Social and Ecological Interactions in the Galapagos Islands

Amanda L. Thompson
Valeria Ochoa-Herrera
Enrique Teran *Editors*

Water, Food and Human Health in the Galapagos, Ecuador

"A Little World Within Itself"

Springer

Social and Ecological Interactions in the Galapagos Islands

The Galapagos Islands are a “living laboratory” for the study of evolution, environmental change, and conflicts between nature and society. Free of human predators for almost all its history, these islands have developed some of the most unique life forms on the planet, adapted to their harsh surroundings and living in ecological isolation. It was not until Charles Darwin’s famous visit in 1835, which helped inspire the theory of evolution that this Archipelago began to receive international recognition. The Galapagos Archipelago encompasses 11 large and 200 small islands totaling approximately 8,010 sq. km. This series will focus on the entire island archipelago, and it will emphasize the study and documentation of human-environment interactions on the four inhabited islands in the Galapagos: Isabela, Santa Cruz, San Cristobal, and Floreana. Together they constitute a well-defined “natural laboratory” for the study of human-environment interactions as they vary in fundamentally important ways.

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Cover illustration: The image shows the deck of a barge delivering supplies to San Cristobal, Galapagos. Beth N.H. Katz, 2011

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Preface

Tourism and migration have ignited economic growth, environmental change, and urban development on the Galapagos Islands. While much research has examined the impact of population and economic growth on the health and biodiversity of the islands' plants and animals, the impacts on human health and well-being have not received as much widespread attention. Yet, these social and economic changes have transformed human health, nutrition, and well-being on the islands as well. The geographic isolation of the islands impacts the quantity and quality of available food, the range of healthcare services available, and the mental health and well-being of island residents. In addition, climate change and the current COVID-19 pandemic are important challenges that the population of the Galapagos islands are facing and could have a major impact on the health and economy of the islands in the short and long term. Therefore, the development and implementation of adaptative measures together with improved infrastructure are essential to assure the sustainability of this fragile ecosystem. As Charles Darwin in his book *Origin of Species* offered a compelling answer to the outstanding question of biology, which was "how life on earth had evolved," the ultimate goal of this book is to put in perspective the human health-related topics that can be addressed in the Galapagos Archipelago and to inspire further analysis.

In this book, we bring together interdisciplinary scholars and clinicians in medicine, public health, anthropology, nutrition, environmental sciences and engineering, and geography from several institutions in different countries, all doing research in the Galapagos Archipelago. Together, these authors provide a comprehensive description of the factors shaping water quality, food availability, and health services on the islands, the interactions between human health and the health of animals and the environment, the implications of these factors for human health and well-being, and potential avenues for intervention.

The volume has four key parts and several chapters within each: Part I, "The Water Environment", has chapters that include water security and supply, water quality and access, climate change and its impacts, and the current COVID-19 pandemic. Part II, "The Food Environment", includes chapters on how water and food insecurity impact the dual burden of diseases, how poor diet quality and processed

food consumption contribute to overweight and obesity, and how the spatial distribution of food resources may shape household decision making around diet. Part III, “The Environment, Animals and Human Health”, includes several chapters on One Health, which links humans, animals, and the environment, the “Galapagos Paradox,” antibiotic resistance among humans and animals, and how human development may compromise wildlife and the environment. Part IV, “Health Problems and Services”, includes a chapter on the first 1000 days of life (pregnancy through the infant's second birthday); how Galapagos may be a unique setting for HIV/STI infections, based on island networks and tourism; a chapter that explores the “lived experience” of residents who experience type 2 diabetes; a chapter on health-seeking behavior to understand the underutilization of the new hospital and its services; and another on how academia and the Ministry of Health worked together through professional development of hospital staff and the engagement of the community to improve health services.

Finally, we would like to thank the many people who have made human health research and this volume possible. In particular, we would like to thank Steve Walsh and Carlos Mena for their continued support throughout this project. We also thank the faculty and staff of the Galapagos Science Center, the Center for Galapagos Studies, GAIAS, all the volunteers for their contributions to field work in the Galapagos, and to the research assistants for their support in the different laboratories. Most importantly, we would like to thank the local authorities and the residents of the Galapagos Islands for their participation.

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Chapter 1
Introduction

Margaret E. Bentley and Jaime Ocampo

Abstract While much research has examined the impact of population and economic growth on the health and biodiversity of the islands' plants and animals over several decades, the impacts on human health and well-being have not received as much widespread attention. Social and economic changes have transformed the environment of the islands with important consequences for human health and well-being. As this chapter describes, population growth, tourism, and limited infrastructure pose health challenges for island residents, who experience high levels of chronic and infectious illnesses. The geographic isolation of the islands also places constraints on the health services available. This chapter provides an overview of human health research on the islands, a discussion of the history of the health system, and a description of current collaborative initiatives to improve human health. This overview highlights the need for interdisciplinary research teams to work alongside community members to identify programs and policies that can help to improve human well-being while preserving this unique and important world heritage site.

Keywords Health services · Human population · Health · Tourism · Dual burden of disease

This volume on human health in the Galapagos Islands reflects the evolution of more than 10 years of research in the archipelago. While several publications are

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already in the literature on this topic by some of the authors in this volume, the book represents new research completed in the last few years across a broad set of topics related to water, food, and human health. The authors are faculty, students, and staff from the University of North Carolina at Chapel Hill and the Universidad San Francisco de Quito, and authors from other universities and staff and the hospital on San Cristobal and the Ministry of Health. These two universities have been collaborating as part of the UNC-USFQ Galapagos Science Center (GSC), on the island of San Cristobal, which was dedicated in 2011 with its own research building, consisting of research offices, laboratories, and educational rooms. The mission of the GSC is to *improve the scientific understanding of the social, terrestrial, and marine sub-systems of the Galapagos; to understand the linkages between the population of the archipelago, its health, and the environment; and to focus on the competing challenges of conservation and economic development.* The GSC is situated right next to USFQ's international training and educational school (a satellite campus of USFQ), the Galapagos Academic Institute for the Arts and Sciences (GAIAS). Students and faculty from the two universities and around the world participate in research related to population, health, and the environment, and several short-term and study abroad opportunities exist for the students and faculty.

The Galapagos, consisting of 14 islands, is a part of Ecuador, located nearly 1000 km off the coast of the mainland. One may see this book title and ask, "Why Galapagos? Do people live there?" Indeed, one of the first studies on human health, published as part of the first book in the Springer series, was titled "People live here: Maternal and Child Health on Isla Isabela, Galapagos" (Page et al. 2013). The UNC authors who led this small study were asked this question repeatedly, hence the title of their chapter.

So, what do people think about when they think of the Galapagos? Why, Charles Darwin of course. This is where he stepped off the ship HMS Beagle in 1835 and whose collections of flora and fauna led to the theory of evolution, which was published in 1851 (Barlow 1935). The islands were then a stopping point for pirates and other sailing ships, such as whaling ships, nearly decimating the highland tortoises and Galapagos sea turtles, because they could be turned on their backs and would survive for months and provide a food source for the sailors (Bassett 2009). Many other species were left to evolve as distinct species without human settlements or disruption, except by changes in climate and the warming and cooling temperatures of the Pacific Ocean surrounding the archipelago.

A small influx of migrants began settling on small farms and establishing a fisheries industry in the late 1800s, coming primarily from Scandinavia and Europe (Quiroga 2013). With them they brought animals for husbandry, such as goats and cattle, and the promise of prosperity. Soon, blackberry bushes and guava trees were planted, and these and others became invasive species that still threaten the environment and survival of some of the native species.

The four habitable and populated islands are Isabela, at the westernmost part of the archipelago; Santa Cruz, where the population is currently by far the largest; San Cristobal, the government seat and easternmost island; and Floreana, with a very small population but a dramatic history (Instituto Nacional de Estadistica y Censos 2015). Satellite imagery of the most populated island, Santa Cruz, tells the story

over the last five decades (Pizzitutti et al. 2020). In 1974, the resident population on Santa Cruz was 1577, which grew to 11,000 in 2007. In 2018, there were more than 28,000 residents in the Galapagos, living on the four populated islands, primarily along the coasts but also in the highlands (Instituto Nacional de Estadistica y Censos 2015). Although tourists with private boats and yachts occasionally stopped in the Galapagos over the decades, tourism did not begin in earnest until the 1980s. Residents migrated primarily from coastal and highland Ecuador to work in the tourism industry, where livelihoods are better than the mainland. Tourism has supplanted fishing as a major driver of population growth and the economy (Hoyman and McCall 2013). The government of Ecuador and the Galapagos National Park do restrict migration and tourism; more than 97% of the island is protected by the Galapagos National Park, and tourists are not free to roam anywhere and they must have certified guides (Wolford et al. 2013). However, tension between conservation and economic development remains one of the most political and challenging issues facing preservation of the archipelago.

In 2015, more than 225,000 national and international tourists visited the islands, primarily arriving by air from the mainland to the most populated island, Santa Cruz, and, to a lesser extent, a smaller airport on San Cristobal Island (Izurieta 2015). The majority cruise around on small and medium boats and yachts and on large cruise ships, while others stay in small hotels. This influx of tourists places great pressure on the islands to meet the needs of both residents and visitors. With the population of the Galapagos nearly quadrupling in the past decade and the exponential growth of tourism, there is a substantial strain on available water and food resources (Hoyman and McCall 2013). Water and sanitation services have not been able to keep up with the demands placed on the system by expanding urban development and the tourism industry. Island residents are concerned about the quality of municipal water and often resort to buying expensive bottled water for drinking and cooking (Page et al. 2013). Food availability, particularly the availability of fresh foods, is also a critical issue. The designation of most of the island as parkland limits the amount of food that can be grown in the highlands, leaving residents and visitors dependent on food shipped from the mainland by sea and, to a lesser extent, air. The distance of the islands from the mainland means that produce arriving by barge is not fresh (Page et al. 2013; Pera et al. 2019). Residents tend to rely on more heavily processed foods, which are also viewed as less expensive. This combination of exposure to environmental pathogens through unclean water and high-energy, high-fat diets contributes to a dual burden of disease on the islands, with infections persisting alongside micronutrient deficiency and overweight and obesity rates among children and adults that are the highest in Ecuador (Freire et al. 2018; Thompson et al. 2019). Accompanying these are noncommunicable diseases (NCDs), such as diabetes, cardiovascular disease (CVD), and hypertension. Reproductive health issues are also a major concern, with gynecological infections, and requirements for adequate and timely antenatal, birth, delivery, and postpartum care (Page et al. 2013). Prior research by the team has documented substantial rates of anxiety, stress, and depression, particularly among women, who experience isolation living

far from the mainland (Page et al. 2013). A substantial proportion of women also experience domestic violence often related to alcohol abuse, particularly among males.

What is the history and current situation of the health system and services on the islands, in light of these known health issues?

Historically, since Galapagos was inhabited by national and international settlers, the region's medical system has not been constant nor has it been of good quality, which has put the population's well-being at risk, especially that of children and pregnant women. The prevalence of diseases such as upper respiratory and intestinal infections and influenza, among others, is similar to that in continental Ecuador. However, throughout the Galapagos Archipielago, as noted above, there is a high prevalence of metabolic syndrome and its consequences such as overweight, hypertension, diabetes, and cardiovascular diseases.

The Ministry of Health has been in the Galapagos since the 1960s implementing medical units for ambulatory care. At the beginning of the 1970s, in cooperation between the Ministry of Health and an order of priests, the Oskar Jandl Hospital was founded on San Cristobal Island. The physical structure of the hospital was always deficient with scarce or null technology, medicines and medical supplies, and very limited quality care from doctors. The medical professionals and nurses were mostly general practitioners, young professionals with very little experience and no specialty. Specialists, such as pediatricians or gynecologists, visited the islands a few times a month. These many limitations encouraged residents to incur high expenses and travel the mainland to seek medical help. Private medicine, although it exists in the islands, is very limited due to lack of supplies.

In the past 10 years, a new hospital was constructed on San Cristobal, and it has improved with new technology, some permanent specialists, permanent emergency care, and better trained doctors. Despite these improvements, some of the population are reluctant to use the hospital's services due to a lack of trust of Cuban doctors, who were hired by the Ministry of Health. In 2014, a cooperation agreement was signed between Oskar Jandl Hospital, Universidad San Francisco de Quito, and the University of North Carolina at Chapel Hill to complement the medical activities that nurses and physicians perform daily. The cooperation agreement has three parts:

Training: This part of the agreement supposed that both universities are able to develop training plans in professional aspect that doctors and nurses from the hospital need to improve. For example, since 2014, the UNC School of Nursing has sent a group of nursing faculty and advanced graduate students fluent in Spanish each summer to cooperate with local nurses for developing protocols in the emergency room, hospitalization, and pediatric intensive care units. In addition, there are training resources for hospital administrators in leadership and hospital and financial management.

Telemedicine: This section of the agreement is directed to develop a "second opinions" model in different specialties that do not exist in the island. For example, dermatologists, radiologists, cardiologists, and gastroenterologists from the USFQ Medical System advise local doctors in how to handle some diseases and conditions. During the time of the cooperation with the hospital, more than 400 cases were discussed between physicians of both institutions through telemedicine.

Research: This section of the agreement is to increase knowledge of important determinants of health in the islands, for the purpose of addressing community health needs. For example, researchers for both universities and local professionals from the hospital investigate the supply, quality, and access to water. In addition, studies about nutrition and breastfeeding have been performed as described in this volume.

1.1 Conclusion

While much research has examined the impact of population and economic growth on the health and biodiversity of the islands' plants and animals over several decades, the impacts on human health and well-being have not received as much widespread attention. Yet, these social and economic changes have transformed the environment, human health, nutrition, and well-being on the islands as well. The geographic isolation of the islands impacts the range of health care services available. While the islands are served by two hospitals, a small one on Santa Cruz and a larger, more modern hospital on San Cristobal, residents continue to worry about the lack of specialists to manage health emergencies or ongoing chronic conditions. Residents report spending considerable amounts of money to travel to the mainland for health care. The sense of isolation also impacts mental health and well-being. Mothers of young children often suffer from depressive symptoms, and substance abuse is also relatively common among men. Despite these considerable challenges, the majority of residents perceive their quality of life on the islands to be fair to good. Economic development and tourism have brought about a standard of living and education higher than that on the mainland. Rates of unemployment are low and literacy high.

It is clear that the Galapagos Islands *are* a "little world within itself" and are a perfect laboratory for research on human health and the environment – and how their interrelationships affect outcomes. This research is well underway, and we hope this volume and the publications that came before it will generate interest in future research. This should include interdisciplinary teams for implementing intervention research that will lead to community engagement and programs and policy that can help to preserve this unique and important world heritage site.

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Part I
Water Environment

Chapter 2
Analysis of Water Supply and Demand Management Strategies in Overcoming Water Scarcity in Santa Cruz

Maria Fernandes Reyes

Abstract Water resources in the Galapagos Islands have been severely strained by exponential increase in tourist visitors. Santa Cruz Island, the main tourism hub in the Galapagos, is facing significant challenges of too many people and not enough available water. There are no permanent freshwater resources on this island, and the municipal water supply system provides only (untreated) brackish water, intermittently.

In view of the scarce data found on water demand, this study involved extensive fieldwork with the aim of generating water-consumption figures from different types of premises (common households, hotels, restaurants and laundries), in order to assess current water demand. Several methodologies were used including 400 surveys and the installation of water meters, aiming to quantify water figures. The study quantified water demand from different categories and sources of water using several methodologies as means to create mitigation options regarding the fragility of the ecosystem.

Results indicated that domestic water demand varies between 163 and 428 litres per capita per day (lpcpd), which is extremely high for such a water-scarce island. Also, total water supply, without taking into account any losses, suggests around 350 lpcpd, which is also a high figure considering water scarcity threats in Santa Cruz Island. The results also suggest the that the presence of non-registered tourist accommodations or excessive water wastage from domestic premises is presenting a significant issue in the total water balance, leaving some premises without water.

This study provides scientific insights for the improvement of water resources management and further contributes for the creation of effective policies to preserve these resources.

Keywords Water demand · Water consumption · Water resource management · Tropical insular environment · Tourism

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2.1 The Island of Santa Cruz

Santa Cruz is the main island (economic and tourism centre) of the archipelago and has a surface area of 985 km^2. Brackish water is supplied by the municipality of Santa Cruz to the settlements, where the technical capacities continue to be limited. The biggest town is Puerto Ayora, located on the south coast, followed by the village of Bellavista, located at 180 m of elevation and 7 kms inland (GADMSC 2012a). Puerto Ayora has approximately 12,000 inhabitants (INEC, 2010), holding 61.3% of the total population of the archipelago, and Bellavista has a rural population of approximately 2500 inhabitants. Over the past 10 years, the rate of development in the highlands has been very high.

The population density in Puerto Ayora is the highest in the archipelago, with approximately 80 inhabitants per km^2 (INEC 2010). On the other hand, Bellavista is practically a suburb of Puerto Ayora, and it is a popular part of the island characterized by private properties distinguished by tranquillity and silence. Currently, there are new developments taking place further than Bellavista which cause additional problems, as the public network does not reach there yet.

The main driver for the significant increase in population (from the mainland) over the last years has been to support the tourism industry and to generate income. Consequently, there has been a noteworthy increase in the number of travel agencies, restaurants, hotels, bars, etc., stressing the water resources and environment in general (GADMSC 2012b). The growth in the local population and tourism in Santa Cruz has increased the demand for basic services, such as water supply without concurrent ways to cover the costs of these services, overwhelming the municipalities and so resulting in deficient services and untrained staff (Guyot-Tephiane et al. 2012).

Because of this exponential increase, low-cost hotels have also increased significantly, as well as the number of backpackers. This has also boosted the creation of small private accommodations with no environmental consideration. In addition, more restaurants (also informal) have started, as well as the number of local tourist agencies, offering day tours of occasionally questionable quality. The problem of tourism is further enhanced by the lack of monitoring by the Ministry of Tourism (MINTUR). Consequently, the lack of control and regulation boosts these illegal accommodations. According to the MINTUR, as of December 2013, there were 106 unregistered accommodations out of a total of 159 (Reyes et al. 2017a, b). Moreover, according to the Department of Potable Water and Sewage (DPWS), there are only 40 service connections belonging to the category of hotels (Sarango 2013).

Similarly, the number of laundries has grown as well. However, in the land cadastre of Santa Cruz, there are no premises categorized as laundries, while according to the DPWS, there are only five service connections of this category. An update of the land cadastre is lacking and stricter control over this type of premises regarding operating licenses. It is commonly known that laundries are a profitable business.

The main source of supply in Santa Cruz, which is extracted from the basal aquifer, is non-potable due to high concentration of chlorides (800–1200 mg/L) and is

further distributed without any prior treatment (d'Ozouville and Merlen 2007). In addition, the water is also contaminated with *Escherichia coli*, due to the lack of sewerage system (d'Ozouville et al. 2008). Wastewater is mainly disposed into septic tanks, which are installed individually by each household. It has been identified that most of these septic tanks are not constructed technically, resulting in infiltration to the water sources (Liu and d'Ozouville 2013).

As a consequence of uncontrolled urban growth, the local government councils are blocked of providing a permanent and optimal service to the local population. Furthermore, the water supply is intermittent and rationed, with an average supply of 2–3 h per day (Reyes et al. 2016), which has influenced inhabitants to build their own water storage in the form of cisterns and elevated tanks. Also, there is an excessive water loss in Puerto Ayora, which is caused by aging pipes and lack of maintenance along the distribution system. This problem has further worsened by the lack of water meters in the town of Puerto Ayora, which results in excessive water wastage within the households. This is also a consequence of the lack of water-saving practices or specific policies promoting water conservation in this fragile ecosystem. In addition, there are also financial constraints that contribute to the difficulties faced by the municipality to improve the water service.

On top of this, the lack of communication among different entities and unclear distribution of responsibilities within the institutions regarding water management contribute to the situation (Reyes et al. 2016). Lastly, there is a significant absence of data and information, causing difficulties in the assessment of the current situation and the future planning for the improvement of the water scarcity.

2.2 Quantification of Water Demand

The data for this study were collected from a survey carried out to 374 households in Puerto Ayora and Bellavista. This section reveals the daily average water demand per capita and how it differs between the two settlements, as well as the impact resulting from difference in the water tariff structures. Also, it analyses the type of consumer in the tourist category and how much it accounts of the total water demand within the island.

2.2.1 Research Methodology

In order to assess the water demand in Santa Cruz, a quantitative survey was carried out during the fieldwork conducted from November 2013 to January 2014 in Puerto Ayora and Bellavista. The minimum sample size was calculated based on the total number of land properties according to the 2012 cadastre from the municipality of Santa Cruz. With a total of 2460 properties in Puerto Ayora and 435 properties in Bellavista, the minimum sample size was calculated at 339, by applying the

confidence interval of 95% (DeVault 2014). Next, the actual sample size per consumption category was determined. The surveys were carried out during a period of 6 weeks.

The final version of the domestic survey contained five main parts: (i) general information about the location, (ii) family habits, (iii) water demand (bottled, municipal and/or from trucks), (iv) water-saving practices and (v) sanitation practices.

The surveys for other demand categories were less detailed and contained four groups of questions: (i) general information, (ii) average capacity of customers, (iii) water demand quantification regarding different type of sources and (iv) environmental awareness.

2.2.2 Analyses of Results in Puerto Ayora and Bellavista

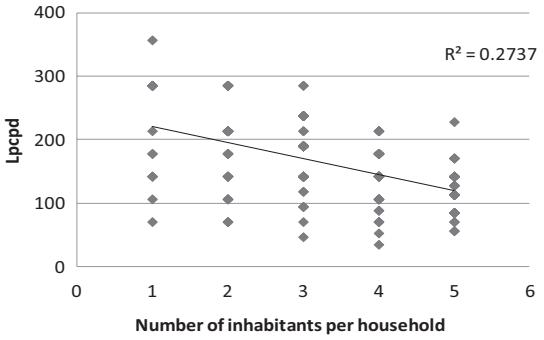
2.2.2.1 The Domestic Category

The results of the survey show several similarities and differences between the two settlements. Firstly, the percentage of connections to the municipal service is higher in Puerto Ayora (91%) than in Bellavista (81%), which could be attributed to the faster growth in the number of households in Bellavista and the consequent inability of the municipality to cope with it. The average annual increase of connections from 2005 to 2013 was approximately 9% in Bellavista, while in Puerto Ayora, it was only 2%. Furthermore, the frequency of service is worse in Bellavista, which differs from the information provided by the municipality, which claims that water is supplied every day.

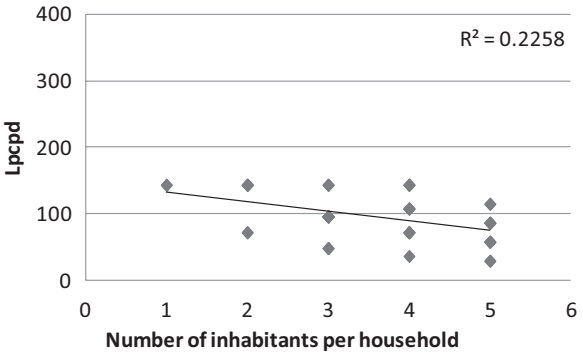
Using the capacity of household storage units (tanks or cisterns), the reported frequency of filling these and the number of users per household, an attempt was made to estimate the total water demand from the municipal supply system, as well as the specific demand per capita. This is shown in Fig. 2.1a for Puerto Ayora and in Fig. 2.2b for Bellavista.

From Fig. 2.1, it can be seen that larger households tend to have lower demand per capita. This can be explained by the fact that the water consumption for general activities like watering gardens, cleaning common areas and cooking is independent of the number of occupants. Furthermore, the figures for Puerto Ayora show a wider range of demand for the same number of inhabitants, suggesting diverse water use, probably due to different living standards and/or habits than in Bellavista. The average specific demand and standard deviation for Puerto Ayora is 163 ± 80 lpcpd and in Bellavista is 96 ± 34 lpcpd. This average differs significantly between the two settlements, probably due to different water tariff structures.

Puerto Ayora has fixed water fees per month for different categories established by the municipality. On the other hand, Bellavista has a metered system, with a consumption-based tariff structure (USD 1.21/m^3). As a consequence, the population in Bellavista tends to consume less than in Puerto Ayora. However, they



(a)



(b)

Fig. 2.1 Municipal water demand per capita and number of inhabitants per household in (**a**) Puerto Ayora and (**b**) Bellavista

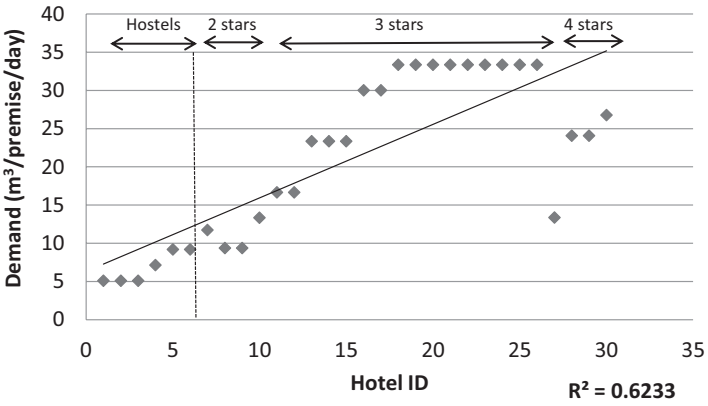


Fig. 2.2 Demand per surveyed hotel regarding rating

supplement their demand with rainwater, increasing the total water demand per capita. In Bellavista, customers are more aware of the value of water, unlike in Puerto Ayora, where higher wastage of water is evident with spilling of tanks. The fixed monthly fees in Puerto Ayora seem to be the main reason for such behaviour. According to the municipality, the biggest losses occur at the moment of filling household storage when faucets are not closed when tanks are full, resulting in significant overflow of water. It was observed during the fieldwork that these overflowing tanks were left unattended for more than half an hour in some cases. Lack of metering and low tariffs in Puerto Ayora appear to encourage the population to waste water. However, some households have shown to use much lower quantities of water than the others, for the same number of occupants, which in broader terms reflects different styles of living and/or habits. The high standard deviation on both settlements suggests that locals use water randomly per household, and there is no obvious tendency regarding social stratum or number of occupants, or the neighbourhood.

A high percentage of responses in Puerto Ayora (32%) identified leaks within their households. Unfortunately, these leaks are rarely fixed, probably due to the fact that the water lost is not charged to the consumer. On the other hand, the leaks within premises in Bellavista are much lower (reported in 15% of responses), meaning that the tariff structure influences the decision to fix them. The majority of leaks were reported to be in old and inefficient toilets, suggesting high losses since toilets account for major water use in a household of nearly 30% of total water consumption (EPA 2012). Finally, the less frequent spilling of individual tanks in Bellavista confirms overall higher awareness of the customers, which can be also explained by the difference in water tariff.

2.2.2.2 Total Demand Quantification for Domestic Sector

The quantification of domestic water demand was done for all types of sources used. This was possible based on the questions regarding the frequency of service/purchase and volumes of the different sources for every household. The results are shown in Table 2.1 with total demand per capita calculated for both settlements.

Table 2.1 Water demand per different sources of water in Santa Cruz

Settlement	Municipal supply (m^3/year)	Bottled water (m^3/year)	Water trucks[a] (m^3/year)	Rainwater[b] (m^3/year)	Total demand (m^3/year)	Approximate population[c] (no. of inhabitants)	Specific demand (lpcpd)
Puerto Ayora	712,188	7243	57,518	N/A*	776,949	12,000	177
Bellavista	82,481	2683	48,307	97,444	30,914	2500	253
Total	794,669	9925	105,825	97,444	1,007,863	15,000	190

Note: [a]Water from trucks refers to partial pumping from 'private' crevices. [b]Rainwater was not considered in Puerto Ayora for it is practised by less than 10% of surveyed households. [c]Based on the last national census carried out in 2010

Table 2.1 indicates relatively high specific demand in view of the widespread intermittency and scarce water sources. The public perception in both settlements is clearly that additional water next to that supplied by the municipality is necessary. Nevertheless, rainwater is barely collected in Puerto Ayora. One reason is lower precipitation levels than in Bellavista, but also that this practice is considered archaic (Guyot-Tephiane et al. 2012). Oppositely, people in Bellavista collect rainwater regularly and use it for all types of household activities. Furthermore, in both settlements, the bottled-desalinated water is used mainly for drinking and for personal hygiene, while brackish groundwater is used for other domestic activities such as cooking, dish washing, laundry, toilet flushing and showers.

Moreover, the supply by water trucks has high contribution to the high total demand in Bellavista, which could be explained by lower number of municipal service connections. In summary, the average per capita consumption is considerably higher in Bellavista than in Puerto Ayora. It is however to be noted that all the results are based on the personal assessments of the respondents; this certainly needs to be verified by more accurate measurements.

2.2.2.3 Analysis of Tourist and Laundry Category

The total demand was also assessed for tourist facilities in Puerto Ayora: private apartments, hotels and restaurants as shown in Table 2.2. The figures have been derived based on the survey questions regarding the volume of storage facilities and the frequency of refilling of storage tanks, as well as the amount of bottled-desalinated water and water supplied by trucks.

Figure 2.2 shows the daily demand of surveyed hotels; the horizontal axis represents each hotel, given by a serial number. For example, from 1 to 6 are hostels with capacity of 25 to 45 people to be accomodated per day, from 7 to 9 are two-star hotels with capacity of 20 to 25 people, from 10 to 26 are three-star hotels with

Table 2.2 Water demand quantification for hotels and restaurants in Puerto Ayora

Type of accommodation	Average capacity (customers)	Municipal water (m^3/day)	Water trucks (m^3/day)	Bottled water (m^3/day)	Specific demand (lpcpd)
Hostel	40	8.1	0	0	205
2-star hotel	35	4.0	12.3	0.1	470
3-star hotel	45	6.0	29.7	0.3	667
4-star hotel	35	9.6	9.0	0.1	535
Average	**38**	**7.0**	**11.3**	**0.1**	**469**
Restaurants	15	0.2	0.9	0.1	126
	25	0.5	1.7	0.1	158
	45	0.4	0.9	0.2	46
	50	0.4	1.8	0.3	79
Average	**34**	**0.4**	**1.3**	**0.2**	**102**

capacity of 10 to 50 people and from 26 to 30 are four-star hotels with capacity of 25 to 50 people. The water demand varies according to the type of accommodation (hotel rating) and the average capacity.

