. *Geographical Journal*, *168*(1), 6-17.

Bruyere, B., & Rappe, S. (2007). Identifying the motivations of environmental volunteers. *Journal of Environmental Planning and Management*, *50*(4), 503-516.

Cash, D., Clark, W. C., Alcock, F., Dickson, N. M., Eckley, N., & Jäger, J. (2002). Salience, credibility, legitimacy and boundaries: linking research, assessment and decision making.

Charness, G., & Gneezy, U. (2012). Strong evidence for gender differences in risk taking. *Journal of Economic Behavior & Organization*, *83*(1), 50-58.

Charness, G., Gneezy, U., & Imas, A. (2013). Experimental methods: Eliciting risk preferences. *Journal of Economic Behavior & Organization*, *87*, 43-51.

Cialdini, R. B. (2001). The science of persuasion. *Scientific American*, *284*(2), 76-81.

Cialdini, R. B. (2003). Crafting normative messages to protect the environment. *Current directions in psychological science*, *12*(4), 105-109.

Clary, E. G., Snyder, M., Ridge, R. D., Copeland, J., Stukas, A. A., Haugen, J., & Miene, P. (1998). Understanding and assessing the motivations of volunteers: a functional approach. *Journal of personality and social psychology*, *74*(6), 1516.

Conrad, C. C., & Hilchey, K. G. (2011). A review of citizen science and community-based environmental monitoring: issues and opportunities. *Environmental monitoring and assessment*, *176*(1-4), 273-291.

Cook, C. N., Mascia, M. B., Schwartz, M. W., Possingham, H. P., & Fuller, R. A. (2013). Achieving conservation science that bridges the knowledge–action boundary. *Conservation Biology*, *27*(4), 669-678.

Courtenay-Hall, P., & Rogers, L. (2002). Gaps in mind: Problems in environmental knowledge-behaviour modelling research. *Environmental Education Research*, *8*(3), 283-297.

Crawford, D. W., Jackson, E. L., & Godbey, G. (1991). A hierarchical model of leisure constraints. *Leisure sciences*, *13*(4), 309-320.

Czap, N.V., Czap, H.J. & Burbach, M.E. (2019) Encouraging farmers' participation in the Conservation Stewardship Program: A field experiment. *Ecological Economics, 161*: 130-143.

Danielsen, F., Burgess, N. D., Balmford, A., Donald, P. F., Funder, M., Jones, J. P., ... & Child, B. (2009). Local participation in natural resource monitoring: a characterization of approaches. *Conservation Biology*, *23*(1), 31-42.

Deressa, T. T., Hassan, R. M., & Ringler, C. (2011). Perception of and adaptation to climate change by farmers in the Nile basin of Ethiopia. *The Journal of Agricultural Science*, *149*(1), 23-31.

Domroese, M. C., & Johnson, E. A. (2017). Why watch bees? Motivations of citizen science volunteers in the Great Pollinator Project. *Biological Conservation*, *208*, 40-47.

Dustmann, C., Fasani, F., Meng, X., and Minale, L. (2017). Risk attitudes and household migration decisions. *IZA Institute for Labor Economics No. 10603,* Bonn, Germany.

Eakin, H. (2005). Institutional change, climate risk, and rural vulnerability: Cases from Central Mexico. *World Development*, *33*(11), 1923-1938.

Eisenman, D. P., Cordasco, K. M., Asch, S., Golden, J. F., & Glik, D. (2007). Disaster planning and risk communication with vulnerable communities: lessons from Hurricane Katrina. *American journal of public health*, *97*, S109-S115.

Equator Initiative (EI). (2019). Available at: http://www.undp.org/equatorinitiative.

Eveleigh, A., Jennett, C., Lynn, S., & Cox, A. L. (2013, October). "I want to be a Captain! I want to be a Captain!": Gamification in the Old Weather Citizen Science Project. In *Proceedings of the first international conference on gameful design, research, and applications* (pp. 79-82). ACM.

Ferraro, P. J., & Miranda, J. J. (2013). Heterogeneous treatment effects and mechanisms in information-based environmental policies: Evidence from a large-scale field experiment. *Resource and Energy Economics*, *35*(3), 356-379.

Ferraro, P. J., Miranda, J. J., & Price, M. K. (2011). The persistence of treatment effects with norm-based policy instruments: evidence from a randomized environmental policy experiment. *American Economic Review*, *101*(3), 318-22.

Ferraro, P. J., & Price, M. K. (2013). Using nonpecuniary strategies to influence behavior: evidence from a large-scale field experiment. *Review of Economics and Statistics*, *95*(1), 64-73.

Fosu-Mensah, B. Y., Vlek, P. L., & MacCarthy, D. S. (2012). Farmers' perception and adaptation to climate change: a case study of Sekyedumase district in Ghana. *Environment, Development and Sustainability*, *14*(4), 495-505.

Frank, E., Eakin, H., & López-Carr, D. (2011). Social identity, perception and motivation in adaptation to climate risk in the coffee sector of Chiapas, Mexico. *Global environmental change*, *21*(1), 66-76.

Freire, P. (2005). *Pedagogy of the Oppressed.* New York: Seabury Press.

Festinger, L. (1958). The motivating effect of cognitive dissonance. *Assessment of human motives*, 65-86.

Frey, B. S., & Jegen, R. (2001). Motivation crowding theory. *Journal of economic surveys*, *15*(5), 589-611.

Gage III, R. L., & Thapa, B. (2012). Volunteer motivations and constraints among college students: Analysis of the volunteer function inventory and leisure constraints models. *Nonprofit and Voluntary Sector Quarterly*, *41*(3), 405-430.