The majority of the hotels and restaurants are connected to the municipal supply, but some hotels (mainly three stars) and virtually all restaurants are mainly supplied by water trucks. The four-star hotels mostly have their own purification systems (by desalination) and are less dependent on the municipal supply, using it less than lower class tourist accommodations do. Moreover, three-star accommodations use more water because of higher occupancy. In Galápagos, the tendency is towards middle-class tourists, therefore, those who cannot afford luxurious accommodations at average rate of 350 USD/night (which seem to be more careful with water use).

The average water demand per bed, estimated by the survey respondents, was 168 lpcpd, which is far from reality, since the calculated average is 469 lpcpd, i.e. almost three times higher. Furthermore, in 10 out of 30 restaurants, the water demand estimate was approximately 0.5 m^3 per day.

Finally, the total water demand for Puerto Ayora was calculated based on the average consumption derived from the survey, multiplied by the total number of premises per category according to the land cadastre of the municipality. Table 2.3 shows the highest demand from the hotels for municipal water and from trucks. Approximately 24% of total demand of municipal water is from unregistered accommodations, which account for 66% of the total in the category of hotels. As in many other tropical islands, the biggest consumers are tourist accommodations, proportionally to the ranking of the hotel. The restaurants and laundries do not contribute significantly to the total demand in Santa Cruz, although the total number of registered restaurants and laundry premises in the land cadastre may be higher than reported.

Table 2.3 Total water demand quantification considering all categories

Category	Municipal supply (m^3/day)	Bottled water (m^3/day)	Water trucks[a] (m^3/day)	Total demand (m^3/day)
Domestic	1951.2	19.8	157.6	2128.6
Hotels	1107.2	20.6	1788.8	2916.6
Restaurants	69.3	7.6	51.1	128.0
Laundries	28.5	0	20.1	48.6
Total	3156.2	48.0	2017.6	5221.8

Note: [a]Water trucks refers to pumping from ‘private’ crevices

2.3 Assessment of Domestic Consumption in Puerto Ayora's Intermittent Supply Network

The intermittent water supply system, which is caused mainly by the lack of proper management and by sensitive political issues (Reyes et al. 2016), promotes a perception that the system is unreliable. The previous sections suggested the average total municipal water demand ranges from 40 lpcpd to 380 lpcpd. The possible subjectivity and uncertainty of some of the responses in the surveys from Sect. 2.2, pointing the extreme ranges of consumption, question the real effectiveness of the intermittent mode of supply in Puerto Ayora, where the estimates of the domestic consumption ranges from 163 to 177 lpcpd ±60 lpcpd.

WMI, a private organization financially supported by the German Cooperation G.I.Z, installed approximately 300 water meters in the period from 2013 to 2015, in three different pilot zones. Pilot Zone 1 (PZ 1), located in the northern part of the town, included 115 installed water meters. The readings took place in the period from August 2013 to June 2015. This zone was chosen by the municipality due to the prevalence of domestic premises. Furthermore, 140 water meters were installed in Pilot Zone 2 (PZ 2), located in the south-western part of the town. The readings in this zone correspond to the period from February 2014 to June 2015. Lastly, Pilot Zone 3 (PZ 3) was designed to cover the two main avenues of the town where most tourist facilities are located (Av. Baltra and Av. Charles Darwin). The readings in this zone were taken from 54 domestic water meters in the period from September 2013 to June 2015. All of these water meters were placed in the distribution network before the individual storage facilities, accounting also for spillage and wastage. The results from these readings indicate average specific demand ranging from 156 lpcpd to 568 lpcpd, for the different pilot zones and the different years.

This section aims to verify the findings of the survey conducted on water demand estimation presented in the previous section, as well as to establish domestic demand patterns using more accurate measurements. Also, it analyses the lack of equity in attempt to find a correlation between the schedules of intermittent distribution applied by the municipality and the water consumption. The preliminary findings showing extreme high figures of consumption raise the question whether the intermittency is really necessary.

2.3.1 Research Methodology

To get more insight and verify the data obtained in previous researches, a fieldwork was carried out from June to August 2015. In collaboration with the municipality, 18 water meters (Flodis-single jet turbine device) were installed in private premises based on their willingness to cooperate and accessibility to install the meters. Figure 2.3 shows the locations of the installed water meters. These were installed on the pipe after the individual storage facility, therefore not accounting for spillage of

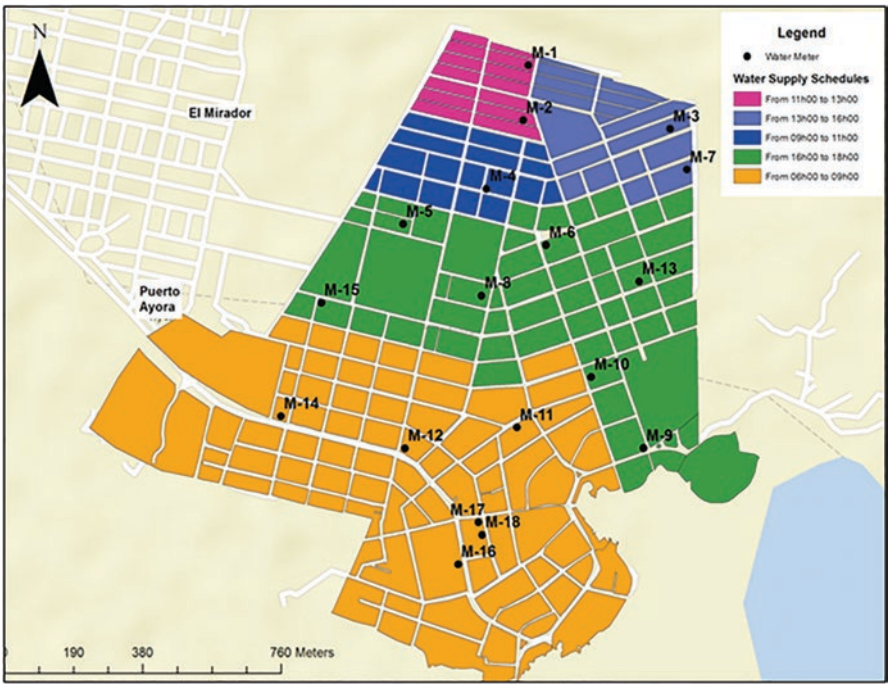


Fig. 2.3 Distribution of installed water meters in Puerto Ayora

tanks or cisterns. The devices were kept for 30 days and then dismantled (for they were borrowed by the municipality of Santa Cruz). Hourly readings from 6 am until 8 pm were observed, and then the following day at 6 am, to observe cumulative demand overnight. The readings were taken during two working days and one weekend day, to compare and register possible change in habits with respect to water use.

Finally, the information from the water cadastres belonging to the pilot zones was thoroughly assessed for each zone. The results were also analysed with the aim of finding some (co)relation between schedules of distribution and wide ranges of consumption.

2.3.2 Results Based on Installed Water Meters

2.3.2.1 Water Consumption

Table 2.4 shows the values obtained from 18 water meters over a period of one month. The average specific demand refers to the weighted average of the readings corresponding to the three days (Eq. 2.1), and the monthly specific demand refers to the per capita average from the 30 days the meter was installed.

Table 2.4 Consumption registered in two working days and a weekend day of 18 installed water meters

Water meter	Consumption working Day 1 (lpcpd)	Consumption working Day 2 (lpcpd)	Consumption weekend (lpcpd)	Average specific demand[a] (lpcpd)	Monthly specific demand[b] (lpcpd)
M1	151	117	208	153	158
M2	101	82	94	91	150
M3	132	78	143	115	140
M4	48	187	216	144	172
M5	257	169	90	176	172
M6	176	114	74	124	288
M7	62	25	76	52	52
M8	247	117	116	162	223
M9	238	238	269	244	275
M10	370	215	97	235	410
M11	140	175	241	179	250
M12	105	71	129	99	86
M13	56	90	80	74	96
M14	80	151	116	114	126
M15	90	54	80	73	71
M16	79	147	51	94	127
M17	78	46	90	69	80
M18	113	50	52	72	75
Average	**140**	**118**	**123**	**126**	**164**
Standard deviation	**±87**	**±62**	**±66**	**±56**	**±94**

[a]Refers to the average of specific demand of the three days of measurement, and [b]refers to the average specific demand based on the monthly measurement taken when the water meters were uninstalled after 30 days and considering the number of inhabitants

$$\text{Weekly specific demand} = \left(\frac{C_{w1} + C_{w2}}{2}\right) * 0.714 + \left(C_{wk} * 0.286\right) \tag{2.1}$$

In Eq. 2.1:

C_{w1} = refers to consumption on the working Day 1
C_{w2} = refers to consumption on the working Day 2
C_{wk} = refers to the consumption in the selected day of the weekend

As can be observed, the average specific demands for the measured week, as well as the specific demands for the whole month, vary significantly. Moreover, most of the monthly-average demands are higher than the weekly-average demands. Furthermore, the results show surprisingly high figures (up to 410 lpcpd), as well as low demands (minimum of 46 lpcpd). For a deeper analysis, the measurements were further assessed from the perspective of the water meter location in a particular

distribution zone and its specific schedule of supply, as well as by anticipating the standard of living of the premises that were metered.

Comparisons could not result in correlations between the demands and a specific zone, i.e. schedule of intermittency. At first, the possible influence of the network pressure due to the location of the households was considered. Also, it was thought that the households located the furthest from the sources of supply could experience lower network pressures and consequently the lower consumptions. However, these hypotheses could not be verified because of the random distribution of demands, regardless the location. Remarkably, the meter M10 with the highest observed specific demand is located in the zone which according to the municipality has a supply for only 2 h per day. Alternatively, these figures may be explained by significant difference in lifestyles and/or volume of individual storage, as well as more negligence in some households than in others, and/or an indication of some sort of informal/illegal tourist business. For example, after the analysis, it was found that one of the households had a small laundry business, explaining the high consumption registered.

On the other hand, low-demand households were also interviewed in order to find the reasons of the low use. In most cases, it has been observed that those families were spending only part of their time in their homes, otherwise spending their time in the premises of their relatives'. Also, in other cases, some members of the family were on holidays.

2.3.2.2 Water Demand Patterns

Daily demand patterns were created from the hourly measurements taken during two weekdays and one weekend day. Since an average for the night hours was calculated, the night period is represented by a straight line. The schedule of intermittent supply reported by the municipality does not specify any supply between 6 pm and 6 am, suggesting that the use of water in this period is, exclusively, from the individual storage.

Figure 2.4 shows the variation in peak factors between different consumption days. The highest peak was observed in the weekend (Saturday), due to the fact that cleaning, laundry and gardening are usually performed during this day. Also, the lower peak was observed in the weekend, portraying the variation in the schedules of the household habits; since it is a non-working day, families tend to leave the premises. Furthermore, in the two weekdays (Tuesday and Thursday), the three peaks (morning, midday and night) are more evident.

2.3.3 Analysis of Water Demand in Pilot Zones

The information from the water cadastres of the municipality were thoroughly organized and analysed. Table 2.5 summarizes the water consumption of the three pilot zones which shows that the average specific demand differs between years and pilot

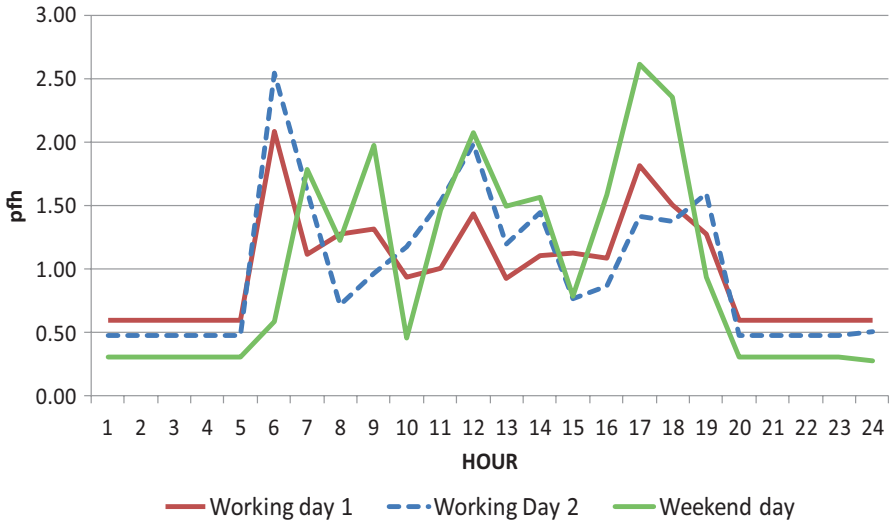


Fig. 2.4 Hourly peak factors for three type of days from 18 installed water meters

Table 2.5 Summary of water demand for three metered pilot zones in Puerto Ayora for 2013, 2014 and 2015

Pilot zone	Year	Total average consumption per month (m^3)	Average consumption per premise (m^3)	Specific demand (lpcpd)	Standard deviation (lpcpd)
PZ 1	2013	2689	23	156	±19
	2014	1039	29	191	±39
	2015	3449	30	200	±36
	Average	**2393**	**27**	**182**	**±31**
PZ 2	2013	–	–	–	–
	2014	2175	24	158	±37
	2015	4877	35	232	±93
	Average	**3526**	**26**	**195**	**±80**
PZ 3	2013	2197	33	217	±32
	2014	4041	75	499	±88
	2015	4599	85	568	±92
	Average	**3612**	**64**	**428**	**±70**

Source: Water cadastres from the municipality of Santa Cruz

zones. PZ 1 and PZ 2 have similar averages of specific demand, as well as standard deviations, showing a wide range of consumption for different households. However, this range of consumption is significantly wider when compared to the results obtained from the surveys in Sect. 2.3. The highest average values of specific demand are in PZ 3. However, most of the tourist facilities are also located in this zone, meaning that it could be a mixture of different consumption categories.

In order to visualize graphically the broad ranges of consumption for the three pilot zones, Fig. 2.5 (a), (b) and (c) show the maximum, minimum and average specific water demand per month, assuming five inhabitants per household.

As observed in Fig. 2.5, per capita demands differ significantly between each pilot zone and each household. There are households consuming as high as 1500 lpcpd and others as low as 50 lpcpd in PZ 1 and PZ 2. Evidently, the highest values indicate some sort of informal tourist accommodation or excessive wastage in form of spilling elevated tanks or cisterns. According to a survey done by WMI (2013), some of the metered premises had informal tourist accommodation businesses. Moreover, on PZ 3, there are premises consuming as high as 4500 lpcpd, implying that these 'households' are actually not 'domestic'. Furthermore, most of the peaks observed are in the months of March, April, May and June, which correspond to the warmest months of the year, while the lowest consumptions are observed in August, September and October, suggesting some influence regarding the season. However, the temperature variations in the Galapagos Islands are not abrupt as in other tourist islands.

2.3.4 Analysis on Scarcity of Water in Puerto Ayora

Table 2.6 shows the comparison of the average water supplied per day obtained from the municipal records, against the estimated average water demand from different scenarios (3 pilot zones and 18 installed water meters). The assumed figure of 17.5% for leakage is the lowest possible based on previous analysis (Reyes et al. 2016; UNICEF 2000; Chowdhury et al. 2002).

By assessing these figures, it can be observed that for most of the scenarios, there is sufficient water to satisfy several average specific demands (even if they are high). Only for the case of PZ 3 scenario (2014 and 2015), the average amount of supplied water would not suffice. However, these averages of specific demand are extremely high and very unlikely to be the representative ones for domestic households.

This also indicates that the perception of limitation of water is not entirely accurate. Furthermore, if the number of unreported tourists in private accommodations is high, it could lower the extreme values of domestic specific demand significantly. If the supplied average is observed, the figure from 2014 increased compared to 2013 by ±1000 m^3/day. Since 2014, one of the pumps has been operating the 24 h per day (according to the municipality), while the other one is still operating 12 h per day; in previous years (e.g., 2013), both pumps were on average extracting water only 12 h per day. Further increase in extraction capacity is questionable due to the extra pressure on the basaltic aquifer and possible increase in salinity of the resource. Also, because of the fixed tariffs and storage tanks, if more water is available, then more water is most likely to be consumed or wasted (some as spillage of tanks). This seems to be the case for the latest years (2014 to 2016), since the amount of water extracted has increased by 50%, but the total supply hours have not increased at all.

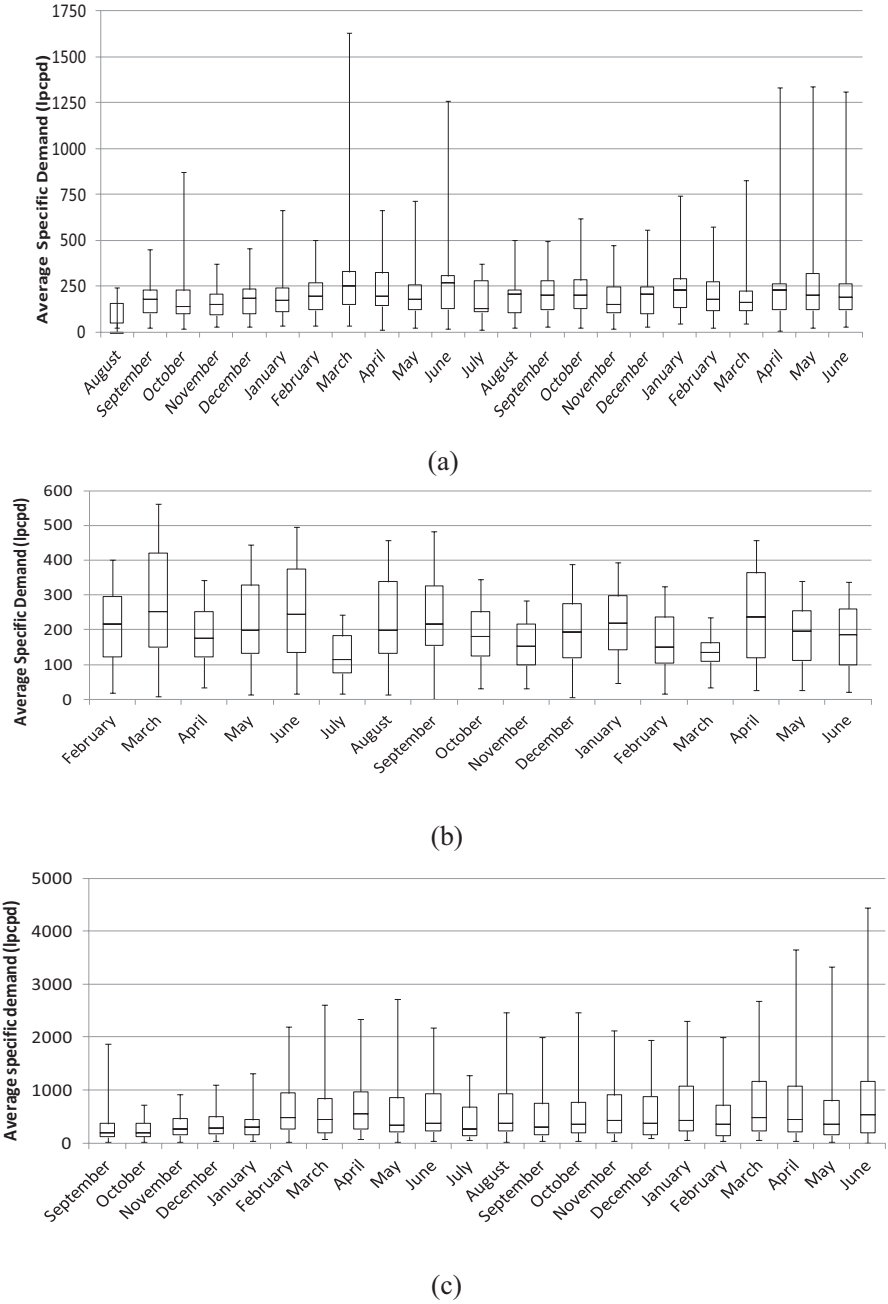


Fig. 2.5 Box plots showing the maximum, upper quartile, median, lower quartile and the minimum values of specific demand on (**a**) Pilot Zone 1, (**b**) Pilot Zone 2 and (**c**) Pilot Zone 3

Table 2.6 Estimation of water remaining based on different scenarios of consumption

2013						2014					2015				
Senarios of consumption	Average specific demand 2013 (lpcpd)	Total demand 2013 (m3/day)	Total average supply 2013 (m3/day)	Leakage[a] (m3/day)	Remaining (m3/day)	Average specific demand 2014 (lpcpd)	Total demand 2014 (m3/day)	Total average supply 2014 (m3/day)	Leakage[a] (m3/day)	Remaining (m3/day)	Average specific demand 2015 (lpcpd)	Total demand 2015 (m3/day)	Total average supply 2015 (m3/day)	Leakage[a] (m3/day)	Remaining (m3/day)
Pilot zone 1	172	2235	3224	403	586	208	2699	4305	538	1067	219	2846	4303	538	919
Pilot zone 2	–	–	–	–	–	221	2875	4305	538	891	207	2693	4303	538	1072
Pilot zone 3	217	2819	3224	403	2	499	6483	4305	538	−2717	568	7378	4303	538	−3613
Water meters	–	–	–	–	–	–	–	–	–	–	164	2130	4303	538	1635

[a]Leakage was assumed to be 50% of previously calculated Non-Revenue Water by Reyes et al. (2015)

The discussion of the results points to an evident lack of management regarding the water distribution system. With the figures obtained for demand and supply, the quantity of water does not seem to be the key issue, but it is more the quality. As observed from specific demand figures, despite the fact that some premises are registered as domestic, they seem to have some sort of informal accommodation or tourist business, especially in PZ 3. This refers also to the lack of cross-checking of information among institutions. As mentioned before, the accurate registration of tourist premises, as well as the information about number of tourists, is essential to get real figures about the domestic (and tourist) specific water demand. Moreover, there is evidence that some households consume extremely high quantities of water. This hints that there is enough water, for at least more hours of distribution than the current ones. It can also be inferred that the storage systems may not be aiding the intermittency, as originally considered, but complicating the situation. This also proves that there is a lack of equity in the distribution of the water, which can be attributed directly to the storage facilities. The bigger the storage facilities, the less the availability of water for the rest of the consumers. Therefore, the individual storage does not necessarily seem to be the best alternative regarding equity within the local population and solving the scarcity issue of the town.

2.4 Conclusions

In this poor-data case study area, the generation of this data is fundamental for decision-makers. Involving the collection of information from different sources and institutions, the lack of communications and cooperation among relevant organizations influences the current water supply crisis since there is no cross-check of information or follow-up of studies. Therefore, this thorough assessment intends to help the authorities seek for specific solutions to the problems portrayed in this fragile ecosystem. Since one of the government's objectives is the exponential growth of tourism, it is necessary to arrive at a full-level scale solution, and not locally-based (as it is currently). Therefore, there is a need for a holistic solution, where the government needs to involve and manage different stakeholders and develop multidisciplinary, interdisciplinary and transdisciplinary approaches.

The survey provided a scenario reasonably close to reality and has enabled preliminary calculations of demand for different consumption categories. The highest water demand was observed for the hotels, with an average consumption of 469 lpcpd, which accounts for 49% total water demand on this island. Regarding the domestic water use, there is an evident difference in per capita averages of consumption of municipal water (163 lpcpd in Puerto Ayora and 96 lpcpd in Bellavista) suggesting that different tariff structures may influence the consumption. In Bellavista, where water is charged per cubic metre, the demand per capita is reduced by nearly 40% than the demand in Puerto Ayora.

The total domestic per capita demand, including all types of sources, is significantly higher in Bellavista (253 lpcpd). This is due to a high consumption from

rainwater and water purchased from trucks. Based on these findings, it can be concluded that in general there is no real scarcity of the water resources within the island (190 lpcpd in average is consumed per inhabitant in Santa Cruz), but instead there is a deficient management of water supply and demand.

This study also addressed the issue of domestic water demand in Puerto Ayora (Santa Cruz Island). For critical analyses of specific domestic water demand, 18 installed water meters were installed, and the meter readings from three pilot zones made available by the municipality of Santa Cruz were analysed. The average specific demand from the different scenarios provided the same conclusion for all three sources of information: There is a wide range of consumption in Puerto Ayora (averages ranging from 156 lpcpd to 568 lpcpd). The wide range of per capita consumption can be most likely attributed to the different habits within the local population. Also, it can be explained by the lack of awareness and consequent wastage of water within premises, which could be a direct consequence of a fixed tariff structure. Spilling of elevated tanks has been identified as a major problem, and it can be supported by the figures in this chapter.

The reported range of consumption is surprising for an island where water resources are perceived as scarce. Thus, the figures clearly portray that currently there is sufficient brackish water available. Finally, the results obtained also suggest that the intermittency could be reduced if the distribution system would be better managed and demand management practices would be taken into account. This study has shown that the hours of intermittency need to be re-evaluated or even completely eliminated. Storage tanks are not necessarily helping the local population as has been thought over the last two decades, but has contributed to the limitation on the performance of the supply system. This also calls for a change on tariff structures, creating awareness within population. Finally, the leakage needs to be further assessed, since this is an important figure when calculating the amount of total actual supply to consumers.

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Chapter 3
Galapagos' Water Management Evaluation Under a Changing Climate and the Current COVID-19 Pandemic

Cristina Mateus and Diego Quiroga

Abstract This chapter analyzes the Galapagos as a socio-ecosystem and addresses the interactions of social and environmental systems amidst important transformations that the Islands are experiencing. We look at two of the most important threats to the Galapagos socio-ecosystem, the current COVID-19 pandemic and the possible effects of climate change as they affect and are affected by the water security of the islands. Water availability in both the urban and the rural areas is examined as a key factor that affects the resilience of the people who reside in the islands and their capacity to adapt and withstand dramatic and often catastrophic changes. We also consider the way different institutions and strategies have operated, usually in a top-down fashion in generating projects to increase the capacity of the Islands to adapt to climate change, and we examine the effectiveness of some of these often expensive projects. Thus, the main goal of this analysis is to understand how these critical threats harm Galapagos local community and economy, both in the short and long term by taking into account the success and failures of past projects, and then explore possible actions and plans to address them.

Keywords Socio-ecosystem · Climate variability · Covid-19 · Water availability · Water security

3.1 Introduction

Galapagos' ecotourism economy which is increasingly dependent on the global socioecological dynamics is starting to be impacted by climate variability, water security, and the current COVID-19 pandemic. Social capital which is based on the trust and transparency of the local institutions and the existing social networks is an

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important part of social resilience. In this analysis we will look at the way in which social resilience relates to the capacity of Galapagos' society to respond to new threats such as the COVID-19 pandemic and climate change particularly as they relate to water availability.

The strong relationship that exists between the current health crisis and the climate crisis needs to be explored and evaluated more in depth. Since COVID-19 health and economic impacts around the world became visible immediately, most countries' political agendas prioritize the preservation of human lives. However, climate change's most pressing issues have not been given equal importance as COVID-19 even though it has become clear that addressing climate should also be a priority in order to preserve human lives, livelihoods, and the economy. Both COVID-19 and the early effects of climate change have become an important challenge to the people living in Galapagos as they have interrupted the flow of tourist on which the local communities depend on a large extend for their income and economic survival.

Climate change in Galapagos threatens to exacerbate stresses on both the natural and built environments due to increases in the frequency and intensity of EL Niño Southern Oscillation (ENSO) floods, sea level rise, soaring sea surface temperatures (SST), heat waves (d'Ozouville et al. 2010; Larrea and Di Carlo 2011), and decreases in ocean pH and intensity of upwelling (Sachs and Ladd 2010). Climate change may also have the opposite effect of decreasing SST and causing prolonged periods of drought. These important changes can affect both food security and the survival of some species whose numbers are already very low. The presence of these species is important not only due to their intrinsic and scientific value but also for the flow of tourists to the islands.

The increasing number of permanent residents and tourists (DPNG 2017; INEC 2015) exacerbates the need to develop alternatives to support the increased demand for water and agricultural products. Higher demand for food resulted in more agricultural products being imported from the mainland to meet those demands. This increased dependence on mainland products was related to environmental and social factors such as the lack of water, poor soils in some areas, and the cost of labor. For many of the locals, it was better, until COVID-19, to work on tourism, commerce, transportation, and the public sector than to work in the field in the highlands. This lack of access to fresh food and increased processed food supply from the mainland resulted in Galapagos having one of the highest rates of obesity in Ecuador. Now, in the midst of the COVID-19 pandemic, which has resulted in the collapse of the tourism economy, there is an increased dependence of agricultural products coming from the highlands. This requires proactive strategies that are more self-sufficient, making the islands even more vulnerable to climate change.

Climate change may also exacerbate the tension of increased human presence on the island. While additional population growth will add to the amount of effluents produced on the islands (GAD Santa Cruz 2007), an increase in extreme events such as intense storms or floods (Larrea and Di Carlo 2011) will also flush more of these effluents into the ocean and groundwater and surface water systems, thus deteriorating the quality of the water. On the other hand, prolonged droughts during La Niña

can affect the availability of freshwater for human consumption and food security as there is not enough water in the highlands where agriculture is centered. Thus, this lack of freshwater or water of good quality most likely will have a negative impact in the islands' agricultural capabilities, especially in Santa Cruz and Isabela where there are already issues with freshwater supply to satisfy the high demand that accompanies the expansion of the tourism industry. Although the number of tourists arriving to the Galapagos dramatically decreased since COVID-19, most likely, the number will recover in the short term. The challenge is whether under the current circumstances of increased fluctuations and unpredictability of water availability, the islands' socio-ecosystems can maintain their resilience and their capacity to adapt to some of the threats that will result from climate change.

Being tourism the main source of income in Galapagos, diseases that affect human health could also have a major impact on the economy. In other areas of the world, it has been reported (Ahmadi et al. 2020) that the most important variables affecting the COVID-19 outbreak rate are population density. In the case of the Galapagos, there has been a significant increase in density in populated areas during the last five decades which has resulted in greater vulnerability to the effects of infectious diseases. Besides density, Galapagos has become much more interconnected to the mainland as the number of flights and cargo boats arriving to the islands increased exponentially during the last decades. The dual effects of increases in density and connectivity resulted in the arrival and spread of diseases such as dengue fever and other mosquito-transmitted diseases as well as influenza and more recently COVID-19.

Additionally, some of the possible effects of climate change such as increase in precipitation and warmer weather are expected to exacerbate many kinds of diseases, especially those that have insects as vectors. Recent studies suggested that temperature variation and humidity may be important factors affecting COVID-19 transmission, which decreased with temperature increasing (Wang et al. 2020), and mortality (Ma et al. 2020). People living in areas with higher exposure to warmer temperatures, droughts, food shortages, loss of clean water, access to healthcare, and/or disease exposure are far less able to fight off the COVID-19 pandemic (Wu et al. 2020). The lack of good medical facilities and specialized physicians, as well as exposure to climate extremes and thus lack freshwater supply, makes the Galapagos a vulnerable area for these kinds of pandemics.

Rethinking and understanding the importance of the relationship between local community, NGOs, technical specialists, and policy to address the current climate and health crisis is crucial. Through a structured multi-stakeholder approach combining the contributions and recommendations and perspectives of technical specialists, local community, NGOs, and governmental institutions, we evaluate the effectiveness of government plans to address climate change issues on the water and food sectors and define a research path and adaptive strategies for the local communities facing the current climate and health crisis. Thus, the analysis is broken down into two sections. First section identifies water and climate needs and priorities described by all stakeholders taking into account funds that were allocated to address water management and climate change issues, the efficacy of

implementation and results, and the progress of such plans beyond government periods. Therefore, recommendations are based on failure and success of proposed actions to address those needs. Second section of the analysis consists on evaluating results from the previous section under two different scenarios: (1) considering only climate change crisis, and (2) considering both climate change and COVID-19 pandemic crisis. Finally, we discuss possible alternatives to address these issues and increase Galapagos resilience to catastrophic changes.

3.2 Methods

3.2.1 Study Area

In general, inhabited islands in the Galapagos suffer of insufficient water supply of adequate quality to meet the increased demand for domestic use and irrigation. Brackish water can be found on all the islands, yet only San Cristobal has an adequate freshwater supply due to its permanent surface freshwater bodies (Maria Reyes et al. 2017). There is a series of freshwater aquifers in San Cristobal island leading to multiple water spring alignments and perennial streams (d'Ozouville 2007; Violette et al. 2014). On the other hand, both Santa Cruz and Isabela islands lack of freshwater supplies and rely on municipal desalination plants that use reverse osmosis to treat brackish water (J. Liu and d'Ozouville 2013). However, either desalination plants functionality is not reliable such as is the case in Santa Cruz or there is not enough storage capacity for treated water such as is the case in Isabela. Water sources in Santa Cruz and Isabela are characterized by basal aquifers at lower elevations (brackish) and deep boreholes at higher elevations where water is fresher (Violette et al. 2014). Brackish water at lower elevation in Santa Cruz island results from both seawater intrusion and overexploitation, and it is contaminated with both organic (J. Liu and d'Ozouville 2013) and inorganic (López and Rueda 2010) matter. At higher elevations, water is fresher since it is extracted from deep boreholes (Reyes et al. 2016; Violette et al. 2014). In general, there is very little supply of freshwater for irrigation purposes for the farmers in the islands (d'Ozouville 2007), an issue exacerbated with more frequent droughts and floods as a result of changes in precipitation patterns and warmer temperatures (Izurieta et al. 2018).

In 2016, the *Ministerio de Agricultura, Ganadería, Acuacultura y Pesca* (MAGAP) invested USD 1,172,728 (MAGAP 2016) for the construction of 130 small reservoirs distributed as follows: 53 in San Cristóbal, 46 in Santa Cruz, 26 in Isabela, and 5 in Floreana (MAGAP 2019). Nevertheless, many of these small reservoirs are not fully functional or do not have access to enough water supply to meet agricultural demands. This happens especially during strong periods of drought as the one that occurred in 2015–2016 when cattle had to be sacrificed and many farmers lost their crops.

In San Cristóbal island, the surface water generally meets domestic and agricultural water requirements (Grube et al. 2020). The 17 main springs present in the island meet both domestic and irrigation demands when sufficient and adequate infrastructure is available (CISPDR 2015). During prolonged dry seasons however, farmers that don't have access to perennial streams rely on rainwater collection and municipal tank trucks (CISPDR 2015). Increases in irrigation water deficits are expected by 2035, and thus exploitations of alternative water sources and water-saving irrigation techniques (i.e., sprinkling, dripping, micro sprinkling, hydroponic, etc.) have been proposed (CISPDR 2015). There are two main water sources located in the highlands to supply water for urban areas: (1) La Toma with El Progreso Drinking Water Plant and (2) Cerro Gato with Las Palmeras Drinking Water Plant. While San Cristobal has an adequate freshwater supply due to its permanent surface freshwater bodies (Maria Reyes et al. 2017), limited water supply from the municipal drinking water forces households to store water in roof tanks or cisterns (Grube et al. 2020). Furthermore, while water treatment plants are able to produce water that meets drinking water standards, contamination of this water seems to be happening through the distribution system and household storage (Grube et al. 2020).

Santa Cruz island has eight water sources for irrigation and three main sources of municipal water for Puerto Ayora (Grieta la Camiseta), Bellavista (Pozo Profundo), and Santa Rosa (Vertiente Santa Rosa) (CISPDR 2015). However, water is scarce and has a high salinity concentration, making it unsuitable for drinking and long-term use in agriculture as it causes alterations of soil properties (Mateus et al. 2019). While MAGAP reservoirs could help irrigation plans and infrastructure for a few areas in the highlands, there has not been sufficient rain to supply the reservoirs. Additionally, there are a few private operations extracting water from crevices that have no regulation or monitoring and thus the amount extracted is unknown (Reyes et al. 2015). In many of these places, groundwater is contaminated due to the proximity of the basal aquifer to dense urban settlements, the lack of effective wastewater treatment plants, and, in some cases, sea water intrusion due to overexploitation of the aquifer (López and Rueda 2010; Violette et al. 2014; Mateus et al. 2019).

Isabela island's natural pools and crevices contain freshwater from rainwater; however, a few meters deep, the water is brackish and salty (Violette et al. 2014). There is no water distribution system for the agricultural and livestock sectors, which completely depend on MAGAP tankers and couple of other distributors (CISPDR 2015). The islands have five water sources for irrigation, and three main sources for municipal water for urban areas come from La Poza San Vicente located in El Chapin region. From here water goes through a desalinization plant and is stored in tanks before it is distributed to the 94.6% of households that have access to the municipal piped water network. As mentioned before, the current issue is that there is not enough space in the tanks to store water treated by this desalinization plant, and thus this treated water only lasts the first couple of hours from distribution; after that, the water being distributed is brackish.

3.2.2 Study Approach

The analysis is divided into two sections as described below.

3.2.2.1 Multi-stakeholder Approach to Identify Proposed Actions to Address Water Needs and Priorities Under Climate Change

This section replicates the methodology presented by Mateus et al. (2020) which consists in a structured bottom-up and top-down multi-stakeholder approach to classify water needs and priorities identified by technical specialists, local community, and NGOs (bottom-up) and evaluate the effectiveness of the science-government-driven plans (top-down). The methodology entails on five steps briefly described below (please refer to Mateus et al. (2020) for more details).

The approach starts by defining the problem or the need described by users (technical specialist, local community, and NGOs), with input of decision-makers but driven by users and stakeholders (bottom-up). This was done throughout an extensive literature review between 2010 and 2020 to better understand the technical specialists' assessment of the Galapagos' hydroclimatic conditions, freshwater sources, and water management systems for human use (potable and irrigation) in which gaps between climate change and research needs were identified (Step 1). Second, through collaborative workshops conducted on May 21, May 23, and June 13, 2018, in San Cristobal, Santa Cruz, and Isabela, respectively, the local community's, NGOs', and governmental institutions' priorities were identified (Step 2). Workshop participants included stakeholders currently involved in Galapagos' water issues, who would contribute significantly and stay engaged throughout the design and implementation of the water strategy selected. The next step identifies government plans and funding based upon the Development and Zoning Planning, known as "Plan de Desarrollo y Ordenamiento Territorial" (PDOT) which are created by the National Secretary of Planning (SENPLADES 2013) for each island (Step 3). Proposed and executed plans were then evaluated, and reasons for failure and success of such plans are identified (Step 4). Finally, plans and alternative actions for water availability, security, and resiliency under a changing climate were proposed (Step 5).

3.2.2.2 Proposed Action Evaluation Under Two Different Scenarios

Results from Sect. 3.2.2.1 will be evaluated looking at two different scenarios considering the two most important threats Galapagos socio-ecosystem is currently facing, the current COVID-19 pandemic and the possible effects of climate change. The first scenario looks at plans and alternatives proposed taking into account climate change as the only threat. The second scenario evaluates plans and alternatives considering both climate change and COVID-19 pandemic as main threats. This

analysis will be made taking into account the fact that COVID-19 crisis could mark a turning point in progress on climate change since the current global pandemic has resulted in significant decreases of greenhouse gas (GHG) emissions. However, emissions will rebound once mobility restrictions are lifted and economies recover. Additionally, as the COVID-19 spreads, it is increasingly clear that public health depends on secure water resources for all, and the people with the least access to essential services like water will feel the most dramatic effects of the pandemic (Otto et al. 2020), such as is the case in the Galapagos.

3.3 Results

3.3.1 Executed Projects and Plans Addressing Climate Change and Water Management Issues in the Galapagos Islands

Approximately USD 138 million was invested in the Galapagos Islands in projects related to water management and climate between 2012 and 2019 (Table 3.1). Most of these projects and government plans focused on addressing climate change impacts and water availability needs in Santa Cruz, San Cristobal, and Isabela islands. While 38% of this funding was invested for community, research, and infrastructure projects in all three islands, the majority of the funding went to projects in Santa Cruz (51%), and the rest of the money (11%) was invested in projects for San Cristobal and Isabela. More information about funding and projects under each initiative with details of project execution and development can be found in the Appendix section (Tables A1, A2 and A3).

Table 3.1 Government funds given to projects that were executed between 2012 and 2019 to address climate and water needs in Santa Cruz, San Cristobal, and Isabela islands

	USD ($)	Percentage
All three islands	**$ 52,552,199**	**38%**
Community	$ 45,810,777	87.2%
Research	$ 49,550	0.1%
Infrastructure	$ 6,691,873	12.7%
Santa Cruz	**$ 71,127,519**	**51%**
Policy	$ 265,184	0.4%
Infrastructure	$ 70,827,335	99.5%
Community	$ 35,000	0.1%
San Cristobal and Isabela	**$ 14,914,637**	**11%**
Infrastructure	$ 6,876,057	46.1%
Community	$ 8,038,080	53.89%
Policy (only for San Cristobal)	$ 500	0.01%
Total invested in water projects	**$ 138,594,356**	**100%**

Between 2013 and 2019, approximately USD 45,8 million was invested in all islands in community projects which includes awareness and trainings to improve conservations of natural resources and sustainable development. Between 2015 and 2017, approximately USD 6.9 million was invested in infrastructure maintenance due to El Niño event and strong precipitation events (mostly road network) as well as construction of sustainable and safe infrastructure in touristic areas. In 2015, the Galapagos Government Council, or CGREG for its initials in Spanish, allocated USD 49,550 in hydrogeological research projects in order to understand and find water sources.

It is important to mention that approximately USD 179,819,308 has been proposed for the "Galápagos compatible con el clima" project in which the responsible agencies are the Development Bank of Latin America (CAF), World Wildlife Foundation (WWF), Food and Agricultural Organization (FAO), CGREG, and Galapagos National Park (PNG). However, neither their plans nor funding is being considered in this analysis.

3.3.2 Agreements Among All Three Groups of Stakeholders

Government plans for Santa Cruz island seem to address the needs and priorities of technical specialists, local community, and NGOs only in areas related with research and community (Fig. 3.1a). All three groups of stakeholders agreed that it is important to improve hydrological data to better understand the water budget and watershed characteristics (d'Ozouville 2008; d'Ozouville et al. 2008; Gonzales Iñiguez 2013; Percy et al. 2016; Violette et al. 2014). This will help water managers in their decision-making process and developing an integrated water resources management plan that considers climate variability and future water scarcity along with the necessary infrastructure that will help adapt and mitigate to new conditions. While plans to address this were proposed by the government (Table A1), only a little amount (USD 49,555) was invested for all three islands to meet this need. Approximately USD 35,000 was invested in 2019 by the government (Table A2) for Santa Cruz (CGREG 2016, 2019; GAD San Cristobal 2017; GAD Santa Cruz 2012) in environmental education campaigns (Responsible: Direccion de Gestión Ambiental). Implementation programs for awareness about water use and conservation of natural resources were proposed during the workshops by stakeholders which agreed with the technical specialists that find this a priority and propose collaborative commitment to understand the consequences of a changing climate and the importance of considering global warming in decision-making processes (d'Ozouville et al. 2010).

In San Cristobal and Isabela islands, there was a general consensus among all parties of the need to create and implement a collaborative management plan to adapt to climate change (d'Ozouville et al. 2010) and seek sustainable development in urban and rural (Fig. 3.1b,c). For this, the government allocated approximately

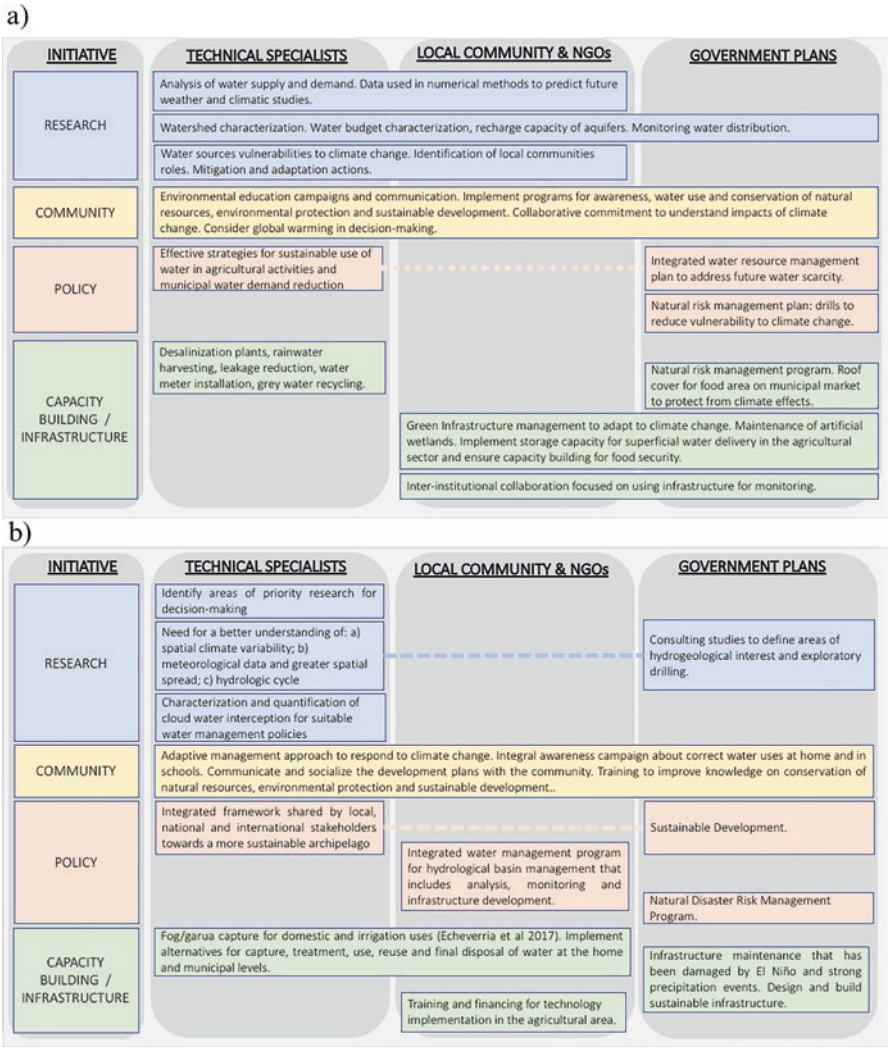

Fig. 3.1 Priorities and concerns identified by technical specialists (Step 1), local community and NGOs (Step 2), and proposed or implemented government plans that address them (Step 3) for (**a**) Santa Cruz Island, (**b**) San Cristobal Island, and (**c**) Isabela Island

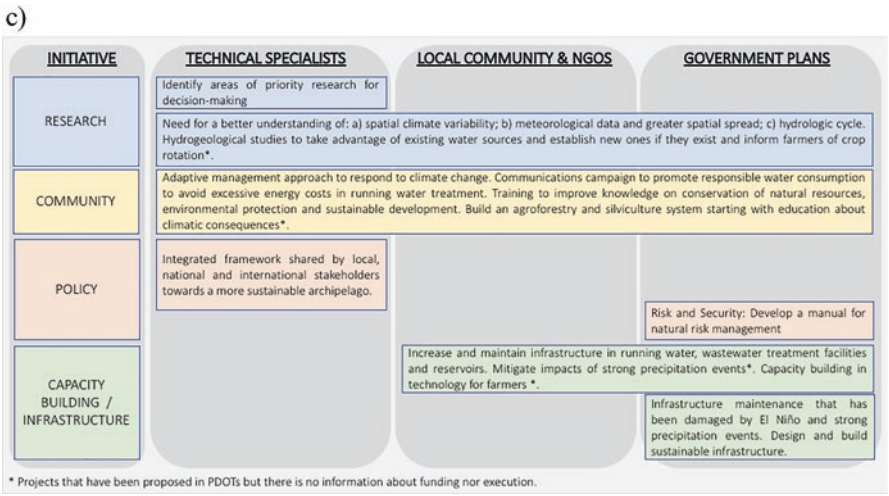

Fig. 3.1 (continued)

USD $ 8 million between 2017 and 2018 (Table A3). Additionally, the technical specialists identified the need for a better understanding of spatial climate variability and access to meteorological data with a greater spatial spread throughout islands (Trueman and d'Ozouville 2010) as well as a better understanding of the hydrologic cycle for Galapagos (Adelinet et al. 2008). This need to improve hydrogeological studies to take advantage of existing water sources and establish new ones (if they exist) was also a priority expressed by stakeholders during the workshop in Isabela (Fig. 3.1c) but not in San Cristobal (Fig. 3.1b). In response to this, the government proposed to develop hydrogeological studies and inform farmers of crop rotation in Isabela island, but the project was never executed. Nevertheless, the government did allocate USD 49,550 (Table A1) for consulting studies to define areas of hydrogeological interest and exploratory drilling in all three islands.

3.3.3 What Has Been Done

In Santa Cruz, approximately USD 71 million were allocated (Table 3.1) for projects addressing climate change and water needs. The majority of the funding (99%) was allocated in infrastructure projects and the rest distributed between policy, community, and capacity building projects as follows:

- Infrastructure: Approximately USD 70 million was proposed (Table A2) to improve infrastructure to adapt to climate change (Fig. 3.1a). Most of the funding was invested on implementing storage capacity for superficial water delivery

to the agricultural sector. For example, approximately USD 20 million was invested in Bellavista for the construction of a reservoir, an integral sewage, and potable water system. This project was managed by the Public Works Management, known as DOOPP (Dirección de Obras Públicas), during 2013 to 2016. Approximately, USD 50 million dollars was invested for the same purposes in Puerto Ayora and El Mirador (new urban development near Puerto Ayora) during the same time period. While in June of 2016, it was announced that Santa Cruz will finally have a potable water system (La Hora 2016), by 2019, Santa Cruz still does not have access to potable water, and people still use bottled water to cook, wash food, and for personal hygiene (El Comercio 2019).

- Policy: An integrated water resource management plan was proposed in 2012 by the GAD of Santa Cruz (GAD Santa Cruz 2012) to which USD 228,184 were invested. This addresses technical specialist's suggestions to develop effective strategies for the sustainable use of water in agricultural activities (Izurieta et al. 2018) and a sustainable solution for mitigating the impact on water supply due to a growing demand with the installation of water meters (María Reyes et al. 2019).
- Policy: While approximately USD 177,000 was proposed for Santa Cruz Natural Risk Management Program between 2014 and 2015, only USD 37,000 was invested in 2014 for risk simulations (Table A2).

For San Cristobal and Isabela islands, approximately USD 14.9 million have been allocated for infrastructure (46%) and community projects (54%) (Table A3). Funds that were invested are distributed as follows:

- Infrastructure: Approximately USD 6.8 million was invested for both islands for the design, construction, and maintenance of sustainable infrastructure to mitigate impacts caused by El Niño and strong precipitations events.
- Community: The government invested USD 8 million for a sustainable social and productive development through planification and land use.
- In 2016, USD 500 was allocated in 2016 in San Cristobal to implement strategies to face alert decreed by El Niño events.

3.3.4 What Needs to Be Done

For Santa Cruz, more research to better understand vulnerabilities and consequences of climate change to assist decision-making was recommended (d'Ozouville et al. 2010; Izurieta et al. 2018; Larrea and Di Carlo 2011; Sachs and Ladd 2010; Trueman and d'Ozouville 2010). While both the Charles Darwin Foundation (CDF) and the Galapagos Science Center (GSC) constantly measure various meteorological variables to predict future weather and develop climatic studies, there is still the need to improve data collection of current and future water supply and demand (Reyes et al. 2017), as well as possible future water sources (d'Ozouville 2008; d'Ozouville et al. 2008, 2010) in order to meet future water demands. Better water infrastructure planning and development is needed in Galapagos populated islands. Several studies

have focused on characterizing water quantity (Reyes et al. 2015, 2016) and quality (López and Rueda 2010; Liu and d'Ozouville 2013; Mateus et al. 2019; Grube et al. 2020) providing useful information to help future water planning. Reyes et al. (2019) concluded that stakeholders think the most sustainable solutions for mitigating the impact on water supply are desalination plants, water meter installation, and leakage reduction (by replacing pipes and installing a control system that monitors pressure and flow in the pipes). However, other solutions were also discussed such as rainwater harvesting, gray water recycling, and water demand reduction which will not only mitigate water scarcity but also other environmental impacts (Reyes et al. 2017).

For San Cristobal, Izurieta et al. (2018) suggested the need to identify areas of priority research to assist in decision-making and Domínguez et al. (2016) the recommended characterization and quantification of cloud water interception for suitable water management policies. It was also suggested the implementation of fog/garúa capture infrastructure for domestic and irrigation uses (Echeverría Garcés et al. 2018) as well as alternatives for treatment, use, reuse, and final disposal of water at the home and municipal levels. During the workshops, the need for agricultural training and financing for technology implementation was proposed as well as an integrated water management program for hydrological basin management that includes analysis, monitoring, and infrastructure development.

Besides the need to identify areas of priority research to assist in decision-making (Izurieta et al. 2018) in Isabela, an integrated framework shared by local, national, and international stakeholders toward a more sustainable archipelago was also proposed (Gonzales et al. 2008).

3.4 Discussion

3.4.1 Evaluation of Proposed Actions Under Climate Change Scenario

Our results demonstrated that a significant amount of money has been invested and proposed toward climate change and water management issues in the archipelago. However, there is still the need to secure funding and guarantee the effectiveness on (i) research projects to improve hydrological data to better understand Galapagos' water balance and watershed characteristics of the islands as well as the development of new alternatives for water supply (i.e., desalinization plants, rainwater harvesting) to meet the already increased demand and possible future demand; (ii) implement programs for awareness about water use and conservation management; (iii) improve water storage and distribution for the agricultural and urban sector, and (iv) integrated water management plans that take into account climatic consequences and solutions.

While some studies have provided useful information toward the calculation of the islands' water balance (d'Ozouville et al. 2008; Sachs and Ladd 2010; Trueman and d'Ozouville 2010), there is still the need to better understand the flows and fluxes that enter and leave these systems (i.e., relationships between precipitation, runoff, and evapotranspiration). This will not only provide useful information for decision-making and water management but will also help explore alternatives for new water sources such fog catchers, rainwater harvesting, and desalinization plants or even look for new wells and aquifers. Capture and storage of storm water during extreme precipitation events will not only prevent urban flooding, soil erosion, beach destruction, and the contamination of water bodies and nonpoint source pollution (EPA 2005) but also provide water to meet human demands. Better understanding of the hydrogeology of the area will also highlight the need to protect and restore areas of hydrological importance.

Water conservation efforts depend on public awareness and understanding of the need for conservation. Beneficial reduction in water use, waste, and loss has been proven to be the most economical and environmentally protective management tool for meeting water supply challenges (Eneng et al. 2018). A broad, deep, and long-term persistent education on water conservation saving will not only provide citizens a better understanding of the importance of saving of water but establish the correct concept of its use based on scientific evidence. Furthermore, education and technical assistance programs for the public at large, municipal officials, and water suppliers are crucial to generating an understanding of current freshwater issues and creating acceptance to the implementation of water conservation efforts and accessibility.

To improve water storage and distribution for the agricultural and urban sector, several technical improvements and mechanisms can be proposed. Such techniques take into account reducing water losses by improving water infrastructure and strategies to encourage water conservation (pricing and water use protocols), for example, control leaks from pipe networks, installation and monitoring of water meters to secure water load, sewage pipeline expansion to improve sewage collection and reduce groundwater contamination, infrastructure to reuse recycled water, effective irrigation systems to improve water efficiency in agriculture, etc.

Desalinations plants have been proposed as a sustainable solution for mitigating the impact on water supply by future local population and tourism growth (Reyes et al. 2019). However, the main problem with desalination as a solution to provide freshwater is related to the high energetic cost and the initial cost of implementing the system. In Galapagos, as in many other oceanic islands, any solution that depends on large amount of energy constitutes a big challenge. Most of the energy that is used in Galapagos comes from fossil fuels which are imported from the mainland. Beside creating a bigger dependence on fossil fuels for the islands, importing oil to the islands from the continent can have detrimental environmental impacts such as the case in 2001 when there was a terrible oil spill from the ship Jessica (Accident of the Oil Tanker "JESSICA" off the Galapagos Islands (Ecuador) 2001). Therefore, any solution that relies in fossil fuels is an environmental threat unless the capacity of the island to produce renewable energy is increased in a

significant manner. Unfortunately this means that any fossil fuel solutions such as desalinization plants must be carefully considered before they are implemented.

In terms of climate change, it is important to consider both El Niño and La Niña effects. In the last 10 years, droughts have been more of a problem than has been excessive rain. A survey made in 2019 (Barrera and Valverde 2019) demonstrated that 90% of the farmers have experienced big changes as a result of climate change and most of them were related with intensive periods of droughts (such as the one in 2015–2016) and higher temperatures rather than strong precipitation events. There have not been strong impacts of the warm cycle of El Niño since the 1980s and 1990s, and recent El Niño events have tended to be mild. Even when strong El Niño occurred, there was no strong effect in Galapagos. Some people claim that the ENSO is changing its nature, termed by some El Niño Modoki (Ashok et al. 2007; Kim et al. 2009).

Climate adaptation options to more likely intense and frequent ENSO events are needed to increase Galapagos' resilience to climate change. Intense and frequent La Niña events, characterized by extreme cooler and drier conditions (Trueman and d'Ozouville 2010), have endangering the water security of both the agricultural and urban sector. Warmer sea surface temperatures during El Niño events means more rainfall than normal and less nutrients to support marine ecosystems in the archipelago (d'Ozouville et al. 2010; Sachs and Ladd 2010). Recent coastal development has made the Galapagos much more vulnerable to changes in sea level, in particular to strong El Niño events such as the 1997–1998 event which led to increases in sea level by up to 45 cm (Sachs and Ladd 2010). In addition, the effect of warmer temperatures on *garúa*, the main source of water supply in the highlands that forms from low stratus clouds during the cool dry season (June to December), is likely to result in a reduction of *garúa* in the Galapagos. While more research is needed to fully understand the complexity of these interactions, actions to address these consequences must be undertaken.

3.4.2 Evaluation of Proposed Actions Under Climate Change and COVID-19 Scenario

It is important to understand the real impact of the COVID-19 pandemic in terms of climate change. Taking into account that transportation is the largest source of carbon emissions (Anenberg et al. 2019), COVID-19 lockdowns have resulted in significant reduction in global air pollution (Venter et al. 2020) due to fewer flights in the sky (Fouquet and O'Garra 2020), reduction of marine traffic (March et al. 2020), and decreased ground transportation (Z. Liu et al. 2020). No tourists in Galapagos means not only fewer flights, fewer boats transporting people from one island to the other, and fewer cars on the ground but also less demand for energy, food, and water. Having fewer tourists in natural areas and in the cities has given wildlife the opportunity to explore more areas (DPNG 2020). However, all these visible positive impacts are only temporary as they are due to the economic slowdown and human suffering. CO_2 emission reduction would need to occur over a long and sustained

period of time in order for it to have a measurable impact on the climate (Venter et al. 2020).

There is also a strong relationship between water, climate change, and COVID-19. For example, access to adequate water is very difficult in Galapagos, especially in rural and agricultural areas. Additionally, the little existing access is being deteriorated due to climate change. In the case of COVID-19, it is very important to regularly wash your hands to combat the disease. To do so, there is the need to have access to sufficient, safe, and affordable water in addition to that required for cooking, hydration, and general sanitation (Armitage and Nellums 2020; Otto et al. 2020). "Water and climate are central to achieving global goals on sustainable development, climate change and disaster risk reduction" (Armitage and Nellums 2020). Investing in long-term water security and access to clean water and sanitation not only is essential for public health but also builds more resilient and thriving communities (Otto et al. 2020). Therefore, as places throughout the world come together to fight COVID-19 and rebuild the social and economic sectors, it is important to remember that water is a vital tool to strengthen communities and build resilience in the long term.