Garner, R. (2005). Post-It® note persuasion: a sticky influence. *Journal of Consumer Psychology*, *15*(3), 230-237.

Gray, C.L., Bilsborrow, R.E., Bremner, J.L. and Lu, F., (2008). Indigenous land use in the Ecuadorian Amazon: a cross-cultural and multilevel analysis. *Human Ecology*, 36(1), pp.97-109.

Greenwood, D. J., & Levin, M. (1998*). Introduction to action research: social research for social change.* Thousand Oaks, CA: Sage Publications.

Griskevicius, V., Cialdini, R. B., & Goldstein, N. J. (2008). Social norms: An underestimated and underemployed lever for managing climate change. *International Journal of Semantic Computing,* 3: 5-13.

Hall, T. E., & Slothower, M. (2009). Cognitive factors affecting homeowners' reactions to defensible space in the Oregon Coast Range. *Society and Natural Resources*, *22*(2), 95-110.

Ho, M. C., Shaw, D., Lin, S., & Chiu, Y. C. (2008). How do disaster characteristics influence risk perception?. *Risk Analysis: An International Journal*, *28*(3), 635-643.

Houle, B. J., Sagarin, B. J., & Kaplan, M. F. (2005). A functional approach to volunteerism: Do volunteer motives predict task preference?. *Basic and applied social psychology*, *27*(4), 337-344.

Hu, Q., Zillig, L. M. P., Lynne, G. D., Tomkins, A. J., Waltman, W. J., Hayes, M. J., ... & Wilhite, D. A. (2006). Understanding farmers' forecast use from their beliefs, values, social norms, and perceived obstacles. *Journal of applied meteorology and climatology*, *45*(9), 1190-1201.

Ibrahim, H., Rahman, S. A., Envulus, E. E., & Oyewole, S. O. (2009). Income and crop diversification among farming households in a rural area of north central Nigeria. *Journal of Tropical Agriculture, Food, Environment and Extension*, *8*(2), 84-89.

Jennett, C., Kloetzer, L., Schneider, D., Iacovides, I., Cox, A., Gold, M., ... & Talsi, Y. (2016). Motivations, learning and creativity in online citizen science. *Journal of Science Communication*, *15*(3).

Kanaiaupuni, S. M. (2000). Reframing the migration question: An analysis of men, women, and gender in Mexico. *Social forces*, *78*(4), 1311-1347.

Katsman, C. A., Sterl, A., Beersma, J. J., Van den Brink, H. W., Church, J. A., Hazeleger, W., ... & Lowe, J. (2011). Exploring high-end scenarios for local sea level rise to develop flood protection strategies for a low-lying delta—the Netherlands as an example. *Climatic change*, *109*(3-4), 617-645.

Kennedy, T., Regehr, G., Rosenfield, J., Roberts, S. W., & Lingard, L. (2004). Exploring the gap between knowledge and behavior: a qualitative study of clinician action following an educational intervention. *Academic Medicine*, *79*(5), 386-393.

Koenig, T.A., Hudnut, K.W., Davis, D.K., and Bright, P.R., 2018, Science for a risky world—A U.S. Geological Survey plan for risk research and applications: U.S. Geological Survey Circular 1444, 57 p., https://doi.org/10.3133/cir1444.

Kollmuss, A., & Agyeman, J. (2002). Mind the gap: why do people act environmentally and what are the barriers to pro-environmental behavior?. *Environmental education research*, *8*(3), 239-260.

Kramer, R. M., & Brewer, M. B. (1984). Effects of group identity on resource use in a simulated commons dilemma. *Journal of personality and social psychology*, *46*(5), 1044.

Kwadijk, J. C., Haasnoot, M., Mulder, J. P., Hoogvliet, M. M., Jeuken, A. B., van der Krogt, R. A., ... & de Wit, M. J. (2010). Using adaptation tipping points to prepare for climate change and sea level rise: a case study in the Netherlands. *Wiley interdisciplinary reviews: climate change*, *1*(5), 729-740.

Lipman, M. (1990) *Thinking in Education.* Cambridge: Cambridge University Press.

Longino, H. E. (1990). *Science as social knowledge: Values and objectivity in scientific inquiry*. Princeton, NJ: Princeton University Press.Frey, B. S., & Goette, L. (1999). Does pay motivate volunteers?. *Working paper/Institute for Empirical Research in Economics*, *7*.

Lourenço, J., Ciriolo, E., Almeida, S.R., & Troussard, X. (2016). Behavioural insights applied to policy: Overview across 32 European countries. *Report by the Joint Research Center of the European Commission,* EUR 27726 EN.

Ludwig, K.A., Ramsey, D.W., Wood, N.J., Pennaz, A.B., Godt, J.W., Plant, N.G., Luco, N.,

Martinez, T. A., & McMullin, S. L. (2004). Factors affecting decisions to volunteer in nongovernmental organizations. *Environment and behavior*, *36*(1), 112-126.

Measham, T. G., & Barnett, G. B. (2008). Environmental volunteering: Motivations, modes and outcomes. *Australian Geographer*, *39*(4), 537-552.

McPherson, J. M., & Rotolo, T. (1996). Testing a dynamic model of social composition: Diversity and change in voluntary groups. *American sociological review*, 179-202.

Mertz, O., Mbow, C., Reenberg, A., & Diouf, A. (2009). Farmers' perceptions of climate change and agricultural adaptation strategies in rural Sahel. *Environmental management*, *43*(5), 804-816.

Messick, D. M., Wilke, H., Brewer, M. B., Kramer, R. M., Zemke, P. E., & Lui, L. (1983). Individual adaptations and structural change as solutions to social dilemmas. *Journal of personality and social psychology*, *44*(2), 294.

Muller, C. L., Chapman, L., Grimmond, C. S. B., Young, D. T., & Cai, X. (2013). Sensors and the city: a review of urban meteorological networks. *International Journal of Climatology*, *33*(7), 1585-1600.

Muradian, R., Arsel, M., Pellegrini, L., Adaman, F., Aguilar, B., Agarwal, B., ... & Garcia-Frapolli, E. (2013). Payments for ecosystem services and the fatal attraction of win-win solutions. *Conservation letters*, *6*(4), 274-279.

Nolan, J. M., Schultz, P. W., Cialdini, R. B., Goldstein, N. J., & Griskevicius, V. (2008). Normative social influence is underdetected. *Personality and social psychology bulletin*, *34*(7), 913-923.

Noss, R. F. (2011). Between the devil and the deep blue sea: Florida's unenviable position with respect to sea level rise. *Climatic Change*, *107*(1-2), 1-16.

Nov, O., Arazy, O., & Anderson, D. (2014). Scientists@ Home: what drives the quantity and quality of online citizen science participation?. *PloS one*, *9*(4), e90375.

Nov, O., Arazy, O., & Anderson, D. (2011, February). Dusting for science: motivation and participation of digital citizen science volunteers. In *Proceedings of the 2011 iConference*(pp. 68-74). ACM.

O'Brien, L., Townsend, M., & Ebden, M. (2010). 'Doing something positive': Volunteers' experiences of the well-being benefits derived from practical conservation activities in nature. *Voluntas: International Journal of Voluntary and Nonprofit Organizations*, *21*(4), 525-545.

Overdevest, C., Orr, C. H., & Stepenuck, K. (2004). Volunteer stream monitoring and local participation in natural resource issues. *Human Ecology Review*, 177-185.

Penner, L. A. (2004). Volunteerism and social problems: Making things better or worse?. *Journal of Social Issues*, *60*(3), 645-666.

Polasky, S., Carpenter, S. R., Folke, C., & Keeler, B. (2011). Decision-making under great uncertainty: environmental management in an era of global change. *Trends in ecology & evolution*, *26*(8), 398-404.

Reid, R. S., Nkedianye, D., Said, M. Y., Kaelo, D., Neselle, M., Makui, O., ... & Ogutu, J. (2016). Evolution of models to support community and policy action with science: Balancing pastoral livelihoods and wildlife conservation in savannas of East Africa. *Proceedings of the National Academy of Sciences*, *113*(17), 4579-4584.

Reid, R. S., Fernández-Giménez, M. E., & Galvin, K. A. (2014). Dynamics and resilience of rangelands and pastoral peoples around the globe. *Annual Review of Environment and Resources*, *39*, 217-242.

Reimer, A., Thompson, A., Prokopy, L. S., Arbuckle, J. G., Genskow, K., Jackson-Smith, D., ... & Nowak, P. (2014). People, place, behavior, and context: A research agenda for expanding our understanding of what motivates farmers' conservation behaviors. *Journal of Soil and Water Conservation*, *69*(2), 57A-61A.

Rehima, M., Belay, K., Dawit, A., & Rashid, S. (2013). Factors affecting farmers' crops diversification: Evidence from SNNPR, Ethiopia. *International Journal of Agricultural Sciences*, *3*(6), 558-565.

Restivo, M., & Van De Rijt, A. (2012). Experimental study of informal rewards in peer production. *PloS one*, *7*(3), e34358 Smit, B., McNabb, D., & Smithers, J. (1996). Agricultural adaptation to climatic variation. *Climatic change*, *33*(1), 7-29.

Ridder, D., & Pahl-Wostl, C. (2005). Participatory Integrated Assessment in local level planning. *Regional Environmental Change*, *5*(4), 188-196.

Ryan, R. L., Kaplan, R., & Grese, R. E. (2001). Predicting volunteer commitment in environmental stewardship programmes. *Journal of Environmental Planning and Management*, *44*(5), 629-648.

Sarkki, S., Tinch, R., Niemelä, J., Heink, U., Waylen, K., Timaeus, J., ... & van den Hove, S. (2015). Adding 'iterativity'to the credibility, relevance, legitimacy: a novel scheme to highlight dynamic aspects of science–policy interfaces. *Environmental Science & Policy*, *54*, 505-512.

Schultz, P. W., Messina, A., Tronu, G., Limas, E. F., Gupta, R., & Estrada, M. (2016). Personalized normative feedback and the moderating role of personal norms: A field experiment to reduce residential water consumption. *Environment and Behavior*, *48*(5), 686-710.

Scoones, I. (1998). Sustainable rural livelihoods: a framework for analysis. *IDS Working Paper,* 72: 1-22.

Selener, D. (1997). *Participatory action research and social change.* Ithaca, NY: Cornell University Press.

Sheeran, P. (2002). Intention—behavior relations: a conceptual and empirical review. *European review of social psychology*, *12*(1), 1-36.

Shirk, J., Ballard, H., Wilderman, C., Phillips, T., Wiggins, A., Jordan, R., ... & Bonney, R. (2012). Public participation in scientific research: a framework for deliberate design. *Ecology and society*, *17*(2).

Simon, H. A. (1955). A behavioral model of rational choice. *The quarterly journal of economics*, *69*(1), 99-118.

Sligo, F. X., & Jameson, A. M. (2000). The knowledge—behavior gap in use of health information. *Journal of the American Society for Information Science*, *51*(9), 858-869.

Smit, B., & Pilifosova, O. (2003). Adaptation to climate change in the context of sustainable development and equity. *Sustainable Development*, *8*(9), 9.