The climate crisis is, in some aspects, similar to the COVID-19 emergency, but in slow motion and much graver (Hepburn et al. 2020). The climate crisis will not give you the opportunity to stay at home for 2 months and then return to normal; rather it is irreversible in the medium and even in the long term. There are no vaccine and no social distancing measures that can help fix the problem. Climate change could however have a similar effect as COVID-19 as it can threaten the most profitable type of tourism activity which is international tourism. For example, climate change affects the survival of key charismatic species such as penguins, sea lions, marine iguanas, and sharks due to changes in the upwelling and water temperatures. In this way, the lack of financial resources that is now being caused by COVID-19 could be a good indicator of some of the economic and social effects that climate change can have in the long term. Nevertheless, the COVID-19 crisis has demonstrated that some governments can intervene decisively once the scale of an emergency is clear and public support is present (Hepburn et al. 2020).

Another similarity between climate change and COVID-19 response is that lack of transparency in the management of the funds available for both situations will result in the mismanagement of the resources that come to the islands. This mismanagement not only leads to the projects being poorly executed or not executed at all but also results in society developing lack of trust and low social capital which in the middle term affect the capacity of the society to execute new projects and implement any participatory strategy. Another related problem is that resources are being channeled outside of the local economy as outside organizations, governmental, private, and nongovernmental, charge large amounts to create studies and solutions that often are not implemented or inadequately implemented.

The COVID-19 pandemic will probably mean that the islands will need to be more self-dependent in the near future. This means that there will be greater pressure put on the local resources. Fishing and agriculture will probably be two of the sectors that will see an increase in the number of people involved in these two economic activities. Food security on the islands will be challenged by the fact that

there will be less integration with the mainland, both because of disruption of the transportation system and also because of the lack of financial resources coming from tourism that allowed the locals to purchase outside goods. During the early days of COVID, bartering of subsistence agriculture has increased the importance of local production. This greater need for water in the agricultural sector will have to be met by improving current water infrastructure and operations (i.e., finding new water sources to provide water for small reservoirs) and better use of the water in the highlands (i.e., improving irrigation systems, reducing evapotranspiration, etc.).

The capacity of the coupled social environmental system to deal with climate change or the current pandemic will depend to a large degree on the resilience of the system. Water plays a key role in the capacity of the system to deal with the different threats. In the case of COVID-19, the flow of tourists stopped abruptly; as we write this chapter, approximately 70% of the economy of the islands has collapsed. In the urban areas, the collapse of the economy could mean that people no longer can afford to purchase clean water for cooking and drinking, and climate change could increase this problem even further. For the agricultural sector, water relates to assuring food security especially as the financial resources coming from tourism disappear and people become more dependent on locally produced food. Although climate change and COVID-19 have two very different time profiles, one being intense and most probably short lived and the other one being less intense but more long term, climate change could further threaten a system that has seen its resiliency already challenged. In the case of the urban sector, climate change can cause disruptions on the water supply and flooding with the consequent destruction of the infrastructure. Although the lack of tourists could mean short-term gains from the point of view of the natural ecosystems, there are also reasons to fear that in the long term, COVID and climate change could mean more trouble for the islands as they affect the flow of tourists. These can cause a vicious cycle as the decreasing number of tourist could result in unemployment and the revival of old threats such as illegal shark finning and sea cucumber gathering and the intensification of new ones such as the contraband of some emblematic species such as baby tortoises will further diminish the amount of nature-loving tourists that go to the islands.

Water is a key aspect of every socio-ecological system as it mediates between the natural and the human dimensions. We have seen that, by affecting the water supply and creating both excess or lack of water, both the biological and the human's systems can be affected. Although the effects of climate change may be difficult to predict, improvements in the material as well as the social and cultural conditions of the local communities may increase their resilience of the socio-ecological system and thus their chances of surviving new perturbations such as COVID-19 or climate change. Lack or excess of water will probably be one of the main challenges to fight both climate change and COVID-19. Improving water infrastructure to secure water quality and quantity such as reservoirs, flood control systems, and waste and potable water treatment plants are essential for the long-term socioecological resilience.

3.5 Conclusions

Galapagos' ecological and socials systems are evolving and changing at an accelerated rate. Disruptions threaten the resilience of the systems, and the residents must constantly adapt to the new conditions. This context of uncertainty and rapid transformation requires resilient, flexible, and adaptive systems that can rapidly accommodate to new conditions. The sustainability of Galapagos' unique ecosystems and the unique but fragile flora and fauna have started facing two very serious challenges in their recent history. In order for the current way of life of the Galapagos residents to survive, measures need to be taken to guarantee the long-term sustainability of the current system. The well-being of the local residents will guarantee the well-being of the unique environments that guarantee the flow of tourists. Water is a key element to guarantee both the viability of the agricultural sector and the health of the urban population. It is important that solutions to the current water situation are found. These solutions will not only require injecting more funds to the system, for as we have seen, the money per se is not always the main limitation and in some cases it may constitute a problem as it increases corruption and lack of trust. Instead changes in the political and social institutions could guarantee more accountability and better monitoring of the people involved in implementing the different measures.

Results suggest that although relatively large amounts of money have been allocated to increase the adaptive capacity of the Galapagos to water management in the context of climate change, much of these funds have not been actually adequately executed. There are different reasons for this to occur. However, transparency and accountability of funds and projects are key for the Galapagos socio-ecosystems to deal better with climate change. The systems in the Galapagos are characterized by mistrust and lack of open transparent and institutions. Information about the sources of funding and the way they are used are not readily available. Projects are often announced and then later cancelled or only executed in the incomplete manner. This has led to the current situation in which people have very little trust in the governmental and nongovernmental institutions that have failed to a large extent to implement realistic and effective solutions to the pressing issues related to the management and the availability of water of good quality both for the rural and the urban sector.

The presence of COVID-19, although not directly related to climate change, has resulted in a series of consequences in the islands. The principal one is the collapse of the tourism industry and thus of the Island economy. The long-term effects of the changes that the new pandemic is bringing will probably not be clear for many years, but resources to invest in adaptive measures to deal with possible effects of climate change and the water system will probably be restricted, and the resilience of the socio-ecological system will be lowered. We believe that well-directed and efficient investments in adaptive measures to climate change and pandemics, new infrastructure development, and the improvement of the capacity of the local communities to deal with these new challenges will be essential to assure the sustainability of these unique socio-environmental systems.

Apppendix

Table A1 Government plans and funding addressing climate change and water quantity issues in Santa Cruz, San Cristobal, and Isabela islands. The amount invested on each island for these plans are not specified

Initiative	Funding allocation	Year	Project status	PDOT description
Infrastructure	$ 528,474	2015	Executed	Design and assist in the implementation of an efficient, equitable, and sustainable integral mobility system in the province of Galapagos that guarantees the well-being of the population and the improvement in the quality of life of its inhabitants. Implement an alternative and sustainable mobility system. Responsible: Consejo de Gobierno del Régimen Especial de Galápagos (CGREG)
	$ 41,379	2016	94% executed by Dec.31, 2016	*Program: Infrastructure maintenance due to El Niño event*. Mitigation actions for impacts caused by the strong precipitation events. Responsible: CGREG
	$ 4,124,068	2016	99% executed by Dec.31, 2016	Reconstruction and maintenance of road network damaged due to El Niño, provide preventive maintenance to the roads and build infrastructure to mitigate impacts caused by the strong precipitation events. Responsible: CGREG
	$ 1,536,237	2015 2016	Executed	*Program: Sustainable infrastructure*.
				*Project 1.*Redesign, improve, and adapt ten docks along the visiting sites network
	$ 461,715	2017		*Project 2.*Redesign according to sustainable and safe infrastructure 15 visiting places from the ecotourist public use network of the Galapagos protected areas. Responsible: Galapagos National Park (PNG)

(continued)

Table A1 (continued)

Initiative	Funding allocation	Year	Project status	PDOT description
Research	$ 49,550	2015	Executed	Consulting studies to define areas of hydrogeological interest and exploratory drilling. Responsible: CGREG
Community	$ 222,810	2013	Executed	Training processes to improve the knowledge and economy of the population: Training for permanent and temporary residents on conservation of natural resources, environmental protection, and sustainable development. Responsible: CGREG
	$ 5,005,277	2017	95% executed by Dec.31, 2017	*Program: Sustainable development for Galápagos* *Project 1.* Stabilize population though optimal migration control and residency management in Galapagos *Project 2.* Plan, regulate, and control mobility within Galapagos *Project 3.* Increase and improve the road system in non-urban zones *Project 4.* Guarantee sustainable development of islands ecosystems through planification and land use. Responsible: CGREG
	$ 3,881,924	2018	99% executed by Dec.31, 2018	
	$ 12,217,866		59% executed by Dec.31, 2018	
	$ 3,745,605	2019	44% executed by Sept.30, 2018	
	$ 4,271,067		42% executed by Sept.30, 2018	
	$ 16,466,228		10% executed by Sept.30, 2018	
Total Invested	**$ 52,552,199**			

Sources: (a) "Plan Operativo Annual (POA)") (CGREG 2019); (b) Santa Cruz 2012–2027 (d'Ozouville et al. 2010; Larrea and Di Carlo 2011) (Gobierno Autonòmo Decentralizado Municipal de Santa Cruz 2012); (c) San Cristobal 2012–2016 (Gobierno Autonòmo Decentralizado Municipal de San Cristobal 2012), and; (d) Isabela 2012–2016 (Gobierno Autonòmo Decentralizado Municipal de Isabela 2012

Table A2 Government plans addressing climate change and water quantity issues in Santa Cruz Island

Initiative	Funding allocation	Year	Project status	PDOT description
Research	No information	2017	Running	Weather station: Measure and record various meteorological variables. Data used in numerical methods to predict future weather and climatic studies. Responsible: Charles Darwin Foundation (CDF)
	No information		Proposed	Contract for the monitoring of gases emitted to the atmosphere
Policy	$228,184	2012	Executed	Integrated water resource management plan to address future water scarcity. Responsible: Gobierno Autónomo Centralizado (GAD) Santa Cruz
	$20,000	2014	Proposed	*Program: Natural Risk Management Program*: *Project 1*: Risk drills to reduce the high threat level of the ecosystem vulnerability index to climate change to 23% and 69% until 2013. Responsible: Secretaría Técnica de Planificación y Desarrollo Sustentable (STPDS)
	$85,000	2014	Proposed	*Project 2*: Update the contingency plan (70% of funding), alert system (18% of funding); training (12% of funding). Responsible: Dirección de Obras Públicas (DOOPP)
	$37,000	2014	Executed	*Project 3*: risk simulations
	$35,000	2015	Proposed	*Project 4*: risk simulations (57% of funding) and early warning system (43% of funding). Responsible**:** STDPS-GR; DOOPP
	$268,970	2012–2013	Executed	Implement infrastructure for the capture, storage, and use of rainwater in the rural sector. Reservoirs in Miramar and Bellavista. Water tank in Santa Rosa. Responsible: GAD Santa Cruz
	$70,000,000	2013–2016	Executed	Implementing storage capacity for superficial water delivery to the agricultural sector (reservoirs and integral sewage and potable water system for Bellavista) and urban developments (Puerto Ayora and El Mirador)

(continued)

Table A2 (continued)

Initiative	Funding allocation	Year	Project status	PDOT description
Infrastructure	$17,000	2014 2015	Proposed	*Program: Natural Risk Management Program:* *Project 1*: risk signage to reduce threats and natural vulnerabilities Responsible: DOOPP. *Project 2*: for the study and design of the hiking road between Punta Estrada and Puerto Ayora. Responsible: STPDS
	No information	2016	Proposed	Implement storage capacity for superficial water delivery to the agricultural sector
	No information		Proposed	Maintenance of artificial wetlands
	$120,000	2014-2015	Proposed	*Program: Safety for all:* Relocate hospital and other institutions located in vulnerable areas. Risk management. Decrease vulnerability to natural disasters. Early warning system. Risk management training and simulation. Responsible: DOOPP -RIES, STPDS-RIES, DOOPP-STPDS, DOOPP-OOPP-RIES
	$37,000	2015	Executed	*Program: Safety for all:* Risk simulations
	$414,965	2016	Executed	Construction of 46 micro reservoirs for irrigation. Responsible: MAGAP
	$80,000	2019	Executed	Construction of a roof cover for the food area of the municipal market to provide protection against the effects of the climate. Responsible: Urban Planning and Land Management
	$60,000	2019	Proposed	Project: Acquisition of a weed crushing machine for the strengthening of the integral solid waste system. Responsible: Dirección de Gestión Ambiental
	$11,200	2019	Running	Consultancy for the construction of phase 2 of the landfill. Responsible: Dirección de Gestión Ambiental
	$15,200	2019	Executed	Contract for environmental audit of the construction and operation of the landfill project. Responsible: Dirección de Gestión Ambiental
Capacity building	$10,000	2016	Proposed	Ensure capacity building in the agricultural industry for food security

(continued)

Table A2 (continued)

Initiative	Funding allocation	Year	Project status	PDOT description
Community	$35,000	2019	Executed	Environmental education campaign including budget for communications. Responsible: Dirección de Gestión Ambiental
Total invested		**USD $ 70,127,519**		
Total proposed		**USD $ 347,000**		

Source: Santa Cruz 2012–2027 (Gobierno Autonòmo Decentralizado Municipal de Santa Cruz 2012)

Table A3 Government plans addressing water quality issues in San Cristobal Island and Isabela Island

Initiative	Funding allocation	Year	Project status	PDOT description
Policy	No information			**San Cristobal:** Natural Disaster Risk Management Program: Create a risk management control plan considering vulnerable areas for natural disasters and re-zoning
	$ 350,000	2012	Proposed	**San Cristobal:** Integrated Water Management: Retaining walls for "Frio and Playa de Oro" neighborhoods. Watershed monitoring and management. Responsible: GAD San Cristobal, Ministerio del Ambiente del Ecuador (MAE), ONG's
	$ 500	2016	Executed	**San Cristobal:** Provision of supplies for the implementation of strategies to face the alert decreed by El Niño events. Responsible**:** GAD San Cristóbal, Secretaría Técnica de Discapacidades
	No information	2016	No information	**San Cristobal:** Risk management 2016: Construction and application of prevention strategies to focus efforts on strategies against the risks of atmospheric and ocean origin. Responsible**:** GAD San Cristóbal
	No information			**Isabela:** Risk and Security: Develop a manual for natural risk management
	$1,500,000	2012	Proposed	**San Cristobal:** Water storage and distribution for agricultural sector. Responsible: GAD San Cristobal, Ministerio de Agricultura y Ganadería (MAGAP), CGREG

(continued)

Table A3 (continued)

Initiative	Funding allocation	Year	Project status	PDOT description
Infrastructure	$ 2,400,000	2014	Proposed	**San Cristobal:** Program for water conservation and management: construction of storm sewer networks. Responsible: GAD San Cristóbal, MIDUVI, ONG's
	$ 41,379	2016	Executed	**San Cristobal and Isabela:** Execution and maintenance of infrastructure and public works. Maintain the infrastructure that has been damaged due to the El Niño event. Provide preventive maintenance to public works to mitigate the negative impacts caused by torrential rains. Responsible**:** Consejo de Gobierno del Régimen Especial de Galápagos (CGREG)
	$ 4,124,068	2016	Executed	**San Cristobal and Isabela:** Reconstruction and maintenance of road network damaged due to El Niño, provide preventive maintenance to the roads and build infrastructure to mitigate impacts caused by the strong precipitation events
	$ 712,068	2016	Executed	**San Cristobal and Isabela:** Construction of 53 micro reservoirs in San Cristobal and 26 micro reservoirs in Isabela. Responsible: MAGAP
	$ 1,997,952	2015–2017	Executed	**San Cristobal and Isabela:** Design and build sustainable infrastructure. 1. Redesign, improve, and adapt ten docks along the visiting sites network. 2. Redesign according to sustainable and safe infrastructure 15 visiting places from the ecotourist public use network of the Galapagos protected areas. Responsible: Galapagos National Park (PNG)

(continued)

Table A3 (continued)

Initiative	Funding allocation	Year	Project status	PDOT description
Community	No information			**San Cristobal:** Consolidate plans for ecological urban centers
	$ 5,005,277	2017	Executed	**San Cristóbal and Isabela:** Sustainable social and productive development in Galapagos. Responsible: CGREG
				1.Stabilize population though and optimal migration control and residency management in Galapagos. Plan, regulate, and control mobility within Galapagos
	$ 3,032,803	2018		2.Increase and improve the road system in non-urban zones. Guarantee sustainable development of islands ecosystems through planification and land use
	No information			**Isabela:** Build an agroforestry and silviculture system starting with education about climatic consequences
Capacity Building	No information			**Isabela:** Capacity building in technology for farmers
Research	No information			**Isabela:** Develop hydrogeological studies and inform farmers of crop rotation
Total invested	**USD $ 14,914,137 for both islands. Additional $500 for San Cristobal only**			
Total proposed	**USD $ 4,250,000 for San Cristobal only**			

Sources: San Cristobal 2012–2016 (Gobierno Autonòmo Decentralizado Municipal de San Cristobal 2012) and Isabela 2012–2016 (Gobierno Autonòmo Decentralizado Municipal de Isabela 2012)

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Chapter 4
Water Quality and Access in Isabela: Results from a Household Water Survey

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Abstract Contaminated water represents one of the major health threats for the inhabitants of Puerto Villamil, Isla Isabela, Galápagos. Water supply on this island depends on brackish groundwater as the main drinking water source. Historically, drinking water quality has been one of the main concerns of the population. This has encouraged the habit of using bottled water as a drinking source and even a cooking water source for most people. In July 2019, an observational pilot study was conducted, focused on analyses of survey data and physicochemical and microbial (total coliforms and *Escherichia coli*) water samples from 35 households spread across town and from the municipal desalination water treatment plant. Two samples were taken at each household, one from tap water and a second from the main drinking water source. In situ parameters such as pH, conductivity, dissolved oxygen, temperature, and salinity were recorded at each sampling point. Results show minimal treatment by the municipal desalination plant with testimonial evidence that current infrastructure is insufficient to meet the water demands of Puerto

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Villamil. All households had total coliforms confirmed in the tap or drinking water source (n = 35), indicating environmental contamination. Ten households exceeded national and international guidelines for *E. coli* coliforms in drinking water, but most tap and drinking water samples tested positive for *E. coli* at concentrations <10 MPN per 100 mL. Physicochemical measurements indicated high salinity, conductivity, and pH in tap water piped to households was similar to that of high levels of water at the treatment plant, although within international guidelines. This pilot study provides comparisons of the water environment on Isabela to that of other islands in the Galápagos and insights on future actions that authorities and inhabitants can take to improve water security.

Keywords Water security · Water quality · Heavy metals · Salinity · Household survey

4.1 Introduction

Inadequate supply of clean water is a major contributor to health disparities worldwide and is of particular concern in tropical island settings that have limited freshwater resources. Water is a foundational component of life, crucial for many hygiene and health-related activities. The health risks associated with contaminated water are well-established and have been linked to gastrointestinal and diarrheal diseases (Cairncross et al. 2010; Fewtrell et al. 2005; Wolf et al. 2014), childhood stunting (Checkley et al. 2008; Danaei et al. 2016), maternal mortality (Benova et al. 2014), and psychological well-being (Bisung and Elliott 2017; Hirve et al. 2015; Wutich and Ragsdale 2008). Water security, here defined as "the capacity of a population to safeguard sustainable access to adequate quantities of acceptable quality water," is recognized as a global priority as part of the United Nations Sustainable Development Goals (United Nations 2015).

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Islands, particularly those located in tropical and subtropical regions, have unique climatic and physical conditions that often lack sustainable freshwater resources. Small volcanic islands, including the Galápagos islands located nearly 1000 km west of mainland Ecuador, are particularly vulnerable to water scarcity (Reyes et al. 2016). Research in the Galápagos has mainly focused on the rich biodiversity adapted to the arid island climate and isolation, with little attention given to the growing human population on the islands, especially the residential population. The Galápagos have had widespread issues related to water and health for decades (Gerhard et al. 2017; Liu and D'Ozouville 2013; Ochoa-Herrera et al. 2014; Reyes et al. 2016; Walsh et al. 2010). San Cristóbal is the only island with available surface freshwater sources in the highlands, El Cerro Gato and La Toma, which are treated by two drinking water treatment plants, Las Palmeras and El Progreso, respectively (Gerhard et al. 2017; Grube et al. 2020). A recent study demonstrated that high-quality drinking water is generally produced in San Cristobal's municipal treatment plants, but *E. coli* was detected in 2–30% of post-treatment samples, suggesting contamination or re-growth during distribution and storage (Grube et al. 2020). The other islands with sizeable human populations, Santa Cruz and Isabela, rely on brackish groundwater for their water needs (Reyes et al. 2016; Walsh et al. 2010). The absence of drinking water infrastructure in Santa Cruz is one of the main water issues in the island. In addition, the basal aquifer proximity to urban area and the seawater intrusion and inefficient wastewater treatment have negatively affected the water quality of groundwater sources in Santa Cruz (Cristina Mateus et al. 2019).

Isabela is the youngest but largest island in the Galápagos on the western edge of the archipelago. A seahorse-shaped, volcanically active island formed from a geothermal hotspot in the Nazca plate, Isabela is famed for its natural beauty and the unique life found there (Bassett 2009). Isabela has the smallest population of the three main human-settled islands in the Galápagos with around 2344 permanent residents (Insitituto Nacional de Estadistica y Censos (INEC) 2015). Most residents are concentrated in Puerto Villamil, a small, low-elevation town on the southern coast. Puerto Villamil was founded in 1893 as a penal colony with fewer than 200 people but has maintained steady growth since the 1970s from economic opportunities in the fishing and tourism industries (Galapagos Conservancy 2020). Advertisements for snorkeling and highland excursions line the streets around town, targeting the island's more than 106,000 annual visitors (Izurieta and Wukitsch 2016). Tourism has had a significant impact on the town with a growth of 336% in accommodations and tourism-related businesses from 2007 to 2015 (Izurieta and Wukitsch 2016). This increasing human presence from population growth and tourism strains the limited water resources available on the island, resulting in residents' concern for availability and quality of clean water in the future (Houck 2017; Nicholas et al. 2019; Page et al. 2013; Walsh et al. 2010).

Rainwater on Isabela collects in underground aquifers forming a freshwater layer that sits on top of more dense, infiltrated seawater, forming a brackish water

source requiring treatment for domestic use (Guyot-téphany et al. 2013). In 2014, a reverse-osmosis desalination plant was built on Isabela to treat this brackish groundwater and consistently produce drinking water for the island (Liu and D'Ozouville 2013). The desalination plant is managed by the municipality and uses two cells of membranes to filter water from La Poza San Vicente in the El Chapin region, but only one membrane remains functional (Mateus et al. 2020). Water from this region is pumped to two 300 m^3/day storage tanks, treated, and distributed throughout Puerto Villamil for 3 h in the morning and 3 h in the evening. However, treated water runs out before the 3 h are completed and untreated water continues to be pumped (Mateus et al. 2020). The municipality has plans to incrementally increase the size of storage tanks, but funding and potential issues with the effectiveness of water treatment (reported here) and the maintenance of the piping system (including sea water intrusion, leaks in home piping, and other issues) stand as barriers to improvement (personal communications with the municipality, 2019).

Our research team was encouraged to come to Puerto Villamil by residents who have routinely expressed concerns with their water. A previous study on Isabela found that 12 of the 20 mothers interviewed cited water as a significant issue in their lives, with one mother saying, "I wish you could take a sample of the tap water to a lab. It isn't even acceptable, even to bathe with" (Page et al. 2013). Other studies have reported that up to 70% of illnesses in Puerto Villamil may be related to contaminated water (Walsh et al. 2010). Inconsistent water availability in the Galápagos has led many households to invest in roof tanks and cisterns to store water. This long-term storage can increase the risk for contamination and has been associated with water-related diseases (Clasen and Bastable 2003; Houck et al. 2020). Many residents in the Galápagos rely on water sources outside the municipality for drinking and cooking, often purchasing bottled water to meet their needs. Research on Isabela has been limited because of its smaller population and greater isolation relative to the rest of the Galápagos archipelago, resulting in minimal information known about the state of the water environment and its relationship with the people who live there.

In summer 2019, a pilot study was conducted on Puerto Villamil, Isabela, Galápagos, to (1) profile household tap and drinking water through tests for fecal indicator bacteria and physicochemical measurements, (2) contextualize residential water insecurity using household observation and survey data, and (3) profile water provided by the municipal water treatment plant through tests for fecal indicator bacteria and physicochemical measurements. This work aims to build on previous investigations into the water environment of the Galápagos. It will also help inform authorities, decision-makers, inhabitants, and researchers on potential areas for interventions and in-depth study.

4.2 Methods

4.2.1 Study Location and Population

Data for this research was collected during June–July 2019 in Puerto Villamil, Isabela, Galápagos, by researchers from the Galapagos Science Center (GSC), University of North Carolina at Chapel Hill (UNC-CH), and Universidad de San Francisco de Quito (USFQ) in conjunction with the municipal government of Isabela. This research is part of a larger study on the dual burden of disease in the Galápagos related to food, water, and psychological well-being. Data included point-of-use water sampling (n = 70) and individual survey results (n = 106) from 35 households. Municipal workers initially identified three households from each of the 14 neighborhoods of Puerto Villamil interested in participating, and additional households were recruited via convenience sampling.

This study was approved by Institutional Review Boards at the University of North Carolina at Chapel Hill and USFQ. All participants gave written consent through provided English and Spanish consent forms prior to data collection. Microbial water quality results from this study were reported to the municipal government, and individual households received results from their own samples along with appropriate household treatment recommendations based on World Health Organization (WHO) guidelines (World Health Organization 2017).

4.2.2 Household Water Sampling

A total of 84 water samples from 35 households (n = 70), municipal treatment plant operative units (n = 12), and controls (n = 2) were collected for fecal indicator bacterial, physicochemical, and metal analyses. Sterile 120 mL vessels were used to collect two samples from each household, one from a tap water source and a second from the principal drinking water source used by the household (Table 4.1). For metal analyses, 30 mL of each sample were filtered using 0.45 μm syringe filters and preserved in a 2% nitric acid concentration in plastic bottles. The main household drinking water sources in this study were three bottled water providers (54%), bottled water directly from the treatment plant (9%), self-filtered tap water (9%), and rainwater collected from the highlands (6%). Many households did not disclose their drinking water provider (23%). In situ parameters for each source were measured during the initial meeting with each household. Microbial analysis required samples to be processed within 12 h of collection, with the requisite infrastructure set up in the Water Quality Laboratory at the Galápagos Science Center (GSC) on San Cristóbal Island. Households were sampled a single time during five morning 4-h collection periods in early July. Twelve samples were also collected from the operative units of the municipal desalination water treatment plant on two separate days: the groundwater source (n = 2), untreated tank filling station (n = 1), plant

Table 4.1 Drinking water sources of sampled households (n = 35) Puerto Villamil, 2019

Source	n	(%)
Private bottled water provider 1	8	(22.9)
Private bottled water provider 2	7	(20.0)
Private bottled water provider 3	4	(11.4)
[a]Municipal bottled water	3	(8.6)
Filtered tap water from municipality	3	(8.6)
Rainwater from the highlands	2	(5.7)
Did not know provider/chose not to disclose	8	(22.9)

[a]Some municipal treatment plant workers directly bottled water at the plant

influent tank (n = 2), plant effluent tank (n = 4), and bottling tank (n = 3). Bottled water purchased from local stores served as controls for microbial analyses. After each collection period, a cooler with the samples, controls, and icepacks were sent by plane to San Cristóbal for collection and same-day processing at the Water Quality Laboratory at the GSC.

Each water sample was analyzed for fecal indicator bacteria including total coliforms and *Escherichia coli* (*E. coli*) using the IDEXX Colilert-18 method (IDEXX Laboratories 2017) as described previously (Grube et al. 2020). Colilert media and 100 mL of each sample were combined in a Quanti-Tray/2000, sealed by an IDEXX Quanti-Tray Sealer, and incubated at 35 °C for 18 h. After incubation, wells were counted for yellow coloration indicating total coliform presence and fluorescence under UV light indicating *E. coli* presence. Total coliform and *E. coli* enumeration followed manufacturer guidelines to estimate the most probable number (MPN) per 100 mL sample based on a Poisson statistical distribution (IDEXX Laboratories 2017).

All sources were also analyzed for in situ parameters including temperature, dissolved oxygen (DO), conductivity, salinity, and pH. A YSI ProDSS handheld water quality meter (Yellow Springs OH, USA) was used to collect measurements from a sterilized container filled with water from each source. Measurements were recorded three times and averaged for each sample.

Metals dissolved in water were analyzed using an adapted APHA (American Public Health Association) 3500 method. Filtered and acidified samples were analyzed using a Thermo Scientific iCAP 7400 ICP-OES at the Laboratory of Environmental Engineering at USFQ (LIA-USFQ). Calibration curves were constructed employing a 100 mg/L multi-element standard solution 6 for ICP, grade Trace CERT (Sigma Aldrich, St. Louis, MO, USA). Blank samples with at least 8 replicates were analyzed to obtain the standard deviation which was multiplied by 3 to obtain the limit of detection (LD) and by to 10 to obtain the limit of quantification (LQ). Quality control for metal analysis was conducted by employing a NIST

certified reference material (CRM 1640a) (NIST, Gaithersburg, MD, USA) every ten samples (Table S1). The recovery percentages were calculated to determine the matrix effects and to measure the accurateness of the method. All the concentrations of metals were corrected based on the percentage of recoveries obtained in each analysis, ranging from 91% to 102%.

4.2.3 Individual Household Surveys

All members of households included in water sampling were asked to complete a survey, with a parent filling out the survey for children and adolescents under the age of 15. Open Data Kit software (ODK 2019) was used to code, collect, and back up surveys and results. Survey sections were adapted from previous research on San Cristóbal, other studies in similar contexts, and validation studies for survey tools in similar contexts. Survey items included de-identified household and sociodemographic information, followed by questions on water access, security, practices, and perceptions related to household and community water. The questionnaire included an adapted water security scale from the Household Water InSecurity Experiences (HWISE) scale (Young et al. 2019).