Sundeen, R. A., Raskoff, S. A., & Garcia, M. C. (2007). Differences in perceived barriers to volunteering to formal organizations: Lack of time versus lack of interest. *Nonprofit Management and Leadership*, *17*(3), 279-300.

Tengö, M., Brondizio, E. S., Elmqvist, T., Malmer, P., & Spierenburg, M. (2014). Connecting diverse knowledge systems for enhanced ecosystem governance: the multiple evidence base approach. *Ambio*, *43*(5), 579-591.

Thaler, R. H. (2000). From homo economicus to homo sapiens. *Journal of economic perspectives*, *14*(1), 133-141.

Tobin, G. A., Whiteford, L. M., Jones, E. C., Murphy, A. D., Garren, S. J., & Padros, C. V. (2011). The role of individual well-being in risk perception and evacuation for chronic vs. acute natural hazards in Mexico. *Applied Geography*, *31*(2), 700-711.

Tucker, C. M., Eakin, H., & Castellanos, E. J. (2010). Perceptions of risk and adaptation: coffee producers, market shocks, and extreme weather in Central America and Mexico. *Global Environmental Change*, *20*(1), 23-32.

Tversky, A., & Kahneman, D. (1974). Judgment under uncertainty: Heuristics and biases. *science*, *185*(4157), 1124-1131.

U.S. Agency for International Development (USAID). (2011). USAID Country Profile: Property rights and resource governance, Mexico. Washington, D.C., USAID.

VanKoningsveld, M., Mulder, J. P., Stive, M. J., VanDerValk, L., & VanDerWeck, A. W. (2008). Living with sea-level rise and climate change: a case study of the Netherlands. *Journal of Coastal Research*, 367-379.

Van Vugt, M. (2001). Community identification moderating the impact of financial incentives in a natural social dilemma: Water conservation. *Personality and Social Psychology Bulletin*, *27*(11), 1440-1449.

Wdowinski, S., Bray, R., Kirtman, B. P., & Wu, Z. (2016). Increasing flooding hazard in coastal communities due to rising sea level: Case study of Miami Beach, Florida. *Ocean & Coastal Management*, *126*, 1-8.Henderson, S. (2012). Citizen science comes of age. *Frontiers in Ecology and the Environment*, *10*(6), 283-283.

Wallander, S., Ferraro, P., & Higgins, N. (2017). Addressing participant inattention in federal programs: A field experiment with the Conservation Reserve Program. *American Journal of Agricultural Economics*, *99*(4), 914-931.

Weaver, D. (2015). Volunteer tourism and beyond: Motivations and barriers to participation in protected area enhancement. *Journal of Sustainable Tourism*, *23*(5), 683-70

West, S. E., & Pateman, R. M. (2016). Recruiting and retaining participants in citizen science: What can be learned from the volunteering literature?. *Citizen Science: Theory and Practice*.

Wiggins, A., Bonney, R., Graham, E., Henderson, S., Kelling, S., LeBuhn, G., ... & Newman, G. (2013). Data management guide for public participation in scientific research. *DataOne Working Group*, 1-41.

Wiggins, A., & Crowston, K. (2010). Developing a conceptual model of virtual organisations for citizen science. *International Journal of Organisational Design and Engineering*, *1*(1), 148-162.

Woolley, A. W., Chabris, C. F., Pentland, A., Hashmi, N., & Malone, T. W. (2010). Evidence for a collective intelligence factor in the performance of human groups. *Science*, *330*(6004), 686-688.

APPENDICES

APPENDIX I

A.1.1 Table 1. Descriptive statistics of household level variables.

Category	***Indicator***	***Definition***	***Mean***	***Std Dev***
Human	Age	Average age of head of household	52.24	13.41
	Education	Percent of households with primary school education or less	71.03	0.97
	Family size	Average number of people within the household	5.08	2.11
	Sex	Percent of head of households that are male	80.97	0.39
Financial	Subsidies	Government subsidies received in 2015 in Mexican pesos*	13,478	12,530
Natural	Land holdings	Average number of hectares owned	10.90	13.96
Physical	Assets	Household assets transformed by PCA	NA	NA
Social	Group membership	Average number of groups in which households are involved	0.90	0.91
Climate	Climate perceptions	Average perceptions of climate change on a 5-point Likert scale	3.99	0.50
Vulnerability context	Disaster experience	% that have experienced a natural disaster in the last 10 years	80.70	0.37
	Market distance	Distance from their fields to markets in minutes	117.74	82.79

**15 Mexican Pesos = 1 US$ in mid 2015*

A.1.2 Table 2. Household assets PCA: eigenvalues

Factor	Asset	*Coefficient*
Factor 1	Car	0.753
	Motorcycle	0.674
	Gas stove	0.599
	Variance explained by factor 1	**1.471**
Factor 2	Bicycle	0.724
	Cell phone	0.727
	Variance explained by factor 2	**1.301**
Factor 3	Animals	0.822
	Horses	0.576
	Variance explained by factor 3	**1.197**
Factor 4	Electricity	0.703
	Chainsaw	-0.647
	Variance explained by factor 4	1.145

A.1.3 Table 3. T-test of capital asset differences between highly and low adaptive households.

Category	*Indicator*	*Highly adaptive Mean (stdev)*	*Low adaptation Mean (stdev)*	*t-value*	*p-value*
Human	Age	52.30 (12.93)	52.18 (14.00)	0.08	0.9378
	Education	1.19 (0.99)	1.08 (0.94)	0.90	0.3681
	Family size	5.22 (1.94)	4.91 (2.29)	1.23	0.2183
	Sex (% female)	**0.15 (0.36)**	**0.24 (0.43)**	**-1.90**	**0.0585**
Financial	**Subsidies**	**15,275 (15,212)**	**11,571 (8,260)**	**2.53**	**0.0121**
Natural	**Land holdings**	**13.22 (16.16)**	**8.34 (10.63)**	**2.99**	**0.0030**
Physical	Assets	-	-	-	-
Social	**Group membership**	**1.01 (0.93)**	**0.77 (0.88)**	**2.22**	**0.0273**
Climate perceptions	**Temperature**	**4.40 (0.57)**	**4.28 (0.65)**	**1.65**	**0.1003**
	Drought	**4.26 (0.74)**	**4.07 (0.87)**	**1.99**	**0.0471**
	Hurricane	2.94 (1.43)	3.01 (1.52)	0.42	0.6764
	Coffee rust	4.56 (0.81)	4.53 (1.01)	0.23	0.8188
	Insects	3.46 (1.43)	3.32 (1.43)	0.08	0.4218
	Total average perceptions	**4.03 (0.49)**	**3.93 (0.51)**	**1.66**	**0.0981**
Vulnerability context	Disaster experience	0.84 (0.37)	0.77 (0.42)	1.50	0.1353
	Market distance	**130.70 (92.63)**	**102.00 (67.49)**	**2.86**	**0.0046**
Observations		*156*	*135*		

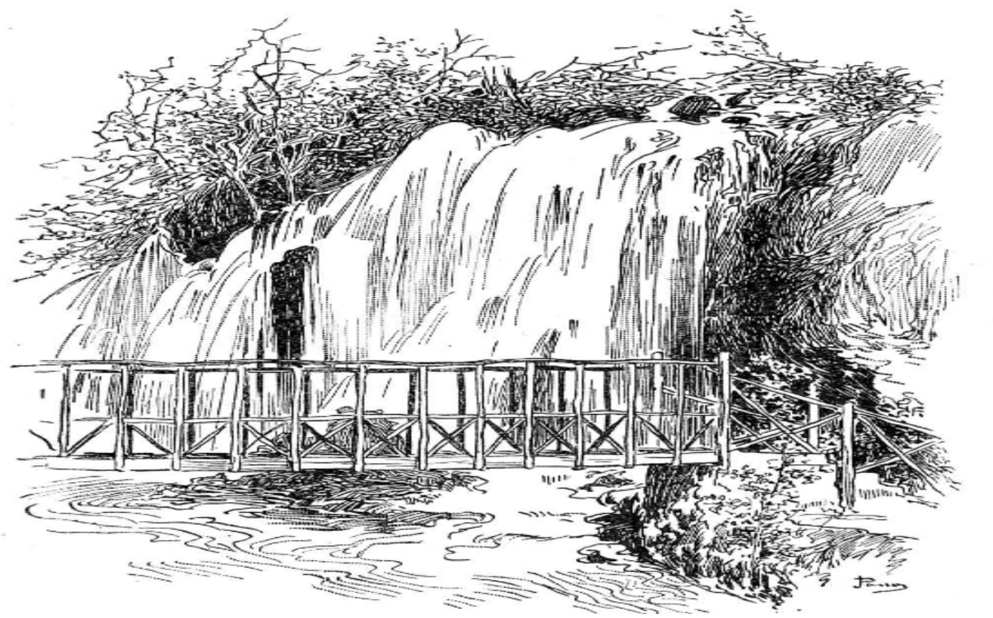
A.1.4 Table 4. Summary of factors that explain adoption of adaptive strategies, with positive (+) or negative (-) coefficients.

Capitals	***Indicators***	***Migration***	***Storage***	***Land use diversification***	***Market exchange***	***Community investment***
Human	Sex	(+)*				
	Age					
	Education					
	Family size					(+)**
Financial	Subsidies					
Natural	Land holdings	(+)***		(+)*	(+)***	(+)***
Physical	Assets			(+)*	(+)*	(+)**
Social	Group participation			(+)**	(+)***	(+)***
Climate	Climate perceptions		(+)**	(+)*		
Vulnerability Context	Experience disaster				(+)**	(+)**
	Market distance			(+)***		
R^2		0.098	0.045	0.142	0.094	0.148
Observations		268	268	268	268	268

**p≤0.10, **p≤0.05, ***p≤0.001*

APPENDIX II

A2.1 A survey example for citizen scientist volunteers.



Name: ___________________________________

Hello,

Colorado State University, with the help of Global Water Watch Mexico, are conducting a study to understand your motivations to participate in monitoring water, knowledge and behaviors about conservation, and your perceptions about payment for ecosystem service programs. Your participation in this survey is completely voluntary, however, we appreciate if you would answer the questions that we pose. There are no direct risks are benefits to you, but this study could provide improvements to some volunteer programs in the region. The information will be used only for research purposes, we will not use your name. The survey should take around 15 minutes.

Do you agree to participate in this survey? 1. Yes (___) 2. No (___)

A. Demographics and Personal Characteristics *(pre-survey only)*

1. How many people live with you in your house, yourself included? _______

    1.1 Of those, how many are less than 15 years old? ___________

    1.2 How old are you? ___________

    1.3 *(Circle one)*

    Man *Woman*

2. What is the highest level of education you've finished? *(Mark one)*

( ) Didn't go to school	( ) Secondary	( ) Technical Career
( ) Primary	( ) High school	( ) Graduate school

3. What is your primary profession? *(Mark one)*

( ) Farmer
( ) Housewife
( ) Machinist
( ) Construction
( ) Business
( ) Transportation
( ) Student
( ) Teacher
( ) Reteired
( ) Other, specify_________

B. Motivations

1. These quesitons are about your motivations to participate as a volunteer. Please indicate on a scale of 1 to 5 your opinion about the following phrases. *(Circle the response in the corresponding space.)*