The self-identified head of household answered questions related to water security, practices, and perceptions. Extensive efforts were made to include as many household members as possible in the study, sometimes going to a work site or returning to a home multiple times to finish incomplete surveys. A total of 65 adults out of 106 total participants from 34 of the 35 study households completed the survey (Table 4.2).

4.2.4 Data Analysis

Data was processed in spreadsheets where it was cleaned and aggregated into a single file. Data was imported into SAS version 9.4 (Cary, NC) for analysis. Standard errors are included for physicochemical parameters and microbial analyses. Microbial results below the lower limit of detection (LLOD) due to IDEXX testing were assigned a value of $\frac{\text{LLOD}}{\sqrt{2}}$ (0.7 MPN per 100 mL); results above the upper limit were assigned a value of the upper limit (2491.6 MPN per 100 mL). The data was log-transformed to better model a normal distribution. These adjustments were made by following common methods (Finkelstein and Verma 2001; Gerhard et al. 2017; Grube et al. 2020) in an effort to include microbial results outside of the quantification range for the Colilert test in estimations of fecal contamination of community water. World Health Organization guidelines for Drinking Water Quality (DWQ) were consulted for health risks associated with *E. coli* and total coliform concentrations (World Health Organization 2017).

Table 4.2 Characteristics of adult survey participants (n = 65) collected from 34 sampled households in Puerto Villamil, Isabela, 2019

	n	%
Gender		
Female	38	58.5
Male	27	41.5
Highest education		
None	1	1.5
Primary	12	18.6
Secondary	48	73.8
Post-secondary	4	6.1
Income range		
1 basic salary	16	47.1
2–5 basic salaries	15	44.1
>5 basic salaries	3	8.8
Ethnicity		
Mestizo	54	83.1
Other	11	16.9
Birth location		
Galapagos islands	30	46.2
Mainland Ecuador	30	46.2
Other	5	7.7
Marital status		
Married	38	58.5
Other	27	41.5
Children		
Has children	56	86.2
No children	9	13.8
Age of all participants (n = 106)		
<5	10	9.4
5–17	31	29.2
18–64	59	55.7
>65	6	5.7

4.3 Results

4.3.1 Water Quality

Fecal indicator bacteria were measured in tap (one sample) and drinking water (one sample) sources from 35 households in Puerto Villamil and 12 samples from the water treatment plant. Total coliforms were measured at concentrations above

the LLOD (1 MPN per 100 mL) in 93% (n = 65) of total samples and *E.coli* in 33% (n = 23) of total samples. Tap water sources had a higher geometric mean for total coliforms ($\bar{x}$ =804 MPN per 100 mL) compared to drinking water sources ($\bar{x}$ =135 MPN per 100 mL). The geometric mean for *E. coli* was low in both household tap ($\bar{x}$ =1.04 MPN per 100 mL) and drinking ($\bar{x}$ =1.08 MPN per 100 mL) water samples. *E. coli* was detectable in 29% (n = 10) of drinking water samples, 37% (n = 13) of tap water samples, and 54% (n = 19) of total households. The associated health risk from *E. coli* contamination is shown in Table 4.3. Based on WHO drinking water quality guidelines, any drinking water sample with *E. coli* concentrations >1 MPN per 100 mL is considered unsafe (World Health Organization 2017). According to this criterion, most household drinking water samples were considered low health risk (71%), with a smaller proportion at medium (26%) and high (3%) risk. Samples from the water treatment plant had a high geometric mean for total coliforms (source, $\bar{x}$ = 117; influent, $\bar{x}$ = 1414; effluent, 1916 MPN per 100 mL) with *E. coli* levels below the LLOD in all but one sample from the groundwater source (2 MPN per 100 mL). No coliforms of either type were detected in controls.

4.3.2 Physicochemical Parameters

The conductivity of tap water ($\bar{x}$ =1190, σ = 210 μs/cm) was much higher than that of drinking water ($\bar{x}$ =110, σ = 270 μs/cm), and the salinity of tap sources (μ = 0.59, σ = 0.10 ppt) was 0.57 ppt higher than that of drinking water (μ = 0.05, σ = 0.14 ppt). The pH, temperature, and DO content were also higher in tap water sources compared to drinking water. Results from the water treatment plant showed similar physicochemical measurements at the source, pre- and post-treatment. Physicochemical characteristics of both household and water treatment plant samples are displayed in Table 4.4.

Table 4.3 Health risk associated with *E. coli* concentrations in tap and drinking water from households (n = 35) in Puerto Villamil, Isabela, 2019

Health risk[a]	Drinking water		Tap water		Drinking or tap water[b]	
Low	25	(71%)	22	(63%)	16	(45.7%)
Moderate	9	(26%)	12	(34%)	17	(48.6%)
High	1	(3%)	1	(3%)	2	(5.7%)

[a]Associated health risk based on WHO (2017) DWQ guidelines determined by *E. coli* concentration: low (<1 MPN per 100 mL), moderate (1–10 MPN per 100 mL), and high (>10 MPN per 100 mL)

[b]The highest *E. coli* concentration from the drinking or tap source for each household was used to calculate the combined risk

Table 4.4 Microbiological and physicochemical results of drinking and tap water samples from surveyed households (n = 35) and municipal water treatment plant samples (n = 12) in Puerto Villamil, Isabela, 2019

Parameters	Units	WHO limits[a]	Household (drinking)		Household (tap)		Treatment plant (source)		Treatment plant (influent)		Treatment plant (effluent)	
			Mean	σ	Mean	σ	Mean	σ	Mean	σ	Mean	σ
Temperature	°C	No guideline	23.1	4.53	25.8	3.40	25.2	2.76	24.9	2.11	25.0	2.80
DO	mg/L	No guideline	7.96	0.37	8.09	0.31	7.15	0.09	8.01	0.08	7.67	0.06
Conductivity	µs/cm	1660	110	270	1190	210	1200	290	1110	260	1190	300
Salinity	ppt	No guideline	0.05	0.14	0.59	0.10	0.56	0.15	0.50	0.11	0.60	0.11
pH	pH	6.5–9.5	7.04	0.49	7.86	0.26	7.82	0.34	7.88	0.31	7.84	0.30
TC	$\log_{10}$ MPN	0.00	2.13	1.11	2.98	0.49	2.07	1.68	3.15	0.60	3.28	0.14
E. coli	$\log_{10}$ MPN	0.00	0.03	0.44	0.09	0.30	0.09	0.12	0.00	N/A	0.00	N/A

[a]Maximum permissible level of measurement from WHO drinking water quality guidelines (World Health Organization 2017)

Table 4.5 Metals of interest concentrations in drinking and tap water samples from surveyed households (n = 35) and municipal water treatment plant samples (n = 12) in Puerto Villamil, Isabela, 2019

Parameters	Units	WHO limits[a]	Drinking water		Tap water		Treatment plant (effluent)	
			Mean	σ	Mean	σ	Mean	σ
Copper	µg/L	2000	34.33(n = 18)	10.19	26.68(n = 34)	17.24	10.20(n = 12)	5.31
Chromium	µg/L	50	13.25(n = 6)	11.47	8.73(n = 5)	7.57	11.89(n = 1)	0.89
Barium	µg/L	1300	6.36(n = 9)	2.27	–	–	–	–
Nickel	µg/L	70	–	–	6.08(n = 2)	1.00	–	–

[a]Maximum permissible level of measurement from WHO drinking water quality guidelines (World Health Organization 2017)
n represents the number of samples with reported values above the limit of quantification (LQ)

4.3.3 Metal Analyses

Measurements of metals of importance according to the WHO guidelines are shown in Table 4.5. Only a limited number of samples reported values higher than the limit of quantification (LQ) for copper, chromium, barium, and nickel. All measurements for arsenic were below the detection limit (LD = 6.73 mg L^{-1}), with a WHO established limit of 0.01 mg/L. Similar scenarios were found for cadmium, with all samples being below the detection or quantification limit (LD = 0.87 µg/L, LQ = 1.01 µg/L, WHO limit = 3 µg/L), and lead (LD = 5.23 µg/L, LQ = 17.43 µg/L, WHO limit = 10 µg/L).

4.3.4 Household Water Insecurity

Of the 34 households that filled out the survey, 32 completed the section on water insecurity (Table 4.6). The majority of households reported minimal water insecurity based on the adapted HWISE scale, with 3 of the 32 households finishing with a score above 11, the cutoff for water insecurity. Twelve of the households received a score of 0, responding "Never" to all water security questions, and 75% of households scored below 4.

Items with relatively high response variation were further analyzed to understand potential issues with water security and access. Within the prior 4 weeks: 22% of households reported "worrying about not having enough water" often (more than 10 times within the time frame), 31% said that their main water supply had been limited at least once, and 31% responded that someone in their household had been upset with their water situation at least once. When asked to rate their satisfaction with their water situation on a scale from 1 (lowest) to 5 (highest), 34% of households reported a rating of 1, with 75% giving a rating of 3 or below.

4.4 Discussion

This research investigated the water environment in Puerto Villamil, Isabela, Galápagos, through an analysis of household water based on microbiological and physicochemical parameters and security issues. Over half of households tested positive for *E. coli*, including 29% with detectable contamination in the drinking water. This places households in at least "moderate" risk for disease based on WHO DWQ guidelines and drinking water standards set by the Ecuadorian Institute of Normalization (INEN) that state *E. coli* and any fecal coliform bacteria should not be detectable in any 100 mL sample of water directly intended for drinking (Instituto Ecuatoriano de Normalización 2011; World Health Organization 2017).

The mean value for *E. coli* in drinking water on Isabela (1.08 MPN per 100 mL) was similar to values found on San Cristóbal (1.6 MPN per 100 mL) following the construction of their water treatment plant in 2013 (Gerhard et al. 2017). Log-transformed *E. coli* measurements differed slightly from recent results on San Cristobal (Grube et al. 2020). Freshwater source and influent water on San Cristobal had detectable *E. coli*, whereas all source, influent, and effluent sample but one source water sample from Isabela did not. Total coliforms were detectable and high in sources from both Isabela and San Cristobal (95% CI >2.00 $\log_{10}$ MPN per 100 mL); however, effluent and distributed water samples from San Cristobal showed less detected total coliforms (95% CI <1.50 $\log_{10}$ MPN per 100 mL) than effluent and tap water samples from Isabela in this study. The only other external value of *E. coli* concentration in a household on Isabela reported 1011 MPN per 100 mL in a single Isabela household, much greater than concentrations reported here (Lopez and Rueda 2010). *E. coli* concentrations in tap water provided by the

Table 4.6 Household water insecurity (n = 32) question distribution from adapted HWISE scale (Young et al. 2019)

Water security questions	Never	Hardly ever	Occasionally	Often or always
In the past 4 weeks…	(0 times)	(1–2 times)	(3–10 times)	(>10 times)
1. How often were you or a family member worried about not having enough water for all your household needs?	65.6%	12.5%	–	21.9%
2. How often has the water supply for your main water source been interrupted or limited? (e.g., issues with water pressure or had less water than usual)	68.8%	18.8%	6.3%	6.3%
3. How often have you not been able to wash clothes in your home due to lack of water?	78.1%	12.5%	3.1%	6.3%
4. How often did you or someone in your home have to change schedules/plans due to problems with the water situation?	90.6%	3.1%	6.2%	–
5. How often did you or someone in your home have to change what you were eating because there were problems with water?	87.5%	6.3%	3.1%	3.1%
6. How often did you or someone in your family not wash your hands or wash your child's face due to problems with water?	90.6%	9.4%	–	–
7. How often have you or someone in your family had to leave the house without bathing due to problems with water? (e.g., there was not enough water, or the water was dirty)	87.5%	12.5	–	–
8. How often have you or a member of your household not drank as much water as you would like?	87.5%	6.3%	–	6.3%
9. How often have you or someone in your household been upset about the water situation?	68.8%	25.0%	3.1%	3.1%
10. How often have you or someone in your household gone to sleep thirsty because there was no water to drink?	84.4%	6.3%	3.1%	6.3%
11. How often has there been no drinking water in your home?	84.4%	9.4%	3.1%	3.1%
12. How often did water problems cause you or someone in your home to feel ashamed/excluded/stigmatized?	93.8%	3.1%	–	3.1%

Reponses for each item were scored as follows: "Never (0 times)" = 0, "Hardly ever (1–2 times)" = 1, "Occasionally (3–10 times)" = 2, and "Often (11–20 times)" and "Always (more than 20 times)" = 3. Reponses of "I don't know" or "Does not apply" were also given a score of 0 for those items. A cumulative HWISE scale score was calculated for each household by taking the sum of the 12-item scale, with a total of 12 or more indicating household water insecurity

municipality was very similar to drinking water, whereas the total coliform concentrations were drastically higher overall and higher in tap water than in drinking water. Total coliforms are a less specific indicator of fecal contamination than *E. coli* and can originate from environmental contaminants such as leaves, soil, and other animal debris (Liu and D'Ozouville 2013). However, high total coliforms can point to low system integrity that may be at risk for further contamination. In total, 54% and 100% of households had detectable concentrations of *E. coli* and total coliforms in either their tap or drinking water sources, showing high prevalence of community water contamination.

Conductivity and salinity were of particular importance because of long-standing community concerns over untreated and overly salty water. Tap water conductivity was relatively high, yet within applicable drinking water standards from INEN and WHO. Although tap water salinity was much lower than seawater levels (~35 ppt), INEN guidelines state that high levels of salts, bad taste or odor, and other similar issues that could be indicated by physicochemical measurements should not be present in water for drinking (Instituto Ecuatoriano de Normalización 2011). In comparison, drinking water samples from varied sources had much lower conductivity, salinity, and pH levels that were generally acceptable to residents.

Groundwater source, influent, and effluent measurements from the treatment plant on Isabela showed high conductivity, salinity, and pH closely resembling household tap water samples. While results are limited by high variability in the few measurements taken for fecal coliforms, nevertheless, the similarities in physicochemical measurements and contamination levels – especially conductivity, salinity, and pH – between water at the treatment plant and measurements taken when it arrived in household taps indicate minimal effective treatment. No substantial differences between influent and effluent (pre- and post-treatment) samples at the plant were detected, while elevated fecal contamination and physicochemical measurements continued throughout the piped supply, storage in roof tanks and cisterns, and tap dispensing in the home. Effective treatment of water supplied to households from the desalination plant was not observed in this study.

Metal analyses are of significant importance because information about possible sources of contamination can be provided. Naturally occurring elements such as barium and chromium were found to be below the limit established by the WHO guidelines for drinking water (1300 μg L^{-1} for barium and 50 μg L^{-1} for chromium) in drinking, tap, and treatment plant water samples. In the case of arsenic, no information could be obtained because all samples were found to be below the detection limit. Cadmium values were all below the limit of detection or quantification, showing no significant contamination from industrial sources in all the water samples analyzed as expected. Contamination from pipes and fittings was also found to be insignificant as all copper, lead, and nickel values were below the established limits by the WHO guidelines (World Health Organization 2017).

Desalination plants have been recognized as costly and ineffective in many settings around the world (Bhattacharjee 2007; Brady et al. 2009; Ghaffour et al. 2013). Chlorine disinfection was not conducted at the drinking water treatment plant (Personal communications with the municipality, 2019). However, chlorine

disinfection can reduce microbial contamination, and residual chlorine was found to have a negative moderate relationship with microbial contamination on San Cristobal, indicating chlorine disinfection may help reduce the environmental microbial contamination of piped water coming from the municipal treatment plant and being stored at and piped to homes (Grube et al. 2020). Additional expertise in water treatment and engineering are likely needed to consistently produce high-quality drinking water on Isabela Island.

Residents raised abundant concerns about the tap water in surveys, saying that it was not drinkable, untreated, too salty, or dirty or that it would make them sick. All residents instead used other sources for drinking water, most commonly through private bottled water sources and rainwater collection. Residents listed three private companies that filtered water and sold 5-gallon jugs of water around town. Small samples of each source type, hesitancy of households to disclose provider, and inability to collect data from the providers did not allow for further analysis. However, most residents stated they would prefer to receive piped drinking water and that they thought it was the municipality's responsibility to supply household water.

The adapted HWISE scale showed minimal household water insecurity across the study domain. A substantial proportion of households reported having no problems across all items in the scale. However, other survey responses conflicted with these results. When asked directly, 28% of residents responded that they had problems with their water, and 75% were unsatisfied with their water situation. Household water security (75% participating households) may be over-represented in this study because the HWISE scale may have been insufficient for this setting; many items emphasize absolute water quantity, while concerns in the community centered on variability in water quality. Most residents had enough water to perform daily tasks like washing clothes or bathing, yet a third of households worried about having enough water for "needs" like drinking and cooking. While households may have ample water supply most of the time, concerns center on the safety of water for consumption consistent with findings of fecal coliforms within post-treatment tap water supplies. Residents of San Cristobal and Isabela often use roof tanks or cisterns to store water, and on San Cristobal, these storage methods provided for availability yet caused treated water to mix with untreated water during storage because variabilities in contamination of treated water from the plant throughout the day (Grube et al. 2020). Clear issues with confidence in the safety of available water, the cost of procuring water from a private source, and issues with variability in water quality and availability are substantial issues regardless of households being classified as generally water secure based on the HWISE scale and may contribute to psychological stress and related disease (Jepson 2014; Wutich and Ragsdale 2008). This variability may be further exacerbated during times of drought and other low-supply periods not captured in this study.

The results of this study may be limited by a cross-sectional study design including nonrandom convenience sampling with a low sample size. Variance estimates, survey sampling corrections, and the ability to perform statistical tests were impacted by sample size limitations. Previous studies on San Cristóbal have reported

differences in water security according to socioeconomic status and urbanicity (Nicholas et al. 2019). Convenience sampling and partnership with local government included many local businesses and other residents who may have been of a higher socioeconomic status in the study offering potential systematic bias and an underrepresentation of water insecurity prevalence. Participants also showed noticeable survey fatigue, which may have reduced variability in responses.

This research focused on multiple dimensions of the household water environment in Puerto Villamil and offers useful information for future interventions and research. A longitudinal study on water with multiple time periods for data collection might better elucidate other aspects of water insecurity, including seasonality. High seasonal variation in fecal contamination in drinking water, with greater contamination during the wet season, has been relevant in many studies, including work on San Cristobal (Grube et al. 2020; Kostyla et al. 2015). Data for this research was collected during the beginning of the dry season in the Galápagos (June–November), likely underestimating the magnitude of contamination in community water. In the past, there have been reports that some Puerto Villamil residents sometimes dispose of wastewater in volcanic cracks and fissures near their homes (Walsh et al. 2010). During heavy rainfall periods, source groundwater may be exposed to increased runoff resulting in greater contamination.

These issues are further compounded by the inability of the municipal desalination plant to treat and provide enough water for Puerto Villamil. Evaluation of the desalination plant or recommending cost-effective interventions is beyond the scope of this research. However, these results highlight the need for additional measures to safeguard the water and health of residents. This problem will continue to grow in the future with record numbers of tourists visiting the Galápagos each year, putting further strain on the small island's limited resources.

4.5 Conclusion

Fecal indicator tests show high total coliform concentrations in both household drinking and tap water samples but generally low levels of *E. coli*. These results, along with physicochemical data, point to unreliable and ineffective treatment from the municipal desalination plant. Metals are not a concern of contamination in any part of the water system and water consumption on the island. Households reported general water security, but data showed a general dissatisfaction with the current water environment and a desire for safe, potable drinking water provided by the municipality. Almost all households purchased water from small private providers on the island, with high variability in microbial quality that could not be qualitatively assessed in this study. These results highlight the need and desire by residents for additional attention and investment into a sustainable source of potable water in the coming years. Municipality treatment plant operators and other workers suggested increasing the capacity of the desalination plant to meet these needs, but more research is needed to identify a cost-effective and sustainable solution.

Educational interventions for residents supporting behaviors including proper cistern cleaning practices and boiling all water intended for consumption are also recommended in addition to addressing water supply structures.

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Chapter 5
Tourists' Willingness to Fund Improvements of Local Water Services: A Contingent Valuation Study from the Galapagos

William F. Vásquez

Abstract Small islands often lack freshwater and financial resources to satisfy the increasing tourists' demand for safe drinking water. As a result, in many of those tourist sites, water services are frequently interrupted, and tap water is not always safe to drink. That is the case in our study site: the island of Santa Cruz, Galapagos, Ecuador. Under those circumstances, visitor charges may represent an alternative source of financial resources for improving local water services. Using a contingent valuation survey, this study ascertains if tourists are willing to fund improvements of water services in the island of Santa Cruz. Estimation results indicate that the median tourist is willing to make a one-time payment of $45 to install, operate, and maintain the new water system that would continuously provide safe drinking water to tourists and local populations. Policy implications are also discussed.

Keywords Water services · Willingness to pay · Contingent valuation · Responsible tourism · Galapagos Islands

5.1 Introduction

With an average annual growth rate of 5% from 2010 to 2019, tourism has been one of the fastest growing economic sectors worldwide (United Nations World Tourism Organization 2020). This sustained increase in tourism represents an opportunity for the development of local economies and job creation. At the national level, tourism may contribute to government revenues and foreign exchange earnings. However, if not properly managed, tourism may also have negative effects on the

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local economy, culture, and environment (Coccossis 2011; Mason 2015). The tourism industry consumes a significant amount of natural resources to provide tourists with water, food, and energy, among other goods and services. Compared to other tourist destinations, small islands are even more vulnerable to negative consequences from tourism given that freshwater sources are typically scarce in those areas and their overexploitation may result in land subsidence, deteriorating groundwater quality, and saltwater intrusion (Gössling 2001). Under those circumstances, expensive infrastructure (e.g., desalination plants) may be required to satisfy the tourist demand for drinking water (Voivontas et al. 2003). The island of Santa Cruz in the Galapagos archipelago, Ecuador, represents an example of a small island where considerable investments in water infrastructure are required to address freshwater scarcity relative to the increasing tourist demand for water services (Reyes et al. 2018).

In many developing areas, local populations cannot afford investing in water infrastructure that will primarily serve tourists. Yet, tourism has the potential to provide political and financial capital for local development (Buckley 2011). Recent studies have found that tourists are willing to pay for improvements in coastal water quality (Farr et al. 2014; Peng and Oleson 2017), coral reef restoration (Grafeld et al. 2016; Roberts et al. 2017; Trujillo et al. 2016), beach protection (Piriyapada and Wang 2015), and wildlife conservation (Frontuto et al. 2017; Murphy et al. 2018). Together, these studies indicate that tourists value the natural environment of their destinations even if they do not plan to use it in the future. Prior studies have found that such willingness to pay for environmental improvements in tourist sites is related to tourists' preferences for benefiting others (Kumakawa 2016).

Under the premise of responsible tourism (Goodwin 2016), tourists could be willing to pay for improving local water services because they understand that their demand for potable water imposes considerable pressure on local water resources and infrastructure. Yet, few studies, if any, have investigated how tourists would respond to visitor charges as a funding mechanism to install, operate, and maintain water infrastructure that can help satisfy the increasing demand of tourists for potable water. This study aims to fill that gap in the literature by investigating whether visitors are willing to pay for local water service improvements. Using the contingent valuation method, this study elicited how much tourists would contribute to fund an infrastructure project that would provide reliable access to safe drinking water in the island of Santa Cruz, Galapagos, Ecuador. Results indicate that tourists are willing to make a one-time payment of approximately 45 US dollars to fund local water infrastructure projects. Hence, by implementing or increasing visitor charges (e.g., user fees, taxes, and voluntary donations), tourism can generate revenue for improving water services in tourist sites.

The rest of this article is organized as follows. The next section describes the study site, its tourism industry, and current conditions of water services. Then, Sect. 5.3 provides details on our survey design and recruiting procedure. Section 5.4 presents the modeling approach followed in this study. Section 5.5 presents the results. Section 5.6 concludes the paper with policy implications of our findings.

5.2 Study Site

The Galapagos Islands are an archipelago off the coast of Ecuador, known for its singular biodiversity. With an area of 986 km^2, Santa Cruz is the second largest island in the archipelago, and the most populated. The last census reported that the island of Santa Cruz had a population of approximately 15,701 inhabitants in 2015 (INEC 2015). Most of these residents work in the tourism sector, which has significantly increased in the last decades. In the 1960s, an average of 2000 tourists visited the islands annually, hosted by half a dozen ships and hotels. By 2015, the number of accommodations had increased to 291 authorized hotels and 74 vessels (Izurieta 2017). In 2019, the archipelago received almost 271,238 visitors, out of which 72% arrived in the Baltra-Santa Cruz airport (Galapagos National Park 2018).

The increase in tourism and immigrants looking for job opportunities in the tourism industry puts pressure on the environment, particularly on freshwater resources (Reyes et al. 2018). Water stress is even more concerning in the island of Santa Cruz where water availability is limited to brackish water accumulated in crevices in volcanic rocks. Those water sources are insufficient to satisfy a growing demand for drinking water, a majority of which comes from tourists (about 55%). Municipal water services are frequently interrupted, with an average supply of approximately 3 h per day (Reyes et al. 2017). Additionally, there is recent evidence that some water sources are polluted, representing a public health threat (Mateus et al. 2019). From a technical perspective, seawater desalination is deemed as the main alternative to supply drinking water for tourists and locals in the long run (Reyes et al. 2018). Actually, private water vendors and resorts have already invested in small desalination plants (Reyes et al. 2017). However, the local community lacks the resources required to install, operate, and maintain a seawater desalination plant.

As a national park, the Galapagos charges an entrance fee intended for environmental conservation and public services, $100 to each foreign visitor older than 11 years old and $50 to younger visitors. The municipal governments of the Galapagos Islands receive about 25% of those revenues. Yet, those financial resources have not been enough to solve the imbalance between supply and demand for drinking water in the island of Santa Cruz. This represents an acute problem that could potentially be solved by increasing visitor charges and dedicating the additional funds to improve water infrastructure.

5.3 Survey Design and Implementation

When carefully designed and implemented, the contingent valuation (CV) method represents a suitable approach to elicit respondents' willingness to pay for goods and services that are not traded in market settings (Boyle 2017; Carson 2012). An important feature of this survey-based method is that it can estimate non-use values (Birol et al. 2006). The non-use value that tourists assign to improved water services

is particularly important in the context of this study because those tourists would contribute to fund a service even when it is unlikely that they will use it in the future. Therefore, we applied the CV method to estimate tourists' willingness to pay for reliable provision of safe drinking water in Santa Cruz.

We followed best practices to develop a CV scenario in which respondents were presented with the opportunity to assist in financing the installation, operation, and maintenance of a new water system that would continuously provide safe drinking water (see, e.g., Boyle 2017; Gunatilake et al. 2007; Johnston et al. 2017). To design our survey, we conducted an extensive review of scholarly articles and official documents and consulted with domestic researchers with ample experience in the Galapagos' water issues. The survey instrument was administered through in-person interviews to a sample of 175 adult tourists in March 2019.[1] Respondents were selected using a non-discretionary sampling procedure. Three trained interviewers were located in areas where tourists usually agglomerate regardless of their economic status and other sociodemographic characteristics (i.e., piers, beaches, visitor centers, and other tourist sites). Interviewers approached every third person in order to avoid any selectivity bias in the selection of tourists. This protocol produced a nearly random sample of people in selected "democratic areas." Kahn et al. (2017) and Rezende et al. (2015) represent recent examples of survey-based studies that applied a similar sampling procedure in developing country contexts.

Framed as a dichotomous question, the CV scenario began with a description of current water services. Then, respondents were given the opportunity to support a project that would provide safe drinking water without service interruptions. This support consisted of a one-time payment that could randomly vary across respondents from $20 to $100 in increments of $20. Before responding whether they would pay that amount or not, respondents were reminded of their budget constraint to imprint realism to their choice. The CV question presented in the survey read as follows:

> In the last years, the number of tourists and the local population has substantially increased in Santa Cruz, to the extent that the current infrastructure is unable to supply water to visitors and the local community. The water supply is often interrupted, sometimes all day long. Additionally, tap water is unsafe to drink. Suppose that tourists will have the opportunity to give a contribution to finance a project that would improve the quality and quantity of drinking water. The new system would supply treated water for drinking directly from the tap 24 hours a day, every day of the year. To install, operate, and maintain the new water system, a contribution of $ _____ would be asked to each tourist who visits Santa Cruz. Keep in mind that the extra money you pay for water would not be available for other expenses needed during your trip or other needs of your home such as food, clothing, etc. Would you give such contribution to improve the tap water supply in Santa Cruz? (Yes/No)

Follow-up questions were included to measure the certainty levels of respondents regarding their answer to the CV question. As Blumenschein et al. (2008) show, that

[1] Given that tourists are a floating population in a given period of time, we did not compute a sample size a priori. Alternatively, interviewers implemented a non-discretionary protocol to sample as many tourists as possible in the 8 days of data collection.

certainty question can be used to reduce hypothetical biases and thus obtain more precise willingness-to-pay estimates. Additionally, we probed the reasons why some respondents would not contribute to the proposed project in order to identify protest responses. Finally, we included an open-ended question to elicit the maximum amount that sampled tourists would contribute to implement the proposed system.

5.4 Empirical Approach and Variables

Responses to CV questions can be analyzed using a utility-theoretic framework (Boyle 2017). In the context of this study, the main assumption of that model is that the indirect utility (V) of an individual is a function of her income (Y), positive attributes of water services (W), and prices of other goods (P), i.e., $V(Y, W, P)$. Improvements of water services increase the level of utility experienced by the tourist presumably due to altruistic reasons or because the tourist would have an improved service option in case of returning to the tourist site. Decreases in income reduce utility levels. Hence, the maximum amount that a tourist will pay for improved water services ($W_0 \rightarrow W_1$) is equivalent to the income loss that would take her utility back to the original level after improving the service [i.e., $V_0(Y, W_0, P_0) = V_1(Y-WTP, W_1, P_0)$]. This implies that the tourists' willingness to pay (WTP) is related to their income, the service improvement, and prices of other goods.