	Doesn't describe me at all	Doesn't much describe me	Describes me more or less	Describes me pretty well	Describes me perfectly
1.1 You are worried about the impacts humans have on water.	1	2	3	4	5
1.2 You feel like it's a responsibility to conserve the environment.	1	2	3	4	5
1.3 In your opinion, it's the responsibility of the public in general to consider how their actions affect the environment.	1	2	3	4	5
1.4 You like to help others in the community.	1	2	3	4	5
1.5 You like to improve public understanding about water.	1	2	3	4	5
1.6 You don't have an interest in learning about water.	1	2	3	4	5
1.7 You have an interest in learning new things generally.	1	2	3	4	5
1.8 You are interested in learning new techniques for analyzing water.	1	2	3	4	5
1.9 It's not important to you to know more about nature.	1	2	3	4	5
1.10 You would like to learn more about the threats to water.	1	2	3	4	5

1.11 You like to spend time with people who have different interests.	1	2	3	4	5
1.12 You like to spend time on your own the majority of the time.	1	2	3	4	5
1.13 You like to get to know new people.	1	2	3	4	5
1.14 You like to be part of a well-organized team.	1	2	3	4	5
1.15 You like to work independently of an organization.	1	2	3	4	5
1.16 You would like to be part of an organization that values your work.	1	2	3	4	5
1.17 It's better for you to be in the city than in nature.	1	2	3	4	5
1.18 You like to monitor water for quiet reflection time.	1	2	3	4	5
1.19 You like to monitor water to explore the environment.	1	2	3	4	5

1. The last questions were about why you are a water monitor. In your own words, what is the most important reason you participated in this monitoring program? ____

C. Water Knowledge and Awareness

2. These questions are just so that we can understand what changes in knowledge about water you've had, you can simply respond "Don't know" if you do not know the answer.

You think that…	Yes	No	Don't know
3.1 Forests provide the community with clean water.	1	2	0
3.2 Forest procide more sources of water.	1	2	0
3.3 Where there's more forests there is more rain.	1	2	0

3.4 Deforestation causes soils to erode.	1	2	0
3.5 Water supply is sufficient for Xalapa.	1	2	0
3.6 Water supply is sufficient for Coatepec.	1	2	0
3.7 It's better that the rivers are regulated or that they run freely.	Regulate	Run free	0
3.8 Water supply is a problem in your region.	1	2	0
3.9 You know where the source of drinking water is for your house.	1	2	-
3.10 You know where the water treatment plant is.	1	2	-

Please respond to the following questions to the best of your abilities:

3. In your own words, what is a watershed?

   ____

4. What are three things you can do to protect or improve the watershed?
   1. ____
   2. ____
   3. ____

5. How are the limitations of a watershed defined? *(Circle one)*
   a. Politically
   b. The elevation of the surrounding area
   c. Size of the river

6. An example of point source pollution is (*Circle one)*
   a. A drainage tube going directly into the river.
   b. Fertilizers and feces from animals that live around the river.
   c. All the above.

7. An example of diffuse source pollution is (*Circle one)*
   a. A drainage tube going directly into the river.
   b. Fertilizers and feces from animals that live around the river.
   c. All the above.

D. Behaviors related to conservation

8. These questions are related to conservation behaviors you take. Please indicate on a scale of 1 to 5 your level of participation in each activity.

How frequently do you…	Never or almost never	Between every year and every 4 months	Between every 4 months and every month	Between every month and every week	More frequently than every week

9.1 Participate as a volunteer?	1	2	3	4	5
9.2 Write or call politicians about conservation issues?	1	2	3	4	5
9.3 Speak to others like friends or family about conservation?	1	2	3	4	5
9.4 Attend townhalls about conservation?	1	2	3	4	5
9.5 Search for information about water or conservation issues?	1	2	3	4	5
9.6 Write to a newspaper about conservation issues?	1	2	3	4	5
9.7 Write on Facebook about conservation issues?	1	2	3	4	5
9.8 Clean up trash from natural areas like parks?	1	2	3	4	5
9.9 Water plants in the dry season?	1	2	3	4	5
9.10 Save water to use later?	1	2	3	4	5
9.11 Reduce use of water for cleaning or washing?	1	2	3	4	5

E. Perceptions of Payment for Ecosystem Service Programs

9. Do you know about the program Payment for Watershed Services (PWS, the program to conserve forests)?

Yes( ) ***(Continue)***
No ( ) ***(Skip to question 12)***

10. These quesitons are about your perceptions of the program PWS. Please indicate your opinion on a scale of 1 to 5.

In your opinion…	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	Don't know
11.1 PWS reduce forest threats.	1	2	3	4	5	0
11.2 PWS has helped reduced soil erosion.	1	2	3	4	5	0

11.3 PWS has reduced clean water supply.	1	2	3	4	5	0
11.4 PWS benefits you directly.	1	2	3	4	5	0
11.5 PWS benefits others.	1	2	3	4	5	0

F. Perception of saliency

11. Do you know the organizatinos Fidecoagua and SENDAS, that manage the PWS program?

Yes( ) ***(Continue)***

No ( ) ***(Skip to question 14)***

12. These questions are about your perceptions of Fidecoagua and SENDAS. Please respond on a scale of 1 to 5.

In your opinion…	Strongly disagree	Disagree	Neutral	Agree	Strongl y agree	Don't know
13.1 These organizations give important information.	1	2	3	4	5	0
13.2 I would use the information they provide to make decisions.	1	2	3	4	5	0
13.3 They have the goal of benefiting the community.	1	2	3	4	5	0
13.4 Generally, these organizations are trustworthy.	1	2	3	4	5	0

13. These questions are about your perceptions of GWW. Please respond on a scale of 1 to 5.

In your opinion…	Strongly disagree	Disagree	Neutral	Agree	Strongl y agree	Don't know
14.1 GWW has the goal of benefiting the community.	1	2	3	4	5	0
14.2 Generally, GWW is trustworthy.	1	2	3	4	5	0
14.3 You feel like the information they have is trustworthy.	1	2	3	4	5	0

14.4 You would use the information from GWW to make decisions	1	2	3	4	5		0

G. Training for water monitoring

14. Have you monitored water in the last 6 months?

( ) Yes, how many times?___________

( ) No, Why haven't you monitored?____

15. More or less what percent of your data is uploaded on the GWW database?

( ) (75-100%)
( ) (50-75%)
( ) (50%)
( ) (25-50%)
( ) (0-25%)
( ) Don't know/Doesn't apply

16. Please indicate your opinion on a scale of 1 to 5.

In your opinion…	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
17.1 The goals of the monitoring program were clearly explained	1	2	3	4	5
17.2 You are excited to continue monitoring.	1	2	3	4	5
17.3 You plan to continue monitoring for the rest of the month.	1	2	3	4	5
17.4 You plan to continue monitoring for the rest of the year	1	2	3	4	5

17. What are the most important challenges for you in monitoring water? (*Mark all that apply)*

( ) Traveling to the site
( ) Uploading data
( ) Insufficient time
( ) Monitoring isn't fun or interesting
( ) The techniques aren't clear
( ) The organization isn't good.
( ) It's difficult to organize others
( ) Other, ________________________
( ) None

18. In your own words, what are the greatest challenges to monitoring water?

____

____

19. ¿What are the most important benefits that you receive as part of this program? *(Please, choose three of the greatest benefits, putting the numbers 1, 2, and 3, next to your selection)*

( ) Training and capabilities
( ) Understanding more about water
( ) Understanding more about the sciences
( ) New friends and social networks
( ) Making a difference for the communities

( ) Making a difference for the environment

H. INCOME *(pre-survey only)*

21 More or less what is the total monthly income of your household, summing the salaraies of all the members in your house who work? *(Mark one)*

( ) Don't receive income
( ) Less than 1,634MXN
( ) 1,634 to 3,268MXN
( ) 3,269 to 8,170MXN
( ) 8,170 to 16,341MXN
( ) More than 16,341MXN

A.2.2 Table 5. Descriptive statistics of differences between citizen scientist volunteers and the nature-oriented public.

Indicator	*Definition*	*Volunteers Mean (Std Dev)*	*Public Mean (Std Dev)*	*t-test*
Education	% with more than high school education	0.88(0.32)	0.44 (0.50)	6.44***
Age	Years of age	58.14 (15.29)	30.47 (12)	3.30***
Family	# of family members	4.17 (2.31)	3.36 (1.78)	1.87*
Unemployed	% that are unemployed	0.51 (0.51)	0.59 (0.49)	0.81
Children	# of children	0.49 (0.85)	0.7 (0.96)	1.16
Income	% high income (>$3268-$8170 Pesos/month)	0.39 (0.49)	0.31 (0.46)	0.42
Sex	% that are women	0.54 (0.5)	0.48 (0.5)	1.23
Knowledge	Know where their drinking water source is	0.89 (0.32)	0.69 (0.46)	2.62**
Proximity	Minutes walking to nearest body of water	23.42 (33.31)	11.72 (18.14)	1.96*
Volunteer	% that volunteer currently	0.23 (0.43)	0.26 (0.44)	0.38
Environmental volunteer	% that volunteer for an environmental cause	0.20 (0.06)	0.08 (0.02)	1.56*
Social volunteer	% that volunteer for social organization	0.00 (0.00)	0.07 (0.26)	2.53**
Religious volunteer	% that volunteer for the church	0.02 (0.16)	0.10 (0.31)	1.77*
Observations		*35*	*84*	

p-value <0.10, 0.05**, 0.001****

A.2.3 Table 6. Summary statistics of differences in motivations for volunteers and drop outs before the training.

Motivation	*Definition*	*Volunteers Mean (StdDev)*	*Drop Outs Mean (StdDev)*	*t-value*	*p-value*
Responsibility	Feeling responsible for the environment.	4.625 (0.342)	4.553 (0.422)	0.55	0.586
Learning	Desire to learn about nature.	4.875 (0.224)	4.829 (0.264)	0.55	0.586
Social	Desire to spend time with others.	4.094 (0.455)	3.816 (0.785)	1.30	0.202
To be part of something	Desire to be part of something.	4.719 (0.446)	4.553 (0.665)	0.85	0.401
Escape	Desire to escape daily routine in nature	4.313 (0.394)	4.333 (0.628)	0.12	0.906
Observations		*16*	*19*		
p-value <0.10, 0.05**, 0.001****					

A.2.4 Table 7. Summary statistics of differences in motivations for volunteers and drop outs six months after the training.

Motivation	*Definition*	*Volunteers Mean (StdDev)*	*Drop Outs Mean (StdDev)*	*t-value*
Responsibility	Feeling responsible for the environment.	4.617 (0.326)	4.365 (0.565)	1.41
Learning	Desire to learn about nature.	4.833 (0.204)	4.769 (0.239)	0.77
Social	Desire to spend time with others.	3.933 (0.563)	3.500 (0.500)	2.14**
To be part of something	Desire to be part of something.	4.767 (0.320)	4.269 (0.599)	2.68**
Escape	Desire to escape daily routine in nature	4.133 (0.374)	3.821 (0.555)	1.77
Observations		*15*	*13*	
p-value <0.10, 0.05**, 0.001****				

A.2.5 Table 8. Results from the logistic regression for predictors of retention.