From an empirical perspective, we assume that tourists' willingness to contribute to the proposed water system and its determinants are related in a log-linear form:

$$LNWTP = X\beta + \varepsilon \tag{5.1}$$

where $LNWTP$ represents the natural logarithm of the maximum amount that the tourist is willing to pay, X is a vector of covariates, β is a vector of coefficients to be estimated, and ε is a stochastic error term that depicts unobservable covariates. Note that prices of other goods are excluded from vector X because there is no variation in prices across respondents.

We estimate Eq. 5.1 using responses to the follow-up, open-ended question on the maximum willingness to contribute. However, an alternative estimation procedure is needed to analyze responses to the dichotomous CV question because those responses are not a direct measure of tourists' willingness to pay. $LNWTP$ can be indirectly identified because the probability of being willing to contribute to the project is equal to the probability that $LNWTP$ is greater than the natural logarithm of the bid presented in the contingent scenario [i.e., P(Yes) = P($LNWTP > LNBID$)]. Consequently, the probability of a positive response to the CV question (P) can be modeled using the following logit specification:

$$LN\left(\frac{P}{1-P}\right) = \alpha\, LNBID + X\delta + e \tag{5.2}$$

where α and δ are coefficients to be determined using a maximum likelihood estimation approach and the stochastic error term is assumed to follow a logistic distribution. Estimated coefficients can then be used to compute the amount that the median tourist is willing to pay as follows:

$$\text{median}\, WTP = e^{-\left(\bar{X}\hat{\delta}/\hat{\alpha}\right)} \tag{5.3}$$

where $\bar{X}$ is a vector of the average of covariates, $\hat{\delta}$ represents the estimated coefficients of covariates other than the bid proposed in the contingent scenario, and $\hat{\alpha}$ is the coefficient of LNBID.

We estimated Eqs. 5.2 and 5.3 using three procedures. First, those equations were estimated using the original responses of the full sample of respondents. Second, we used responses to the follow-up certainty question to recode positive responses as negative ones if the respondent's certainty level was below a given threshold in a 0 to 10 scale. We use two certainty thresholds: 8 and 9. This approach allows for estimating more conservative and arguably more precise WTP estimates (Blumenschein et al. 2008). Third, we used a follow-up question to identify potential protest responses. We classified respondents as protesters if they are not willing to contribute to the project because they believe that other tourists would not contribute or that the money would be used for other purposes. Those respondents could introduce some biases in our estimations because their willingness to pay could be above the bid present in the contingent scenario but decided not to report so. As a robustness check, we estimated a model that excludes protest responses.

Table 5.1 presents the variables included in vector X. The variable *LNBID* is included to investigate the effect of a payment on the likelihood of supporting the proposed water project. This effect is expected to be negative because such payment would reduce income available for other goods and services. Consistent with our

Table 5.1 Variable definition and descriptive statistics (n = 157)

Variables	Description	Mean	S.D.
LNBID	Natural log of the contribution for water improvement presented to respondents in the CV question	3.888	0.584
INCOME	Annual income of the respondent in intervals of $25,000	2.127	1.842
INTERRUPTION	If the respondent experienced an water service interruption (1 = yes; 0 = no)	0.096	0.295
FEMALE	Sex of the respondent (1 = female; 0 = male)	0.656	0.477
NATIONAL	Nationality of the respondent (1 = national; 0 = foreigner)	0.389	0.489
EDUCATION	Education of the respondent (1 = undergraduate or graduate degree; 0 = otherwise)	0.841	0.367
ACCOMPANIED	If the respondent was with someone else during the interview (1 = yes; 0 = no)	0.465	0.500

theoretical framework, INCOME was included with the expectation of observing a positive income effect on the likelihood of supporting the project. Additionally, the binary indicator INTERRUPTION is included as a proxy of the improvement of water services. Our hypothesis is that tourists who experienced a water service interruption will be willing to pay more for service improvements than tourists who did not note a service interruption. Other relevant individual characteristics such as sex, nationality, and education are included as covariates to control for individuals' heterogeneity. The effect of those covariates remains to be empirically estimated. Finally, we include a binary indicator to control for social desirability biases that could arise if the respondent was accompanied by a relative or friend during the interview.

5.5 Estimation Results

Table 5.2 provides an average profile for our respondents. The average respondent was 37 years old and had an annual income of almost $ 42,000. A majority of respondents were females (65%), and about 38% were citizens of Ecuador. Our sample of respondents had a high level of education, with approximately 83% having an undergraduate or graduate degree. Galapagos National Park (2018) documented a similar profile for the average visitor in 2018. The average visitor was 41 years old. The split between national and international visitors was 34% and 66%, respectively. In terms of gender, 55% of the visitors were females and 45% males. Based on those characteristics, our sample of respondents is representative of tourists in the Galapagos.

In the CV question, respondents were asked if they would pay for improved water services. Less than 48% of the respondents provided a positive answer. Figure 5.1 shows the percentage of respondents who would support the proposed project by the bid presented in the CV scenario. As expected, the likelihood of funding improvements in water services decreases with the amount to be paid, from almost 79% of respondents willing to pay $20 to less than 28% willing to pay $100. Those respondents who provided a negative response for the CV question were asked for the main reason to be against the proposed project. Almost 75% of those respondents reported that they would not pay the propose amount because it was too

Table 5.2 Average profile of respondents

Description	Mean
Annual income of the respondent (in US dollars)	$ 41,818
Percentage of female respondents	65%
Percentage of respondents with Ecuadorian nationality	38%
Percentage of respondents with an undergraduate degree or higher	83%
Age of the respondent (in years)	37

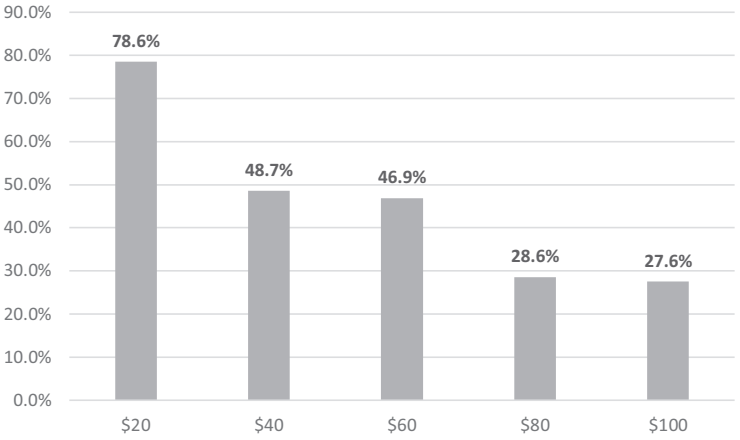

Fig. 5.1 Percentage of positive responses by bid presented in the CV question

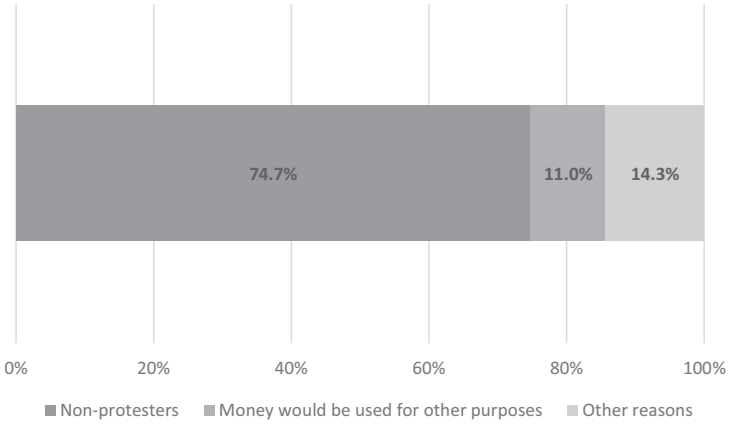

Fig. 5.2 Reasons for negative responses to the CV question

high or because they could not afford it. These respondents were classified as non-protesters (see Fig. 5.2). The rest was classified as protesters because they would not pay the proposed amount due to non-economic reasons including their perception that money collected would be used for other purposes.

Table 5.3 shows five models estimated using responses to the CV scenario and subsequent questions. Model 1 is based on the full sample of responses to the CV scenario without correcting for respondents' uncertainty regarding their response. Due to the binary nature of that response, Model 1 follows a logit specification. The covariates to be included in that model were chosen based on the Akaike and Bayesian Information criteria. Rather than presenting estimated coefficients,

Table 5.3 Estimated willingness-to-pay models

	Model 1: logit uncorrected for (un) certainty	Model 2: logit corrected for 80% certainty	Model 3: logit corrected for 90% certainty	Model 4: logit with non-protesters only	Model 5: OLS open-ended WTP question
Dependent variable	Contribution (yes/no)	Contribution (yes/no)	Contribution (yes/no)	Contribution (yes/no)	Log of maximum willingness to pay
LNBID	−0.274 (0.050)***	−0.205 (0.050)***	−0.190 (0.046)***	−0.313 (0.051)***	–
INCOME	0.036 (0.020)*	0.011 (0.020)	0.016 (0.018)	0.027 (0.021)	0.086 (0.053)*
INTERRUPTION	0.331 (0.103)***	0.209 (0.124)*	0.217 (0.125)*	0.358 (0.096)***	0.728 (0.311)**
FEMALE	−0.174 (0.078)**	−0.235 (0.077)***	−0.126 (0.068)*	−0.184 (0.080)**	−0.234 (0.199)
NATIONAL	0.129 (0.079)	0.175 (0.078)**	0.163 (0.072)**	0.060 (0.085)	0.497 (0.205)**
EDUCATION	−0.162 (0.097)*	−0.080 (0.097)	−0.037 (0.084)	−0.162 (0.098)	−0.173 (0.253)
ACCOMPANIED	0.032 (0.075)	0.041 (0.071)	0.075 (0.063)	0.049 (0.079)	0.215 (0.189)
Constant	–	–	–	–	2.872 (0.360)***
Observations	157	157	157	138	155
Pseudo R^2	0.175	0.165	0.171	0.199	–
R^2	–	–	–	–	0.087

Notes: ***, **, and * imply significance at 1%, 5%, and 10% levels, respectively. Standard errors are reported in parentheses. Estimated coefficients in Models 1 to 4 are marginal effects on the likelihood that the average tourist is willing to pay for improved services. Estimated coefficients in Model 5 are semi-elasticities of the tourists' maximum willingness to pay

Table 5.3 shows the marginal effects of corresponding covariates on the likelihood of being willing to pay for improved water services. Model 2 and Model 3 follow a specification similar to Model 1. However, for those models, positive responses are recorded as negative ones when the respondent's certainty regarding that response does not surpass a certainty threshold of 80% or 90%, respectively (i.e., 8 or 9 in a 0–10 scale). Model 4 was estimated using the subsample of non-protesters only. A total of 19 protesters were excluded because they can downwardly bias WTP estimates. Protesters could be willing to pay but decided to report the opposite for non-economic reasons. Model 5 was estimated using the open-ended question on the respondent's maximum willingness to pay. Hence, coefficients in that model can be interpreted as the percentage change (i.e., semi-elasticities) in tourists' maximum willingness to pay for improved services due to a minimal change in corresponding covariates.

Estimated coefficients on LNFEE are negative and statistically significant across all logit models, which indicates that the probability that tourists would support the proposed project decreases with the amount they would have to pay. Estimation results also suggest that income has a positive effect on the likelihood of supporting the proposed project, although corresponding coefficients are statistically insignificant when controlling for the (un)certainty of responses to the CV question (Models 2 and 3) and when protesters are excluded (Model 4). The marginal effects of INTERRUPTION are positive and statistically significant across all logit models. Based on Model 1, tourists who experienced a service interruption while visiting the study site would be 33 percentage points more likely to pay for water service improvements than those who did not have that experience. Together these results support the construct validity of our CV scenario given their consistency with our utility-theoretic framework.

Findings also indicate that the likelihood of supporting the proposed project varies depending on some respondents' sociodemographic characteristics. For instance, females seem to be less likely to pay for improvements of local water services than males, with a difference of about 17 percentage points in their likelihood of supporting the project. In terms of nationality, results suggest that Ecuadorian tourists would be more likely to support the proposed project than foreigners. However, those marginal effects are statistically significant only after correcting for (un)certainty regarding the response to the CV question. Additionally, in Model 1, the estimated effect of EDUCATION suggest that tourists with an undergraduate or graduate degree are less likely to pay than tourists with lower education levels. In other models, this effect was statistically insignificant. Finally, we did not find evidence of social desirability biases in tourists' responses to the CV question.

Compared to the logit models (i.e., Models 1 to 4), the OLS regression model (i.e., Model 5) yielded similar results. Tourists' maximum willingness to pay increases with income, significant at a 10% level. Having experienced interruptions in water services also increases the willingness to pay for improved services by approximately 73% of the average WTP. Also, the WTP differential between national and foreign visitors is statistically significant, suggesting that Ecuadorians would pay 50% more than foreigners. The effect of other covariates was found statistically insignificant.

The four logit models (i.e., Models 1–4) were used to estimate the median willingness to pay with corresponding 95% confidence intervals. Figure 5.3 shows those intervals, along with the average willingness to pay based on responses to the open-ended question that followed the CV scenario (i.e., Model 5). Based on Model 1, the median tourist would make a one-time payment of $45 to improve local water services. Models 2 and 3 yielded more conservative willingness-to-pay estimates at $20 and $15, respectively. The subsample of non-protesters would make a one-time payment of $57. The average willingness to pay based on the open-ended question is estimated at $35. All these estimates are significant as shown by strictly positive confidence intervals.

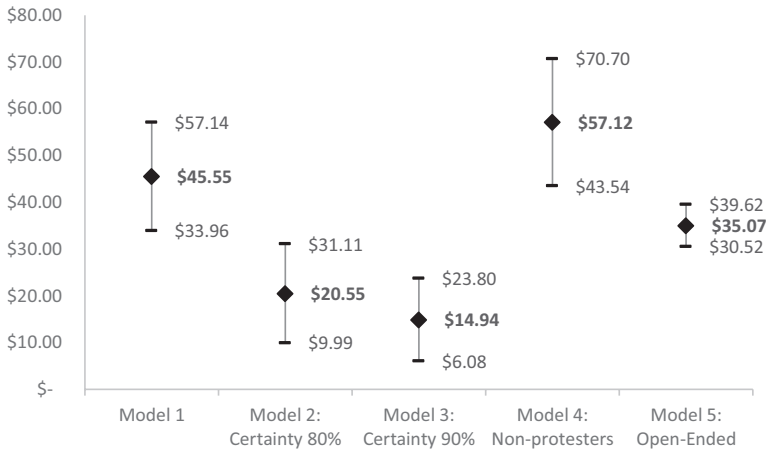

Fig. 5.3 Willingness-to-pay estimates with confidence intervals

5.6 Discussion and Conclusions

As many small islands, the island of Santa Cruz, Galapagos, Ecuador, lacks the freshwater resources required to satisfy the increasing demand for drinking water from the local population, tourists, and immigrants working in the tourism sector (Reyes et al. 2018). This island also lacks financial resources to invest in water infrastructure, and consequently, service interruptions are frequent, and tap water is unsafe to drink (Reyes et al. 2017). This in turn may undermine the experience of tourists while putting the well-being and health of local populations at risk. Because they may be socially and environmentally responsible, or to have the option of an improved service in future visits, tourists could be willing to fund investments in local water infrastructure. This study investigated whether tourism has the potential to generate financial resources to improve local water infrastructure.

Our results demonstrate that tourists are willing to pay a significant amount to install, operate, and maintain improved water infrastructure in their destination. This finding is consistent with the premise of responsible tourism (Goodwin 2016), the economic theory of non-use values (Lazo et al. 1997), and prior empirical evidence indicating that tourists are willing to pay for improvements in local water resources (e.g., Farr et al. 2014; Kumakawa 2016). Depending on the level of certainty regarding responses to the contingent valuation question, the median tourist would make a one-time payment of $15–45. Those estimates can be used to calculate the amount of financial resources that can be raised by charging visitors to improve water infrastructure. Based on the most conservative estimate of $15 and the number of visitors in 2018 (i.e., 209,400), the island of Santa Cruz could raise at least $3.14 million annually. Those revenues could be used to fund investments in water infrastructure and to operate and maintain improved water systems.

This study is an initial step toward comprehensive economic assessments of alternatives to supply reliable drinking water services in small islands. Future studies can measure the locals' willingness to pay for improved services and estimate potential revenues from both locals and visitors. Then, those revenues could be compared against supply costs under different technologies to make informed decisions regarding investments in water infrastructure to satisfy the increasing demand for potable water from tourists and the local population.

From a behavioral perspective, it can be important to understand why tourists are willing to pay for water infrastructure that they are unlikely to use. Our results indicate that tourists who experienced service interruptions have a higher willingness to pay for improved water infrastructure than those who did not have that experience. It can be presumed that tourists who experienced a service interruption are willing to pay for the option of having reliable water services in the future (i.e., option value). Altruistic motives and social responsibility can also explain the non-use value that tourists assign to improved water services in the study site. It is a logical extension to this study to investigate the reasons behind tourists' willingness to pay for improving water services in their destination.

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Part II
Food Environment

Chapter 6
Syndemic Water and Food Insecurity: Impacts on the Dual Burden of Disease in Galapagos

Amanda L. Thompson, Enrique Teran, and Margaret E. Bentley

Abstract Food insecurity is a well-known risk factor for a number of health conditions, including stunting, overweight, and poor mental health. However, less is known about the pathways through which food insecurity shapes health at the individual and household levels and even less about how food insecurity overlaps with poor water quality and access to impact physical and mental health. In this chapter, we describe the individual and joint effects of food and water insecurity on health and argue that limitations in the water and food environments interact synergistically as a syndemic contributing to co-occurring overweight and cardiometabolic disease alongside persistent infectious disease and undernutrition. Such research is needed to understand the social and biological pathways linking the experiences of food and water insecurity to the dual burden of disease in low- and middle-income country settings like the Galapagos.

Keywords Food insecurity · Water insecurity · Dual burden of disease · Syndemics

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6.1 Introduction

Over the past several decades, the Galapagos Islands have undergone dramatic physical and social environmental change driven by increases in migration and the tourism industry (Villacis and Carrillo 2010; Walsh and Mena 2016). The vast majority of residents and tourist visits are concentrated in the urban areas of three populated islands, Santa Cruz, San Cristobal, and Isabela, leading to increased urban development. Yet, this growth has not been accompanied by expansion of the urban infrastructure (Walsh et al. 2010), leading to increasing strain on water availability, sanitation services, and food resources. Of the inhabited islands, only San Cristobal has fresh water sources (Grube et al. 2020). The other islands rely on brackish water that is sometimes, but not consistently, desalinated (Mateus et al. 2019; Walsh et al. 2010). Consequently, the availability of water for drinking and household use has been a pressing issue for many residents (Liu and d'Ozouville 2011; Walsh et al. 2010). Sanitation infrastructure also varies across the islands, and wastewater treatment is inconsistent to non-existent, contributing to concerns about water quality for both human use and environmental impact (Walsh et al. 2010). Food resources are also affected by the growing populations of residents and tourists. Nearly 97% of the land is designated as part of the Galapagos National Park, limiting the amount of food that can be grown locally and leaving residents and visitors dependent on food imported from the mainland.

Despite these documented limitations in water and food resources, relatively little research has focused on their impacts on human health. Poor water and food quality are established risk factors for a host of health conditions. Exposure to unclean water and fecal contamination in the environment are common contributors to respiratory and gastrointestinal infections (Günther and Fink 2010; Hunter et al. 2010), stunting, and micronutrient malnutrition (Günther and Fink 2010; Vilcins et al. 2018). Shifts in the food environment away from traditional foods and fresh fruits and vegetables toward high-fat, energy-dense processed foods contribute to overweight, obesity, and the development of cardiometabolic disease (Popkin et al. 2019). The simultaneous exposure to environmental pathogens through unclean water and high-energy, high-fat diets due to limited food availability can contribute to a dual burden of disease, the co-existence of undernutrition, particularly stunting or micronutrient deficiencies, alongside overnutrition and noncommunicable disease within individuals, households, or communities (Varela-Silva et al. 2012). Previous research in the Galapagos documents that this dual burden of disease is indeed present. Stunting rates, while lower than those on the mainland, remain above 10%, and micronutrient deficiencies are high among both children under 5 and reproductive-aged women. At the same time, the prevalence of overweight and obesity is among the highest in Ecuador with over 40% of children and 75% of adults overweight or obese in 2012 (Freire et al. 2015).

Using a syndemic framework, which views the clustering of two or more health problems as resulting from the interaction between them and detrimental social and physical environments (Mendenhall 2017; Singer et al. 2017), we argue that

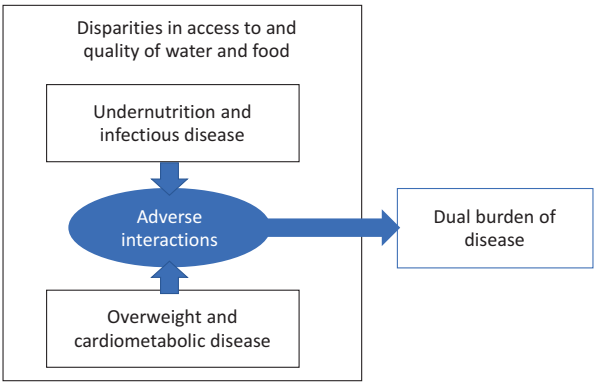

Fig. 6.1 Syndemic model of the contribution of poor water and food environments to the dual burden of disease. (Adapted from Singer et al. 2017)

limitations in the water and food environments, shaped by tourism and economic development, contribute to individuals' and households' risk of both infectious conditions and undernutrition and overweight/obesity and cardiometabolic disease (Fig. 6.1). Further, we argue that the experience of facing both water and food insecurity simultaneously will amplify these negative impacts on health. In this chapter, we (1) describe the water and food environments of San Cristobal, the island where we have done most of our research, (2) provide evidence that water and food limitations interact to contribute to the dual burden of disease, and (3) suggest areas for future research in the hope of identifying avenues for intervention.

6.2 Water Environment

The water infrastructure varies significantly between the inhabited islands of San Cristobal, Santa Cruz, and Isabela. While over 80% of the population on all three islands have public water access, San Cristóbal is the only island in the archipelago with a fresh water source and water treatment plant, which supplies water for the municipal network year-round (Guyot-Tephany et al. 2013). On Santa Cruz and Isabela, the municipalities provide water that is mainly brackish, is not treated, and is considered non-potable according to national and international regulations (Reyes et al. 2015; Walsh et al. 2010). The presence of fresh water sources and a conventional water treatment plant, which opened in 2013, may suggest that water security, defined by the United Nations as having reliable access to adequate water, may not be a concern for San Cristobal residents. Yet, concerns with water access and quality remain.

Although 93% of residents receive municipal water distributed to their homes, the flow of water is not constant throughout the day, leading households to store treated water in roof tanks and/or cisterns which increases the potential for

contamination from environmental exposures (Gerhard et al. 2017; Guyot-Tephany et al. 2013; Houck et al. 2020). Households without piped water rely on water delivery by truck or, less commonly, by collecting rainwater. In our recent household survey of 120 San Cristobal households, the Healthy Families Study (*Estudio Familias Saludables*), we found that 80% of households relied on piped water for household use, with others relying on bottled water (13%), rainwater, (4%) or delivery (2%). Our secondary analysis of the household data from the *Encuesta Nacional de Salud y Nutrición* (ENSANUT; Freire et al. 2015) showed a similar distribution and documented that water access differs by socioeconomic status and location (Nicholas et al. 2019). Wealthier households and those in urban areas had more secure access than those with lower income or in rural areas. Water access was also lower among households with older household heads and those with more individuals per room, even when controlling for income and urban/rural residence, suggesting that larger households with older members may be more vulnerable to water insecurity.

In addition to concerns with consistent access to municipal water, residents have concerns about the quality of this water. In a survey conducted in 2013, 71% of participants agreed that they could not use water on San Cristóbal the same way they could use water on the mainland, citing that it was polluted or that it can cause disease or that it is a limited resource (Guyot-Tephany et al. 2013). These concerns were voiced by residents in some of our prior studies (Jahnke et al., Chap. 16, this volume):

> The water is not drinkable
>
> I think that one of the biggest problems here on the island are the illnesses related to poor water quality. Although we know that we have potable water…that the water is clean when it leaves the treatment plant, nonetheless, there are still problems with the pipes.

Ongoing water quality monitoring on the island demonstrates that the quality of the municipal water has improved considerably since the water treatment plant opened. Evidence of environmental and fecal contamination declined by three- and twofold, respectively, at point-of-use sites from before and after the plant became operational (Gerhard et al. 2017). In a subsample of households (n = 29) participating in our longitudinal 2013–2014 Child Gut Health Survey before and after the opening of the treatment plant, 87% saw their household water quality go from high-risk levels of contamination with *E. coli*, based on WHO standards, to low risk (Houck et al. 2020). Nevertheless, 10% remained at intermediate levels of risk and 7% at high risk. In our household survey conducted from 2018 to 2019, we found similar levels of contamination to these earlier studies, with 70% of households having total coliforms and 22% having *E. coli* in their tap water. Together, these studies suggest that, while water quality has improved significantly, households still face intermittent risk of having unsafe water quality. This interpretation is supported by recent research by Grube et al. (2020). They report that the municipal water treatment plants generally produce high-quality drinking water, but the detection of *E. coli* in 2–30% of post-treatment distribution samples suggests contamination and/or regrowth during distribution and storage (Grube et al. 2020).

The perception, and reality, that water is unsafe shapes how households use municipal water (Houck et al. 2020). Mothers in the Child Gut Health Study report using municipal water for household cleaning, cooking, and hygiene practices (bathing, handwashing, and toothbrushing). However, the vast majority of participating households (85%) rely on bottled water for drinking water, and another 11% relied on bottled or filtered water for cooking and 15% for cleaning fruits and vegetables (Houck et al. 2020). Interestingly, these practices persisted across the opening of the water treatment plant with few differences seen in drinking water source after the plant. Similar concerns with water persist in our Healthy Families Study. Among the 115 participating households, the majority rated their water quality as fair (*regular)* to good (*bueno)*. Yet, over 50% of households purchased bottled water for drinking, and almost half treated their tap water by filtering or boiling it before using as drinking water or for cooking. Purchasing bottled water constitutes a considerable expense for residents. As one participant noted: "In our family, we pay $40 a month for bottled water, which is a large part of my salary."

In summary, although overall water insecurity is low on the island with the majority of residents having access to adequate and clean municipal water, a sizeable minority of residents continue to experience shortages and poor water quality. Residents continue to report concerns with their water such as not having as much as they would like, not having the money to pay for water or drinking water that they thought was bad or unsafe. Further, water quality remains an issue with intermittent risk of microbial contamination that may lead to health issues.

6.3 The Food Environment

Similar to the situation with water, food availability is shaped by the geographic isolation of the islands, and problems are exacerbated by population growth and the tourism industry. As described by Sampedro et al. (2018), the food system of the Galapagos is characterized by weak local agriculture, a reliance on foods imported from the mainland, and the direct and indirect effects of tourism. Tourism directly contributes to increased need for food supplies and shapes the types of food available. Indirectly, tourism reduces agricultural output, by offering more lucrative employment opportunities than those available through farming. While land use restrictions limit the food that can be grown on the island and regulate the number of livestock that can be raised, much farm- and pasture land is underutilized due to a decrease in full-time farmers (Sampedro et al. 2018). The percentage of locally grown foods is declining, and many farms are primarily used as weekend retreats and family gardens for urban residents (Walsh and Mena 2016).

Consequently, residents rely almost entirely on foods shipped in from the mainland by barge and, increasingly, by air cargo (Sampedro et al. 2018). Participants in our studies have repeatedly described concerns with the quantity and quality of fresh foods available on the islands. As they describe, produce often arrives spoiled due to the time required to ship it to the islands. Consequently, residents view this

food as low quality. In a 2011 study of mothers on San Cristobal (Pera et al. 2019), for example, 60% of participants complained about the limited availability of acceptable produce. As one of the participants noted, "sometimes [the vegetables] don't reach here. They go to other islands and then it gets here all rotten."

Pilot data we collected in the summer of 2015 suggests that not only is food availability an issue, but the distribution is not equal across the island. We mapped the location of markets and food vendors and estimated the proportion of food on the shelves (from 0% in red to 100% in green) to describe the food environment (Fig. 6.2). In between barge shipments, food was more readily available near the coast, where the markets catering to tourists are located, and became less readily available away from the coast where more residents live. When we looked at the types of foods available (Fig. 6.3), we saw that while sweets and sugary beverages were available in nearly 70% of stores, vegetable, dairy, and meat availability was lower.