Themes	*Variables*	*Likelihood estimates (standard error)*
Demographics	1. Age	0.062 (0.291)*
Motivations	2. Social	0.463 (0.643)
	3. To be part of something	0.519 (0.738)
Observations		*33*
R^2		*0.1897*
p-value 0.05, 0.01**, <0.001****		

APPENDIX III

A.3.1 Table 9. Interview guide.

Theme	Corresponding Questions and Prompts
Experiences	Could you tell me a little about your experience working in the environmental field, had you had any experience before the training?
	Can you explain to me how you heard about the training and why you decided to enroll?
	Could you tell me a little about your experience with the citizen science training? What did you think about it?
	Could you tell me a little about your experience working as a citizen scientist with Global Water Watch, Mexico?
Attitudes	The goal of this research is to inform a conservation program in the region, Payment for Hydrologic Services (PHS). Have you heard of it?
	What is your experience with PHS?
	What do you think about the functionality of PHS?
Behaviors	Do you believe your behaviors make a difference for the environment? If so how?
	Since the training, have you noticed any changes in your behaviors? If so, what kinds of changes have you noticed?

A.3.2 Table 10. Summary statistics of differences before and 2 weeks after the training.

Theme	**Parameter**	**Before the training Mean (SD)**	**2 wks. after training Mean (SD)**	**t-value**
General knowledge	Know that deforestation reduces water flow	1.00 (0)	1.00 (0)	-
	Know where there are forests there is more rain	1.00 (0)	1.00 (0)	-
	Know forests provide clean water	1.00 (0)	1.00 (0)	-
	Know forests provide more water downstream	0.97 (0.18)	1.00 (0)	1.00
	Know location of drinking water sources	0.54 (0.51)	0.81 (0.39)	3.75***
	Know location of water treatment plant	0.54 (0.51)	0.68 (0.48)	1.68*
	Comprehensive content knowledge score	*0.83 (0.14)*	*0.91 (0.12)*	3.86***
	Aware of need for regulations for rivers	0.50 (0.51)	0.19 (0.39)	2.29**
	Aware of PHS	0.31 (0.47)	0.72 (0.45)	4.56***
	Aware of river flows problems in the region	0.47 (0.51)	0.59 (0.50)	0.44
	Aware there is insufficient water in Coatepec	0.88 (0.42)	0.70 (0.47)	1.00
	Aware there is insufficient water in Xalapa	0.89 (0.33)	0.90 (0.31)	-
	Comprehensive awareness score	*0.34 (0.22)*	*0.39 (0.17)*	*0.87*
Attitudes	PHS reduces threats to forests	3.57 (1.27)	3.68 (0.82)	0.31
	PHS improves water supply	4.22 (0.66)	4.29 (0.62)	0.32
	PHS reduces soil erosion	4.00 (0.58)	3.77 (0.68)	-1.00
	PHS benefits me	4.70 (0.48)	4.04 (0.75)	-0.51
	PHS benefits others	4.11 (1.05)	4.41 (0.65)	0.00
	Comprehensive attitudes score	*4.15 (0.56)*	*4.06 (0.49)*	*-0.06*
Behaviors	Volunteers for an environmental cause	2.03 (1.48)	2.16 (1.25)	0.18
	Writes politician on environmental issues	1.43 (0.94)	1.47 (1.14)	0.00
	Attends townhall meetings on environmental issues	1.57 (1.31)	1.63 (0.98)	0.00

	Looks up information on environmental issues	3.74 (1.11)	3.76 (1.18)	-0.32
	Talks with others about environmental issues	4.22 (1.40)	3.84 (1.14)	2.09**
	Cleans up trash locally	2.77 (1.48)	2.69 (1.12)	0.73
	Saves water for later use	4.57 (0.85)	4.63 (0.75)	0.00
	Reduces time using water bathing	4.57 (0.81)	4.41 (0.98)	1.23
Observations		*35*	*32*	
*p-value *<0.10, **<0.05, ***<0.01*				

A.3.3 Table 11. Attitudes towards payment for watershed service programs

Group	Positive (e.g., shows promise)	Neutral (e.g. limited extent in payments and reach)	Negative (e.g. unfair, unstable funding)
Interv-ention	What is working is that there are still trees, maybe not the quality or quantity there should be, but they are *there*.	There needs to be much more dissemination, so that people know more, that they see the possibility that they can go and engage in PHS.	
	I think it's a good initiative… That if a landowner wants to conserve and realizes that it could be a great benefit, well it helps.	But maybe the sums that they receive aren't very large.	
	I think it's a good initiative, it is necessary to have these types of incentives. It functions in rural areas where there is much need, and a need to protect the space they live.	But I think the program's reach is still very limited in two senses: there isn't very much dissemination of the program, and it can't compete with other productive sectors.	
	I think it's a good support for people who take care of this natural resource.	The benefit doesn't go to many - there are people who may have land but still don't receive this benefit because they don't know about it. PHS still doesn't help everyone conserving.	
Control	I get this benefit, [PHS], in my receipt and I pay it happily because I trust that it is moving in the right direction… It's a way to make people aware.	I do think it functions, but maybe not at the moment, maybe that will happen further ahead.	Sadly, when there is a change in government, everyone brings their own ideas. As other ideas arrive the [PHS] programs decrease.
		I like the objective the PHS has, but the payments are small. Maybe it's better than nothing, but it isn't a great economic incentive.	
		It's a question to see whether the payments really go where they should. I hope so.	
			The payments are given to landowners that have larger properties. So PHS is still a little unfair.