Along with this uneven distribution of food, our analyses suggest that food security, defined as having access to sufficient quantities of culturally appropriate foods (FAO), remains a concern for a significant proportion of families. Supporting previous estimates that all families should be able to afford the minimum amount of food required (Granda et al. 2012), we have found few families suffering from severe food insecurity (Pera et al. 2019; Thompson et al. 2020). However, many families

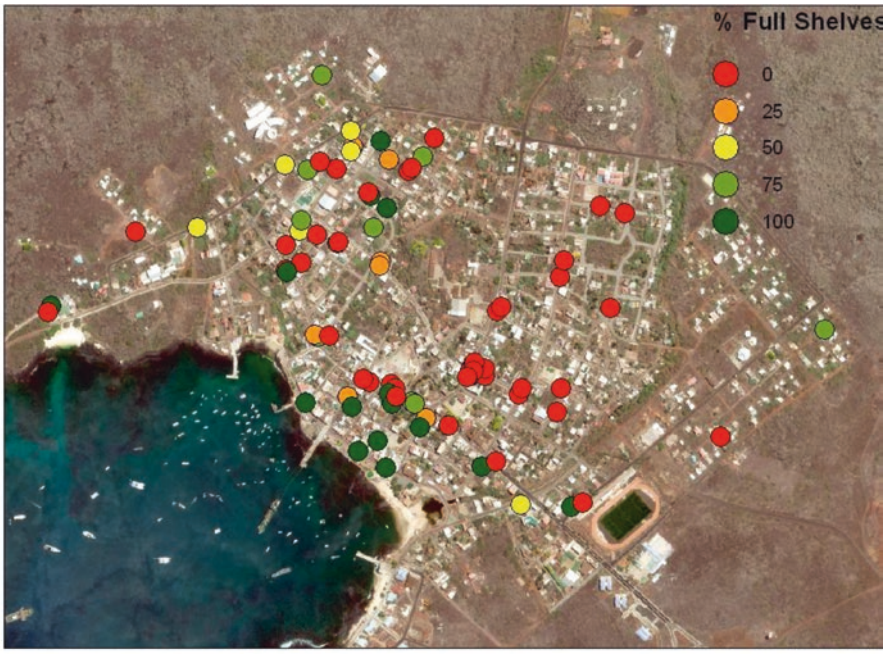

Fig. 6.2 Estimated percentage of food available on the shelves of markets and stalls in Puerto Baquerizo Moreno

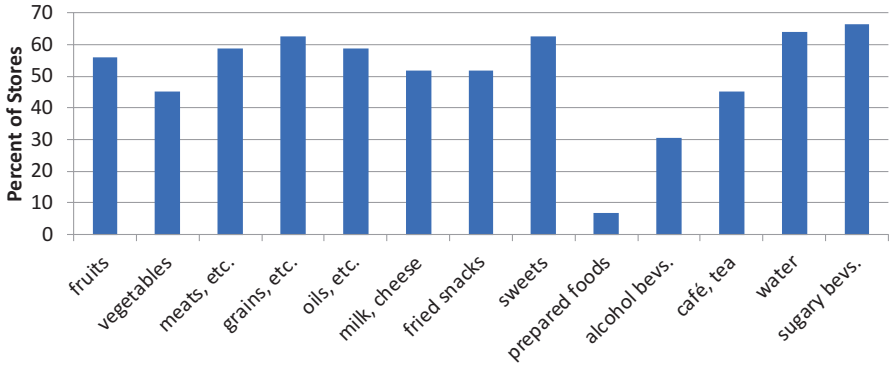

Fig. 6.3 Types of foods available in markets and tiendas in Puerto Baquerizo Moreno

do suffer from mild-to-moderate food insecurity. In our Healthy Families Study, nearly 40% of households were categorized as having low-to-mild food insecurity. Our secondary data analysis from ENSANUT-ECU suggests that, in addition to the island-wide limitations in food availability, a sizeable minority of households do struggle to purchase sufficient food. Among surveyed households, 8.7% had insufficient food in the previous 2 weeks, 23.8% had problems paying for food, and 7.5% had both insufficient food and problems paying for food (Thompson et al. 2020). Although the monthly income for public and private workers in Galapagos is almost 3 times higher than that on the mainland ($772.03/ month vs $251.70/month; Villacis and Carrillo 2010), the cost of living, including foods, is higher, contributing to food insecurity. The "cost of basic basket," a composite economic measure of 75 goods and services considered necessary to satisfy basic needs, is considerably more expensive on the islands ($869 on Galapagos vs $536 on the mainland in March 2010; Villacis and Carrillo 2010). Consequently, 47.6% of households are considered unable to meet basic needs (Villacis and Carrillo 2010).

Such food insecurity shapes the quality and adequacy of the diets of Galapagos residents. Diet adequacy is lower in food-insecure households (Watson 2019). Further, diet quality is shaped by many of the characteristics that are also typically associated with lower food security, including lower educational attainment of the head of household, larger household size, and living in rural areas. Lower diet quality in this and other research (Freire et al. 2018; Pera et al. 2019) is associated with a lower consumption of fresh foods and a greater reliance on packaged, processed foods.

In summary, while severe food insecurity is rare on the Galapagos, households continue to report inadequate access to fresh fruits and vegetables due to reliance on imported foods. The perception that these foods are of low quality and expensive limits the diet quality of island residents. While cost may not prevent families from meeting minimum dietary requirements, the cost of fresh foods and the dynamics of market availability are likely experienced differently by residents.

6.4 Syndemic of Food and Water Insecurity and Impacts on Health

Returning to the syndemic framework, we will describe how water and food insecurity impact health for island residents. We first describe how each of these exposures may contribute to infectious illness, poor nutrition and/or overweight, and cardiometabolic conditions. Finally, we look at the combined effects of facing both water and food insecurity to argue that these conditions interact to exacerbate poor health outcomes, as hypothesized from a syndemic perspective.

6.4.1 Water and Health

In Galapagos, poor water quality contributes to the burden of infectious disease. Water-related infections, including gastrointestinal infections, urinary tract infections, and skin conditions, like rashes, are common complaints. For example, on Isabela, physicians estimated that in 2009, up to 70% of illnesses were caused by consumption of or exposure to contaminated water with diarrhea, gastritis, intestinal parasites, and vaginal and urinary tract infections being the most commonly seen conditions (Walsh et al. 2010). Our work with doctors, key informants, and community members (Jahnke et al., Chap. 16, this volume) similarly highlighted that medical conditions associated with poor water quality are among the major health concerns for each of these groups. Each group identified at least one water-related health issue, including GI problems, urinary tract infection, gastroenteritis, and diarrhea as a health concern, and several directly linked these health problems to poor water quality.

These perceptions that poor water quality is contributing to poor health are supported by research led by Houck et al. (2020) linking household water quality to the prevalence of self-reported GI and urinary tract infections. Mothers and children living in households with evidence of high fecal contamination (>10 MPN *E. coli*) in their tap water had significantly higher occurrence of UTIs than those living in households with no or low contamination. Children in households with high contamination also had more reported GI infections than those with no or low contamination. Interestingly, this work also found an association between the opening of the water treatment plant and the prevalence of infection at the household and community levels. At the household level, mothers reported fewer urinary tract infections in themselves or their children after treatment began and fewer gastrointestinal infections in their children (Houck et al. 2020). At the community level, the number of cases of GI infections and UTIs diagnosed at the public hospital declined significantly, providing overall support for an association between water quality and infection on the island.

Whether exposure to contaminated water and recurrent infections have longer-term effects on health is less clear in our analyses. Our secondary data analysis of

water security and stunting in the ENSANUT data (Nicholas et al. 2019) found no significant association between water access or quality and stunting in children in the Galapagos. Similarly, we found no significant independent effects of poor water access or quality on underweight/infectious illness or overweight/cardiometabolic disease in children and adults (Thompson et al. 2020). We did find, however, that better water quality and access were associated with a lower risk of a household experiencing the dual burden of both overweight and stunting among household members. While this secondary analysis did not allow us to fully explore the mechanisms through which water security may reduce the risk of experiencing stunting from both undernutrition and infectious disease along with overweight/obesity, our findings may indicate that having more secure access to water improves individual and household well-being across a number of dimensions.

Food and Health The lack of strong associations between water quality and access to longer-term health indicators of the dual burden may stem from the dietary environment of the Galapagos. Like many LMIC settings, the diet of the Galapagos reflects the nutrition transition, from traditional diets to diets characterized by high-fat, energy-dense, and processed foods (Freire et al. 2018; Monteiro et al. 2013; Popkin et al. 2019). These types of diets, while high in energy, tend to have low nutrient quality, contributing to overweight through excess energy intake and micronutrient deficiencies (Darmon and Drewnowski 2015). Research also suggests that these nutrient-poor diets may also contribute to stunting in early life (Pries et al. 2019), serving as risk factor for the development of the dual burden in individuals.

Along with poor diet quality, insecure access to food may contribute to both undernutrition and, increasingly, overweight and cardiometabolic disease (Gorton et al. 2010; Seligman et al. 2010). In particular, exposure to mild–moderate episodic or cyclical food insecurity, something that may best categorize the food security situation in Galapagos, is associated with poorer diet quality, less frequent consumption of fresh foods, and higher consumption of processed foods (Weigel et al. 2016a, b). An inability to predict when foods will be available or when families will be able to afford food shapes food choice, often leading to a reliance on less costly, processed foods that can be stored. Unfortunately, these are foods that are also associated with weight gain (Monteiro et al. 2013). In Galapagos, this cyclical food insecurity may underlie the increasing reliance on processed and ultra-processed foods (Freire et al. 2018). In addition to these direct effects of food insecurity on diet quality, food insecurity can also contribute to overweight and cardiometabolic disease indirectly. Psychological responses, the stress and depression that may accompany food insecurity, increase the risk for overweight and cardiometabolic disease by increasing cortisol production leading to accumulation of visceral adipose tissue, inflammation, and insulin dysregulation (Pérez-Escamilla et al. 2014).

Our secondary analysis of the ENSANUT data provides preliminary evidence that diet quality and the variety of foods consumed do indeed shape health outcomes at the individual and household level (Thompson et al. 2020). At both levels, individual and household, we found interesting and, somewhat paradoxical, relationships between the diet quality and disease risk. Among individuals, better diet

quality was associated with a greater risk of the dual burden, while lower variety was associated with a reduced risk. At the household level, higher diet quality and mild food insecurity were associated with a greater likelihood of the dual burden. These findings may stem from the cyclical nature of food insecurity on the islands, with residents overconsuming when foods are available and relying heavily on processed foods at other times. The positive association between diet quality and risk of dual burden and the negative association between variety and dual burden may reflect differences in access to and the ability to afford more expensive, fresh foods. Further, the positive association between food issues (quality and insecurity) and higher risk of overweight/cardiometabolic risk factors at the individual level suggests that further research is needed to more fully understand the components of "healthy" and "unhealthy" diets in this context, the factors that shape individuals' and families' diet, and the links between these diets and health outcomes.

6.4.2 Water, Food, and Health

A growing body of research documents that water and food insecurity are likely to co-occur within households, and preliminary work from our group and others suggest that these conditions interact as a syndemic to worsen physical and mental health outcomes (Brewis et al. 2020a). We find considerable overlap between water and food insecurity in Galapagos. 36% of households participating in the Healthy Families Study suffered from both conditions, with an additional 35% experiencing water insecurity alone and 12% food insecurity alone. While the proportions differ due to differing measures of water and food insecurity, we found that one in five of Galapagos households participating in the ENSANUT-ECU had some combination of water and food limitations (Thompson et al. 2020).

A number of mechanisms have been proposed to explain this overlap between water and food insecurity within households (Brewis et al. 2019, 2020a, b). The co-occurrence of water and food insecurity may derive from household poverty. While few households in the Galapagos suffer from extreme poverty, participants in our and others' studies frequently lament the high costs incurred from purchasing bottled water for drinking and the prices of fresh food (Freire et al. 2018; Houck et al. 2020; Pera et al. 2019). The reliance on purchased bottled water, even in San Cristobal where residents have access to treated municipal water, represents a considerable expense for families that may limit the money available for other household needs. As in other settings, the time and money needed to procure and treat water may strain household resources and limit food budgets (Brewis et al. 2020b). In addition to these economic links, limited water availability may shape the types of foods families consume, limiting the cooking that households can do (Wutich and Brewis 2014; Collins et al. 2019) and possibly contributing to more meals consumed outside the home.

While studies looking at both types of insecurity simultaneously are relatively limited, the existing literature supports the contention that water and food insecurity

act as a syndemic to amplify the risk of poorer health outcomes (Brewis et al. 2019, 2020b). Our analysis from ENSANUT documented that Galapagos households with both water and food limitations were at the greatest risk for experiencing the dual burden (Thompson et al. 2020). Preliminary analysis from our Healthy Families Study suggests that the interactive impacts of water and food insecurity may be even more evident on mental health. The probability of suffering from distress (depression, anxiety, or high stress) was almost twice as high for individuals living in households with water and food insecurity (37%) than those living in households with water insecurity alone (19%), over twice as high as living in households with only food insecurity (15%), and over three times that of individuals living in households with neither concern (11%). Similar results have been seen in other LMIC, where the co-occurrence of water and food insecurity has been associated with worse anxiety and depression scores, compared to experience of suffering from food or water insecurity alone (Brewis et al. 2019; Workman and Ureksoy 2017). Together, these results support the need to understand the experience of co-occurring water and food insecurity on both physical and mental health.

6.4.3 Conclusions and Recommendations

Limitations in the water and food environments cause considerable health problems for Galapagos residents. Rates of infections remain high, while a growing proportion of the population is overweight or obese. The increasing burden of cardiometabolic conditions, like high blood pressure and diabetes, is a concern for the healthcare system, which is under-resourced to deal with the long-term monitoring and treatment of chronic conditions (Jahnke et al., Chap. 16., this volume; Barrington et al., Chap. 15., this volume; Waldrop et al., Chap. 17, this volume). Importantly, while the actual quality of water and food contributes to poor health behaviors and outcomes, the *perception* that these resources are costly and of poor quality also importantly adds to the burden of disease. Perceived limitations in water and food availability shape individual and household strategies, for example, by increasing the consumption of processed foods or the money spent on bottled water for drinking, in ways that may ultimately contribute to increased risk for the dual burden disease. Worry about these limitations may further exacerbate stressors, contributing to psychological distress.

From a syndemic perspective, understanding the social and environmental factors placing individuals at risk for disease is critical. The geographic isolation of the Galapagos Islands makes residents vulnerable to household food insecurity, poor water quality, and limited healthcare, which in turn contribute to poor diet quality, infections, and the dual burden of disease. Yet, this vulnerability is exacerbated by growing populations and increasing tourism. Tourism is the dominant driver of economic development of and migration to the islands, directly employing around 60% of island residents. At the same time, the industry and the high flow of migrants to the islands looking for tourism-related employment accelerates the consumption of

water, food, and other resources and increases the pressure on basic services (Walsh and Mena 2016). Arguably, the tourism industry also exacerbates social stratification, tending to benefit individuals and families with the resources to run businesses catering to tourists and with the education to speak English (Walsh and Mena 2016). Those less able to access these tourism-related opportunities, due to limited incomes, education, and/or rural residence, are also likely to be more vulnerable to the high costs of foods and limited availability of water and sanitation services. The preliminary analyses we have presented here suggest that those with lower income, less education, and potentially fewer social ties on the island are indeed at greater risk of having poorer water access and quality (Nicholas et al. 2019), poorer diet quality (Watson 2019), and greater food insecurity (Pera et al. 2019). Further research into *how* and *why* food and water resources are distributed is important for better understanding the health impacts of uneven economic development and the growth of the tourism industry.

Also critical is understanding the environmental, social, and biological mechanisms linking water and food exposures to the development of the dual burden within individuals and households. Globally, the increasing prevalence of the dual burden of malnutrition is considered a pressing public health priority (Popkin et al. 2019). While diet is changing dramatically, infrastructural change has been slower in many LMIC contexts. Continued exposure to environmental pathogens through unclean water may exacerbate the dual burden. Exposure to environmental pathogens contributes to ongoing undernutrition by increasing the risk of GI infections and by contributing to dysbiosis in the gut microbiome. This gut dysbiosis further enhances the risk of overweight and cardiometabolic disease by stimulating inflammation, insulin dysregulation, and weight gain when high-fat diets are consumed (Ding and Lund 2011; Kau et al. 2011). Together, these dual exposures of poor dietary and water environments enhance the development of the dual burden within individuals. Similar pathways likely link the diet and water environments to the development of the dual burden in the Galapagos, and further research is needed to understand how these exposures contribute to individuals' nutrient status, gut microbiota, and cardiometabolic risk factors.

Identifying those most at risk for dual burden is also important for developing interventions. Research from LMIC suggests that the prevalence of the dual burden at the household level is shifting to poorer households (Popkin et al. 2019), exacerbating health risks in those households whose ability to cope with stressors may already be limited. Our work in the Galapagos indicates that the patterning of the household dual burden varies by income, indigeneity, and migration history, highlighting the importance of both understanding the factors placing households at risk and targeting interventions toward those who are most vulnerable.

In conclusion, our research documents that Galapagos residents face considerable challenges in accessing clean, affordable water and healthy, affordable diets and that these factors likely contribute to the high prevalence of the dual burden seen in individuals and among households. These water and food environments are influenced geographically by the island context and, perhaps even more importantly, by the social and economic context associated with tourism, migration, and

economic development. Together, these factors serve to exacerbate the risk factors contributing the syndemic of the dual burden. Further research is needed to understand the biological and behavioral pathways linking these exposures to the dual burden of disease at the individual and household levels. Even more importantly, understanding the strategies households employ to manage these limitations is critical for identifying avenues of intervention in the Galápagos and LMIC more broadly.

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Chapter 7
Overweight and Obesity in Galapagos: Food Consumption Patterns and Globalization in the *Encantadas*

William F. Waters and Wilma B. Freire

Abstract National-level survey data show that Galapagos has the highest rate of overweight and obesity of all Ecuadorian provinces. This phenomenon reflects trends observable nationally and globally, but also are the product of unique characteristics of the Galapagos population. Most importantly, nearly all food must be brought from the Ecuadorian mainland, as local production is limited. This factor necessarily means that food availability, variety, and quality are generally lower than elsewhere in the country, while prices are considerably higher.

Much of the food that is brought from the continent—usually by ship but sometimes by air—consists of staples (especially rice), meat, and poultry. Additionally, industrialized food products are extensively imported. The NOVA system classifies foods according to the level of processing and identifies processed and ultra-processed products as those that incorporate artificial ingredients and added salt, fat, and sugar. These products have been associated with overweight and obesity both globally and nationally.

This chapter will analyze food availability and quality (according to the NOVA system) in order to shed light on the high rates of overweight and obesity in Galapagos, not as a unique problem, but rather as a case in which national and global trends are clearly observed.

Keywords Overweight · Obesity · Globalization · Food production · Ultra-processed Foods

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7.1 Introduction

Why is the prevalence of overweight and obesity in Galapagos the highest of all Ecuadorian provinces? Three fourths of *Galapageños* are overweight or obese: nearly 10% more than the Ecuadorian national average and more than the countries with the highest prevalence rates in the world. This surprising fact contrasts with the image of healthy outdoor activities related to the islands' position as a unique tourist destination, thanks to its endemic species and geology. Here, it might be thought that a wide variety of nutritious foods must surely be available to accompany vigorous physical activity. But a walk of scarcely a half dozen blocks from Puerto Ayora's tourist-oriented harbor district (and even less from the bayside restaurants in Puerto Baquerizo Moreno and Puerto Villamil's modest town center) reveals another side of Galapagos, which closely resembles small towns and cities on the Ecuadorian mainland. Away from the purview of tourists are hardware stores, small clothing shops, pharmacies, repair shops, tiny corner groceries, and rustic eateries that cater to the local community. This side of the Galapagos is one of low incomes, susceptibility to tropical diseases—including dengue and others transmitted by insect vectors (Real-Cotto et al. 2017)—and limited access to food for reasons that are present elsewhere in the region and the world, but which are accentuated in the archipelago.

It might be thought that the residents of Galapagos live in such unique circumstances that a study of health and nutrition conditions could not provide any useful lessons of interest elsewhere in the world. We would argue otherwise, though; rather, we view conditions in the Galapagos as a "window on the world" (Freire et al. 2018a) because they represent a vivid example of how the global nutrition transition has unfolded and how generalized trends and tendencies are brought into sharp relief as few other places can. In this chapter, we locate overweight and obesity in Galapagos within the context of broad historical and structural processes that have been developing for decades throughout the world. Specifically, we argue that changes in food consumption patterns and concomitant increases in overweight and obesity are products of complex transformations in global systems of food production, marketing, distribution, and consumption that are characterized by the increasing dominance of processed and ultra-processed food products on a transnational scale. These transformations, we argue, are replicated locally in even the most remote corners of the world.

Counterintuitive as it may seem in a world where undernutrition, hunger, and food insecurity are widely discussed, overweight and obesity may be the greatest threat not only to nutrition but to public health in general. Overnutrition and undernutrition are not contradictory phenomena but are, rather, opposite sides of the same coin. But the increase in overweight and obesity over the past several decades has been so extraordinary that it was referred to as a pandemic before the coronavirus struck in 2020 (Popkin et al. 2012; National Academies of Sciences, Engineering, and Medicine 2019). About two billion adults are overweight worldwide, and third

of them are obese following a threefold increase in obesity rates since 1975. Particularly concerning is that 340 million children and adolescents between 5 and 19 years of age are overweight or obese, as were 38 million children under 5 years of age (WHO 2020). The prevalence rates for children and adolescents are particularly alarming because of the strong association between overweight and obesity in childhood and adulthood (Rolland-Cachera et al. 2006).

This trend is observed even in the poorest countries in Asia and Africa because undernutrition and overnutrition overlap at the national, community, and family levels and disproportionately affect the poor, thus contributing to a double burden of undernutrition on one hand and overweight and obesity on the other, including in Ecuador (Freire et al. 2018b). Overweight and obesity are not only serious problems in themselves but, in addition, are associated with a wide variety of chronic diseases, including cardiovascular disease, several forms of cancer, diabetes, and hypertension (Bastien et al. 2014: Larsson and Wolk 2007), and have been identified as underlying conditions of COVID-19 (Kluge et al. 2020: Ryan et al. 2020).

Beginning in the 1970s, researchers noted a shift in diets from unprocessed (or "natural") foods to products that are transformed through different manufacturing procedures in order to enhance durability, flavor, and appearance by incorporating added oils, fats, sugar, and salt as well as artificial flavors and colors. In order to understand this dramatic shift in consumption patterns, foods have been classified in four groups according to the level of processing to which they are subjected as a complement to the analysis of nutritional content (Monteiro et al. 2016). First, *unprocessed* and *minimally processed foods* are extracted from nature and are consumed after removing inedible parts and by cooking when appropriate. Second, *culinary ingredients* include condiments and spices that are added to foods in the first group. Third, processed foods include items in the first group, to which culinary ingredients are added and which are then preserved through cooking, canning, bottling, or other processes designed to increase durability or to enhance sensory qualities. Fourth, ultra-processed products are the result of manufacturing processes that transform foods by adding sugar, oil, fat, salt, and ingredients that are used only in industrial process and that were not previously used in food preparation, such as stabilizers and chemicals that render the original food ingredients basically unrecognizable. The increasing incorporation of processed and ultra-processed foods and beverages into the global diet is associated with the overweight and obesity pandemic (Malik et al. 2013; Zobel et al. 2016). This nutrition transition has accompanied reduced physical activity and sedentary lifestyles throughout the life cycle and is associated with broad social transformations, including urbanization and emerging occupational structures associated with the service sector (Popkin et al. 2012; Waters 2001). We consider these factors in greater detail below, following a description of overweight and obesity in Ecuador and Galapagos.

7.2 Overweight and Obesity in Galapagos

While rates of chronic malnutrition in children have slowly declined in Ecuador, those of overweight and obesity have systematically increased in all age groups (Freire et al. 2014a, b). Data provided by the 2012 National Health and Nutrition Survey (ENSANUT-ECU) suggest that the prevalence rates of overweight and obesity in Ecuador are among the highest in Latin America, rivaling those of Mexico and Chile. Using standard body mass index cutoff points, the ENSANUT survey shows that among Ecuadorian adults from 20 to 59 years of age, more than six in ten were overweight or obese in 2012, as were over half of those 60 years of age or older in 2010 (Freire et al. 2010, 2014a, b). In contrast, more than three fourths of adults in Galapagos were overweight or obese, as were substantial proportions of children and over a third of adolescents. Table 7.1 provides a comparison between national and provincial overweight and obesity rates by age group, showing that rates in Galapagos are higher than national averages in all age groups, except in the first 2 years of life.

In order to elucidate factors that contribute to overweight and obesity in Galapagos, mixed-methods research was conducted in 2016 and 2017 (Tashakkori and Teddlie 2009). Based on data that are regularly collected on living conditions (*Encuesta de Condiciones de Vida*) by the national statistics and census bureau (INEC), we calculated how much was spent in Galapagos in 2009 and 2014 on food items that were categorized according to the NOVA system described above and applied to Ecuadorian foods (Freire et al. 2017). This information was contextualized with field-based qualitative information on knowledge, attitudes, and practices related to food purchases and consumption that was collected through focus group discussion, key informant interviews, and structured observations of grocery stores, shops, and restaurants (Freire et al. 2018a).

The analysis of household expenditures showed that purchases of unprocessed and minimally processed foods declined significantly between 2009 and 2014 among urban residents in Galapagos (who represent about 90% of the total), but not their rural counterparts. This trend was accompanied by a significantly increased expenditures for ultra-processed products in urban areas, but not rural areas. An analysis of different population subgroups shows that expenditures for unprocessed

Table 7.1 Rates of overweight and obesity: Ecuador and Galapagos, 2012 (percent)

	Ecuador		Galapagos	
	Overweight	Obesity	Overweight	Obesity
0–23 months	9.5[a]		9.1[a]	
24–60 months	7.8[a]		15.1[a]	
5–11 years	19.0	10.9	25.8	18.3
12–19 years	18.8	7.1	20.7	13.8
19–59 years	40.6	22.2	45.8	30.0

Source: Freire et al. (2014a)
[a]Combined overweight and obesity rates.

and minimally processed foods significantly decreased among adults 20–39 years of age and 60 years or more, while expenditures for processed foods increased in all age groups. The study also shows that expenditures for unprocessed and minimally processed foods declined between 2009 and 2014 among persons with a high school education or less, while people in this group spent more for processed and ultra-processed products. Likewise, expenditures for ultra-processed foods were significantly higher among men than women (Freire et al. 2018a).

Based on an analysis of transcriptions of focus groups and key informant interviews (Strauss and Corbin 1998), we found that study participants described their diets as generally unhealthy and unbalanced, being composed largely of rice and other carbohydrates served with meat or poultry (and surprisingly little fish) that is usually fried in oil. This was true especially when meals are consumed in restaurants, which is frequent when adults work outside of the house and when families eat together on weekends (Freire et al. 2018a). While knowledge of healthy diets varied among adult focus group participants, many reported that awareness of and positive attitudes toward healthy diets do not necessarily translate into the purchase or consumption of healthy foods because other considerations (described below) intercede. Children and adolescents similarly reported purchasing and consuming ultra-processed snacks, often after school.

The qualitative research component revealed that women were more likely than men to translate their understanding of the Ecuadorian graphic nutrition label (known as the traffic light label) on packages of processed and ultra-processed foods (which provides information on added fats, sugar, and salt) than men, who prioritized food preferences over contributions to a healthy diet. These findings are consistent with results of a national-level qualitative study, in which we also found that urban consumers are more likely than their rural counterparts to purchase and consume processed and ultra-processed products (Freire et al. 2016). Since Galapagos residents are mostly urban, this factor is also relevant.

The Fig. 7.1 below is an example of the nutritional label, which uses red, yellow, and green colors to show that this product has a high level of added sugar, a medium level of added fat, and a low level of added salt according to established cut-off values.

Like their parents, adolescents observed that physical activity is limited. While many students walk to and from school, distances are reduced, and opportunities to participate in structured or unstructured sports are perceived to be limited (Freire et al. 2018a). Factors that were identified by participants as inhibiting healthy diets are not unique to Galapagos, but they are accentuated there because of the complex and expensive transportation and distribution chain that is based largely on periodic delivery by ships from the mainland. According to focus group participants and key informants, the principal reason for purchasing and consuming few fruits or vegetables is the high cost of produce brought from the mainland. Local agricultural production is limited, taking place on only 3% of the islands' land area (Franke et al. 2017; Torre 2013), and local produce is seen as inferior in quality and appearance.

Second, access to healthy foods is limited in that nearly all consumers purchase food in small neighborhood shops, where there is little variety and where canned

Photo: Laura Centeno

Fig. 7.1 Ecuadorian graphic nutrition label

and bottled (processed and ultra-processed) foods and sweetened beverages predominate. Structured observations confirmed that these shops carry comparatively few fresh foods. In contrast, surprisingly few families depend on municipal markets or weekly farmers' markets held in Puerto Ayora and Puerto Baquerizo Moreno. Third, unprocessed and minimally processed foods are often in poor condition, largely because they spend so much time in transit and distribution before reaching local shops. Fourth, study participants reported that the best fresh foods are monopolized by the restaurant and tourism sectors (Freire et al. 2018a). In sum, this study showed that residents of Galapagos live in an obesogenic environment characterized by a diet that is dominated by carbohydrates (particularly rice) and large serving sizes but limited consumption of fruit and vegetables. These findings are similar to those reported by Neira-Mosquera et al. (2019), who applied 24-h recall methodology and multivariate analysis to explain food consumption patterns in Galapagos.

7.3 The Globalization of Overweight, Obesity

We live in an increasingly interconnected world in which few remote corners are excluded from the effects of globalization. This phenomenon has been widely discussed for decades using different optics, including the potential contributions of

globalization to generalized well-being (Friedmann 2000; Stiglitz 2006). In contrast, deleterious effects have been identified (Sassen 1998; Stiglitz 2002), especially on specific population groups including women (Aguilar and Lacsamana 2004) and the rural poor (Loker 1999) and more generally on inequality (Bradshaw and Wallace 1996) and the concentration of wealth (Korten 1995; Mander and Goldsmith 1996). In response, social movements have opposed or resisted globalization in different parts of the world (Broad 2002; Edelman 1999; Smith and Johnston 2002).

The interrelationships between globalization and health have also been widely noted, beginning with the oft-quoted observation that microorganisms that cause diseases recognize no international borders and need no passport or visa. A great deal of attention has been paid to new and reemerging infectious disease in this regard (Morens and Fauci 2013), including the 2020 COVID-19 pandemic, which is an extraordinarily dramatic example of the globalization of health. Less dramatic, perhaps, but of enormous consequence, is the relationship between globalization and the pandemic of overweight and obesity (Cuevas García-Dorado et al. 2019), which we address below.

The complex fabric of globalization has been woven with many threads. One line of analysis focuses on the increasingly pervasive spread of culturally based beliefs and practices and focuses on ways in which language, speech, dress, music, and consumption are increasingly homogenized (Nederveen Pieterse 2004). In part, this analysis focuses on the domination of Western modes of thought and action (Ritzer 2004) and the concomitant erosion of rich local cultures, including language (Harrison 2007), traditional health-related behaviors (Gallegos et al. 2017), and dietary beliefs and practices (Atkins and Bowler 2016). The profound expansion of the Internet and social media contributes to cultural globalization.

In contrast, from an economic, financial, and commercial perspective, globalization is seen in terms of complex worldwide interrelationships between nation states and also with international organizations, which increasingly determine the terms of global commerce and finance. Particularly prominent in this regard are the World Bank, the International Monetary Fund, and regional counterparts such as the Inter-American Development Bank. The basic role of these institutions has been to provide financial and technical development assistance to member states, but they also exercise considerable oversight functions. In addition, economic, financial, and commercial globalization has been fostered by the World Trade Organization and the International Labor Organization as well as regional economic and financial agreements created by, for example, the European Union and the North American Free Trade Agreement (NAFTA), which links Canada, the United States, and Mexico. These multilateral institutions were organized as mechanisms to facilitate communication and negotiations between and among member states, but they also play proactive roles in determining and enforcing rules that govern the increasingly complex global economic order based in large part on general principles of trade liberalization and global fluidity of financial transactions (Waters 2006). We argue

below that this global system provides the infrastructure for the nutrition transition throughout the world, including Ecuador and Galapagos.

While it can be argued that to some degree international economic, financial, and commercial relations date from at least the fourteenth century, globalization is usually seen as a new and constantly evolving development paradigm based on three essential characteristics. First, the emergence of the transnational corporation, unlike the multinational corporation of previous decades, is not bound by national borders, economies, societies, or legislative restrictions; it operates on the basis of flexibility to carry out its productive, financial, marketing, communication, and distribution functions. Second, part of the flexible nature of the transnational corporation is that any of its functions—including production—can be carried out in any part of the world on a more or less interchangeable basis wherever conditions are deemed to be most favorable at the moment. The transnational food and beverage industry is one of the most significant examples of economic globalization, representing worldwide sales of $5.65 trillion in 2017 (Cision Newsletter 2018), which accounts for 11% of all global commerce (Casells 2006).

We began this chapter by stating that overweight and obesity constitute a global pandemic that is among the greatest public health challenges worldwide, and which is manifested in Ecuador and, particularly, in Galapagos. The origins of this phenomenon have little to do with individual food choices, but rather correspond to historical antecedents and contemporary social, economic, and political characteristics found in most parts of the world, and which are particularly notable in the small Pacific island nations, ten of which have the highest obesity rates in the world, as shown in Table 7.2.

We make this point because in many ways, the archipelago of Galapagos is like its distant Pacific Ocean neighbors to the west in terms of its contemporary social structure. While the islands listed in Table 7.1 were populated through complex

Table 7.2 Adult obesity rates and population, Pacific island nations, 2020

Country	%Obesity	Population
Nauru	61.0	10,824
Cook Islands	55.9	17,564
Palau	55.3	18,094
Marshall Islands	52.9	59,190
Tuvalu	51.6	11,792
Niue	50.0	1626
Tonga	48.2	105,695
Samoa	47.3	198,414
Kiribati	46.0	119,449
Micronesia	45.8	115,023

Source: World Population Review (2020)

historical processes of commerce and exploration over many centuries (Diamond 1999), Galapagos was not permanently settled until relatively recently (Anderson et al. 2016), so there are no traditional patterns of subsistence agriculture and fishing there. Nevertheless, food acquisition and consumption patterns and their consequences are remarkably similar in that they depend almost entirely on external factors. Specifically, the elevated rates of overweight and obesity are related to dependence on imported processed and ultra-processed and energy-dense foods. These products have largely replaced traditional diet that again are reflections of complex globalized commodity chains as well as transformations in local social structure including urbanization, changes in occupational structures, and sedentary lifestyles.

Traditional Pacific island diets were based on local crops and native fruits including taro, breadfruit, yams, coconuts, arrowroot, and bananas, which were complemented by an abundant supply of fish and crustaceans. Consequently, inland inhabitants were described by early European explorers as tall, thin, and muscular. The traditional diet, though, was transformed over the centuries, first by successive waves of seventeenth-century colonizers, who introduced corn, cassava, chickens, and pigs, and continuing into the twentieth century with the introduction of rice and government-sponsored supplementary feeding programs (Casells 2006). In the past half century, the Pacific island diet has increasingly included wheat flour, sugar, meat, and sugar, and in the past several decades, the same processed and ultra-processed food products found elsewhere in the world. These dietary changes were accompanied by and facilitated by broader social, economic, and political transformations, including the introduction of cash economies, wage labor, and the commodification of food; the replacement of traditional crops with market-based and export-oriented crops; and extractive industries such as mining, all of which were sustained by global trade policies (Casells 2006; Kessaram et al. 2015; McLennan and Ulijaszek 2014; Taylor et al. 1992; Throw et al. 2011).

The increased consumption of processed and ultra-processed food products represents the visible part of the unfolding nutrition transition, which is also characterized by food insecurity, industrialized neoliberal diets, overweight and obesity, and concomitant chronic health conditions such as diabetes, hypertension, and cardiovascular diseases that are now so widely observed in the Pacific region (Farrell et al. 2019; Otero et al. 2017). Galapagos is not an independent nation, was never a colony, and as noted, unlike other Pacific islands, was not inhabited until relatively recently. Nevertheless, its size and relative geographic isolation have produced similar results in that it has never been self-sufficient in food, as were the Pacific island nations, but has nevertheless experienced similar economic, financial, and commercial processes in the past half century, which have produced similar results. Healthy diets based principally on unprocessed or minimally processed foods face considerable obstacles, which have not been adequately addressed, resulting in the local expression of the global overweight and obesity pandemic.

7.4 Discussion

The overweight and obesity epidemic observed in Galapagos, fueled by the nutrition transition based in large part on the increasing consumption of processed and ultra-processed foods, is the product of a dramatic restructuring of relationships between food production and consumption. This global transformation began in the early years of the twentieth century when mass production was in its early stages, when most of the world still lived in rural areas, where most people produced or consumed locally produced unprocessed or minimally processed foods. By the 1920s, though, manufacturing was based on the production of uniform, standardized goods, typified by the Model T Ford, the first automobile built on a factory line with standardized parts. The production of other consumer durables such as refrigerators soon followed. Food and beverage production was similarly revolutionized through the emergence of canned and frozen foods, instant coffee, and similar processed products of uniform quality. When prepared and consumed, these products were not very different from unprocessed foods, but they could be stored for long periods of times, transported for long distances, used throughout the year, and consumed by people in all social classes (Waters 2001).

This Fordist food regime has persisted in part to the present day but in an entirely new context, such that the link between production and consumption link is characterized by three overlapping elements. First, pre-Fordist food production of traditional crops persists and can be observed, for example, in rural communities in mainland Ecuador. This millennial process is accompanied by consumption of unprocessed or minimally processed (pre-Fordist) foods by rural and urban residents alike. Second, the world has witnessed the nearly ubiquitous production, marketing, distribution, and consumption of processed and ultra-processed food products in the Fordist mold, where standardized quality and non-perishability continue to be important features in addition to the capability to transport these items literally anywhere in the world, and where fast foods consumed outside the home or delivered to the house are increasingly prominent. Third, like automobiles and consumer goods such as electronics, the massive market of processed and ultra-processed foods is constantly shifting into countless market niches in order to satisfy evolving consumer segments through product differentiation and the "customization of commodities" (Streek 2012: 32). This post-Fordist food regime offers an apparently endless variety of alternatives to standardized foodstuffs, including a wide range of fresh and exotic fruits and vegetables throughout the year in the global supermarket; niche items such as wine, craft beer, and ethnic foods; and items produced for the organic, vegan, and fair trade markets, as well as fresh non-food items such as cut flowers (Waters 2001).

Does the globalization of food production and consumption obviate the possibility of local responses? In our view, the contrary is true. First, a variety of actors in civil society have developed organized political responses to globalization. Hence, political parties and movements across the political spectrum have emerged worldwide and in Ecuador. These niche parties have appeared alongside niche food

markets (Streek 2012). Second, as the economist Alberto Acosta (2005) suggested in the Ecuadorian case, "glocalization" is a reasonable and possible alternative to apparently immutable global economic, financial, and political processes. A "glocal" approach would be based on local organization and actions to counter environmental deterioration and cultural erosion and to unlink local economic activity, including food production and consumption, from transnational corporate control.

Several alternatives are at hand in Ecuador and in Galapagos. Built in part on the country's rich history of community-based organization and decision-making at the local level, particularly in rural indigenous communities in the highlands, Ecuador has witnessed the development of decentralized spheres of local control devolving from the central government to provincial, county (*canton*), municipal, and parish (*parroquia*) levels. These levels have been formally defined as *gobiernos autónomos y descentralizados* (autonomous and decentralized governments) with their own resources and full-time, salaried authorities who are locally elected.

Several local alternatives are available in Galapagos for local health and nutrition policy and promotion. The recent experience of eliminating single-use plastics provides an excellent example for this "glocalized" approach (Latin Trails n.d.). While expanding the agricultural frontier to increase local production is a poor option for environmental reasons, there are excellent opportunities to promote household and school gardens. Second, municipal and periodic farmers' markets can be promoted. Third, the local media and public institutions can be mobilized to promote changes in nutrition behavior. Fourth, restaurants can be designated as nutrition friendly when they provide relevant information in their premises and on their menus and offer health alternatives and smaller serving sizes. Fifth, it is essential that the graphic nutrition label be maintained and locally monitored. These alternatives and others, which will benefit the local population and which will be well received by tourists, can be planned and implemented by local authorities with the collaboration of provincial offices of relevant ministries, public hospitals, schools, and other actors in civil society. With this approach, the Galapagos can become even more *entantadas* ("charmed").

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Chapter 8
Spatial and Social Dimensions of Galápagos Food Environments

Khristopher Nicholas, Paul Delamater, and Amanda Thompson

Abstract This chapter describes the current food environment in the Galápagos and its historical and sociopolitical context. Using market survey data, the chapter describes the spatial distribution of market resources and quality and provides food environment surface maps of quality and access on San Cristóbal Island. Next, it uses household survey data to describe food purchasing strategies. Both approaches are critical in order to understand the interaction between empirical measured in markets and experienced food environments navigated by community members. Spatial models suggest patterning of food environments based on market distribution and stock. Households report distance to markets and cost of goods as the most important contributors to household decision-making when grocery shopping. These findings suggest that the food resources surrounding a household is an important contributor to food availability but also that internal household food purchasing strategies can shape the influence of external food environments. These both present key targets for potential future interventions to increase food availability, desirability, and access.

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8.1 Introduction

Worldwide, over 2 billion people are overweight, and 150 million children are stunted (FAO, IFAD, UNICEF, WFP 2019). The number of countries facing the dual burden of malnutrition, the coexistence of undernutrition (stunting, wasting, micronutrient deficiencies, and underweight) and overnutrition (overweight, obesity, and diet-linked noncommunicable diseases such as diabetes), has risen in recent years (Popkin et al. 2020). These increasing rates are linked to low-nutrient, energy-dense diets, sedentary lifestyles, and continued exposure to diseases.

Fueled by growing income inequality, the dual burden predominates in low- and middle-income countries (LMICs) (Perez-Escamilla et al. 2018). Addressing these challenges in LMIC settings is a growing concern (Azeredo et al. 2016; Colchero et al. 2016; Duran et al. 2016; Fernandes et al. 2017; Pongutta et al. 2018; Rayner et al. 2013; Wang and Shi 2012). Latin America faces major dietary changes such as reduced intake of healthy foods, increased intake of sugary beverages, and away-from-home eating. All of these have been accompanied by high levels of overweight and obesity across all age ranges (Popkin and Reardon 2018). In Ecuador, overweight and obesity affect over 40% of men and women, while stunting persists in over 25% of children (Freire et al. 2014). Furthermore, it is estimated that in over 13% of Ecuadorian households, a stunted child cohabitates with an overweight or obese mother, highlighting the intergenerational complexity of dual burden (Freire et al. 2014).

At the root of this health landscape are rapidly changing dietary patterns, food systems, agricultural policies, and globalized markets. Sugar intake features prominently in modern Latin American diets with three out of five of the world's highest sugar sweetened beverage (SSB) consuming nations located in Latin America (Pereira et al. 2015; Popkin and Hawkes 2016). Total daily per capita junk food intake among Latin Americans is 32 grams, representing as much as 34% of daily caloric intake (Duffey et al. 2013; Popkin and Reardon 2018). Accompanying this high consumption of unhealthy foods has been a reduction in healthier food options. No Latin American countries consume the recommended 5–7 daily servings of fruits and vegetables. Legumes, for example, once high-fiber staples of traditional diets, currently represent less than 10% of daily caloric intake (Monteiro et al. 2013; US Department of Health and Human Services and US Department of Agriculture 2015).

Similar to Small Island Developing States (SIDS), the Galápagos faces additional barriers to food security relating to finite land resources, isolation, and a dependence on global markets (Connell et al. 2020). SIDS have among the highest

rates of noncommunicable diseases (NCDs), overweight and obesity, and childhood obesity rates in the world (Foster et al. 2018). These islands often find themselves distanced from traditional agricultural markets, dependent on international trade to meet rapidly Westernizing domestic food demands, and vulnerable to trajectories of development wherein migration and tourism further concretize their dependence on foreign markets (Connell et al. 2020).

In short, shifting nutrition landscapes throughout Latin America can be attributed to the convergence of global and local diets, globalized markets driven by free trade, the emergence of retail and fast-food service, the rising influence of agribusiness, and a shift away from traditional food acquisition and consumption practices (Monteiro et al. 2013; Popkin and Reardon 2018). In this context of global and regional diet and health challenges, this chapter explores novel techniques in assessing food environments, defines and characterizes the unique Galápagos food environment, and discusses potential implications for future approaches to address these challenges. Our goal in this chapter is to document the potential mechanisms by which Galápagos food environments impact diets and health, providing key insight for future behavioral and environmental interventions.

8.1.1 Summary of Food Environment

The "food environment" is a collective term for the economic, behavioral, and sociopolitical drivers of dietary change and evolving health realities (Lytle and Myers 2017). Food environment research seeks to address these issues by bridging macro-level research on food systems (e.g., agriculture, availability, food policy) and micro-level research on diets (e.g., dietary diversity, overweight/obesity, dietary risk factors for cardiovascular disease). A food environment encompasses the behavioral and geographic factors that influence diets and health (Swinburn et al. 2013; Turner et al. 2018). These include the physical, economic, political, and cultural surroundings that affect people's food and beverage choices and, ultimately, their nutritional status (Swinburn et al. 2013).

Being both place- and people-focused, past food environment interventions have made significant improvements to diet and health throughout Latin America. In Chile, front-of-package warning labels of packaged foods and beverages high in energy, sugar, saturated fat, and sodium led to improved social norms around healthy eating among young consumers (Correa et al. 2019). In Mexico, a 2010 school lunch policy improved dietary habits among elementary school children (López-Olmedo et al. 2018). In Brazil, programs in Belo Horizonte aimed at improving food access and diet quality have increased dietary diversity while supporting local farmers (Rocha and Lessa 2009).

In 2014, Ecuador became among the first countries in Latin America to institute a Nutritional Traffic Light Label (NTLL), a strategy to guide consumers toward healthier food options (Teran et al. 2019). The goal of this intervention was to

improve consumer purchases of healthier prepackaged foods using a simple, effective labelling system. Ecuador has an average per capita consumption of soft drinks of 1.68 L/month, a growing contributor to overweight and obesity (Peñaherrera et al. 2018). Though this policy did not have its intended effect, it represents a meaningful example of leveraging food environment research (i.e., where and when consumer behavior is most malleable) to target dietary and health outcomes.

8.1.2 Food Environments in the Galápagos

A commonly used approach for defining food environments distinguishes between *consumer food environments* (perceived availability, cost, and quality) and *community food environments* (number, type, and location of food outlets) (Glanz et al. 2007). More recently, recognition of the interaction between these two food environment domains has given rise to more complex frameworks that span the socio-ecological spectrum from consumer to community (Turner et al. 2018). In this chapter, we draw upon the theoretical framework proposed by Charreire et al. (2010) and adapted from Penchansky and Thomas (1981) which defines five dimensions of food environments: availability, accessibility, affordability, acceptability, and accommodation (Charreire et al. 2010; Penchansky and Thomas 1981).

Availability refers to the presence or absence of foods and food outlets. In the Galápagos context, we might consider the density of markets, which are small bodegas that often stock food and household items, within a neighborhood (availability at the community level) and the types and amount of food that these markets stock (availability at the consumer level). The temporal aspect of availability is also important. For example, though a given neighborhood may have many markets that regularly stock a wide variety of products, the food available at these markets may vary depending on food shipment delays from the mainland.

Accessibility refers to consumer-level factors that determine individual food environments. For example, a household's distance to markets, time constraints, and available transportation options all influence the food outlet options accessible to a given household. In Galápagos, households with scooters may be able to quickly navigate to additional markets to purchase food in the event that their local market is out of stock. Importantly, accessibility is relevant only insofar as availability is met; food cannot be accessible if it is not available. This is a key example of the complex interaction between community- and consumer-level food environment domains.

Affordability refers to food prices and people's food valuations. In the Galápagos, food prices can vary with seasonality, food shipment delays, and mainland food availability. From a purely supply-demand perspective, these prices (and the fact that foods are typically much more expensive in the Galápagos compared to mainland Ecuador) sharply influence whether or how much of these foods residents will purchase. However, affordability is also concerned with individuals' *ascribed* value. For example, for a household consuming predominantly rice, beans, and meat, a

reduction in the price of fresh fruits and vegetables may not alter their purchasing behavior whatsoever.

Acceptability refers to attitudes and preferences describing whether options within the food environment meet individual standards. These standards can be related to health (e.g., do I have access to enough fresh produce to eat a balanced, healthy diet?) or cultural and personal preferences (e.g., can I cook my preferred dishes using the options available to me?). In the Galápagos, for example, the desire to consume locally grown foods versus imported foods may shape residents' preferences.

Accommodation refers to the extent to which local food sources are aligned with the local community's needs and ways of living. For example, some Galápagos residents might prefer to shop at markets that sell food on credit, are open at certain hours, reliably stock a favorite brand of food, or are owned by a family friend.

The intersection of these dimensions in the Galápagos is especially important. For example, tourism, the largest income generator in the archipelago, has contributed to a reduction in local agricultural production as farmers are pulled toward livelihoods in tourism (Sampedro et al. 2018). This contributes to a reduction in the *availability* of locally produced foods, ties *affordability* to externally set prices for the increasing proportion of imported foods, and is linked to perceived dietary *accommodation* through a nutrition transition and shifts away from local markets toward external trade (Sampedro et al. 2018).

8.1.3 Measuring Food Environments in the Galápagos

Measuring each of the five dimensions of the food environment is important to get a complete picture. The two primary approaches for assessing food environments are geospatial measures of community food environments using geographic information systems (GIS) and observational measures of consumer food environments using household and individual surveys (Caspi et al. 2012; Lake and Townshend 2006; Moore et al. 2008; Ni Mhurchu et al. 2013; Townshend and Lake 2017).

8.1.3.1 Spatial Approach

Geographic analysis is the most common method used to study food environments (L. A. Lytle and Sokol 2017). In the food environment context, this means understanding how households situated at varying distances from various market types may differentially experience outcomes such as diet intake and health.

Geographic proximity does not invariably imply accessibility (Charreire et al. 2010). Of the five dimensions of access in food environments described above (availability, accessibility, affordability, acceptability, and accommodation), only the first two are explicitly spatial measures. Spatial methods are well suited to explore availability and accessibility in food environments. Common measures

include counts or attributes of food outlets within a specific area or distance to the nearest outlet (Charreire et al. 2010). Recent developments have made it easier to incorporate travel time and modes of transportation to food outlets, which leverage more realistic network models (e.g., travel networks, time allocations, modes of transport) and improved estimates, especially in rural and peri-urban areas (Apparicio et al. 2008; Lovett et al. 2002).

Spatial methods are helpful tools to explore neighborhood-level patterns. However, a challenge for spatial research related to food environments is *how* to operationalize "neighborhood" (Lytle 2009). There are numerous approaches to define "neighborhoods," including using existing political or administrative boundaries, distance-based regions based on residential location, and activity spaces. Additional challenges are how to capture food prices and quality, availability and accessibility, spatial representations of food outlet density, individual-level considerations such as decision-making and transportation, and a majority of food outlets available (Bivoltsis et al. 2018; Black et al. 2014; Block and Kouba 2006; Burns and Inglis 2007; Charreire et al. 2010; Frank et al. 2006; Ni Mhurchu et al. 2013). In the Galápagos, where these challenges are compounded in remote island settings, observational tools such as surveys can help capture more nuanced aspects of consumer food environments.

8.1.3.2 Observational Approach

There has been a call for supplementation of spatial methods with more observational and qualitative survey methods that capture consumer food environments (Caspi et al. 2012; Charreire et al. 2010). Store audits are a common form of observational measure that assess shelf-space occupied by various foods, food quality and prices, and less obvious measures of accessibility such as placement of food within stores and whether the surrounding area is pedestrian-friendly (Caspi et al. 2012).

Observational methods targeting consumer food environments are designed to identify structural drivers of food purchasing decisions, diets, and nutritional status (Turner et al. 2018). The Nutritional Environment Measures Survey for Stores (NEMS-S) is a pioneering survey designed to assess food availability and variety within markets, ranging from fresh produce to breakfast cereals (Glanz et al. 2007). Studies using this survey have shed light on health disparities such as the increasing prices and reduced availability of healthy foods in low-income and marginalized communities and the effectiveness of corner store interventions in the United States (Cavanaugh et al. 2014; Story et al. 2008). In the Galápagos, where community markets are the primary food outlet for most residents, these surveys, conducted in all markets, provide key insight into the variety of foods that families have access to, the quality of these foods, and how expensive they are.

Food purchasing behavior is the intermediary between community food environments and individual dietary intake. A host of individual and environmental factors shape food purchasing behavior, including food availability, financial accessibility, seasonality, cultural norms and preferences, religion and belief systems, mode of transportation, and marketing and social conditioning among others. These factors work together in complex ways. Key components of household food purchasing behavior are food outlet preferences, commonly purchased foods, food shopping frequency, budget constraints, and willingness to travel and/or spend money (French et al. 2008). In the Galápagos, a household willing to shop at multiple markets to obtain healthy food and that places higher priority on healthfulness may engage in food purchasing behavior that outweighs the effect of a poor local food environment. These behaviors may act as compensatory mechanisms that attenuate the influence of their environment. Because spatial methods measure environments directly, a focus on household-level factors such as food purchasing behavior sheds light on important human-environment interactions. Though often overlooked in food environment research, understanding food purchasing behavior is a fundamental consideration for dietary and health outcomes.

8.1.4 Empirical vs. Experienced Food Environments

The interaction between built and social environments is complex. A central premise of food environment research is that an individual's geographic location contributes to their diet choices and health (Caspi et al. 2012; Furey et al. 2001; Rose and Richards 2004). However, despite the intuitive appeal of a food environment-health relationship, the scientific evidence is equivocal (Black et al. 2014; Feng et al. 2010). One reason for this uncertainty is that individual behavior is rarely accounted for despite increasing evidence that the intersection between the individual (behavioral) and their environment (geographic) is critically important (Ball et al. 2006; Cummins 2007; Giskes et al. 2007; Hillier et al. 2011; Lytle 2009). For example, in Australia, perceptions of availability and prices were associated with diet intake, while empirically measured food environments were not (Giskes et al. 2007). Similarly, a study in the United States found that low-income families in urban areas traveled longer distances to purchase groceries (outside of their own neighborhoods) despite transportation limitations, likely because of the poor local food options (Hillier et al. 2011). This highlights that the influence of local food environments must be considered alongside factors that determine food purchasing behavior. In short, there is a need to account for the behavioral processes that underlie food environment relationships, because neither empirical nor experienced measures capture the full picture (Caspi et al. 2012; Cummins 2007).

8.2 A Closer Look at Food Environments in the Galápagos

The Galápagos archipelago is a unique island laboratory that provides a rare opportunity to explore the influence of food environments on human diets and health. Located 1000 kilometers away from mainland Ecuador, the Galápagos islands must import sufficient food to supply its 35,000 residents and nearly 250,000 tourists/year (Reyes et al. 2016). With 97% of land cover reserved as parkland, local food production is limited (Page et al. 2013). Food insecurity is of particular concern, because imported food is often expensive, of unpredictable quality, and subject to seasonal availability.

The 2008 Ecuadorian constitution addresses the "strategic objective and obligation of the state that persons, communities, peoples and nations achieve self-sufficiency with respect to healthy and culturally appropriate food on a permanent basis" (Asamblea Nacional 2008). This policy objective and the decades of food sovereignty activism preceding it have promoted diversified farming systems, organic agriculture, and intercropping (Giunta 2014). These practices strive to counteract the reach of transnational food corporations that enable a nutrition transition from low-calorie, predominantly plant-based diets to high-calorie diets rich in fat, sugar, and processed foods (Bernstein 2008; Barry M. Popkin 2001). Yet Ecuadorian diets are increasingly characterized by excessive carbohydrate intake and fresh fruit/vegetable consumption less than half of the recommended levels (Freire et al. 2014). Understanding which factors contribute to these diet patterns, the mechanisms by which these factors influence diets and health, and which populations are most vulnerable to these factors is highly important. In the Galápagos, this can include exploring how food import practices, market distribution, and neighborhood characteristics influence the food environment. Further examples include examining how the physical food landscape shapes not only diets but also community perceptions of food security.

From a scientific standpoint, the natural isolation of the Galápagos islands reduces the influence of key methodological challenges in other regions. The edge effect is one such challenge in food environment research that stems from an inability to account for food environments outside of prespecified boundaries. For example, in the United States, border counties can be mistakenly identified as food deserts, because a household's preferred food outlet may be located in a neighboring state (Sadler et al. 2011). However, Galápagos communities have no terrestrial border with other (human) inhabitants, virtually eliminating the influence of edge effects.

From a practical standpoint, food environments in Galápagos are important because of concerns over rising rates of overweight and obesity. Galápagos has the highest rates of overweight and obesity in Ecuador, with 12.7% of children under 5 and 75.9% of adults overweight or obese (Freire et al. 2018). This is higher than the rates of adult overweight and obesity of any country in Latin America. These rates are also higher than most Small Island Developing States (SIDS) including Samoa, Tonga, Vanuatu, Jamaica, and Barbados (Foster et al. 2018; World Health

Organization 2018). Contributing factors include a shift in diet patterns toward highly processed foods and a perception that food price, availability, and quality are barriers to adopting healthy diets (Freire et al. 2018). By exploring how the food environment and food purchasing behavior contribute to this health landscape, we hope to identify potential avenues to improve diets and health in the Galápagos. In the Galápagos, where local markets are the primary food source, understanding whether the neighborhood in which a family resides has meaningful implications for their diets or their health is important. We are also interested in *which* markets household members most frequent, *why* they choose these markets, *how* they get to these markets, and *what they do* if these markets do not have the foods they seek.

The aim of our case study was to examine the interactions between built and social environments and individual purchasing behavior. For example, a Galápagos household willing to shop at multiple markets to obtain healthy food and that places higher priority on healthfulness may engage in food purchasing behavior that outweighs the effect of a poor local food environment. To assess community food environments, we used the NEMS-S tool adapted for Galápagos markets, a spatial algorithm to calculate food environment scores, and created a food environment surface map. To assess consumer food environments, we used household surveys to define food purchasing behavior types. Key components of household food purchasing behavior are food outlet preferences, commonly purchased foods, food shopping frequency, budget constraints, and willingness to travel and/or spend money (French et al. 2008). Important in our approach to measuring Galápagos food environments is considering these factors in the larger context of an ecological model containing individual, community, and social spheres.

8.2.1 Data Collection

We collected data in Puerto Baquerizo Moreno on San Cristóbal Island in 2018 and 2019 during the rainy and dry seasons, respectively. Using a list of all markets obtained from the municipality, we proceeded grid wise along every street to survey all markets. We assessed markets on the basis of food availability, variety, and quality using NEMS-S tailored to reflect foods commonly sold and consumed in the Galápagos. NEMS-S has been validated for use in Brazil and Costa Rica, and this is its first use in the Galápagos (Golfin et al. 2018; Martins et al. 2013). Using these surveys, we assign each market a score. Markets receive higher scores for an abundance and variety of nutritious foods and a lower score for an abundance and variety of unhealthy foods (Table 8.1). The average market score was 17 with a standard deviation of 12.7 and scores ranging from −13 to 37. Geocoded market locations and their NEM scores are presented in (Fig. 8.1).

In the rainy season of 2018 and the dry season of 2019, we surveyed 388 individuals within 116 households with children <5 years of age in Puerto Baquerizo Moreno and El Progreso on San Cristóbal island. Households with children under 5 years were chosen because of the high prevalence of both overweight (38.7%) and

Table 8.1 Market survey food groups and corresponding scores

NEMS-S food groups	Score effect[a]
Fresh fruit: variety	+++
Fresh fruit: quality	+++
Raw vegetable: variety	+++
Raw vegetable: quality	+++
Chicken	++
Eggs	++
Fresh seafood	+++
Dairy (whole or skim)	+
Cheese	+
Whole grain rice	++
Whole grain: Variety	++
Legumes: Variety	++
Nuts: Variety	+
Cooking oils	+
Whole grain flour	++
Granola	+
Canned vegetables	++
Canned seafood	+
White bread	−
Instant noodles	−
Cookies or ice cream	−
Chocolate or candy	−
Processed breakfast cereal	−
Sodas or sweetened drinks	−
Frozen prepared foods	−
Alcohol	−

[a] + and − signs indicate effect direction and symbol frequency indicates effect magnitude

stunting (8.9%) among children in the Galapagos (Thompson et al. 2019). From each household member, we obtained demographic data, a panel of health indicators, and a 24-h dietary recall. From the primary food preparer in each household, we obtained data on household food purchasing behavior. The primary food preparer self-selected as the person in charge of preparing and/or coordinating meals within the household. This survey identified predominant food groups purchased, what determines market preferences, scenario modeling questions focused on time and money constraints, and frequency of foods consumed outside of home, especially at lunchtime (Table 8.2)**.** The questions in this survey were specifically designed for this study to explore how households operate within their food environments.

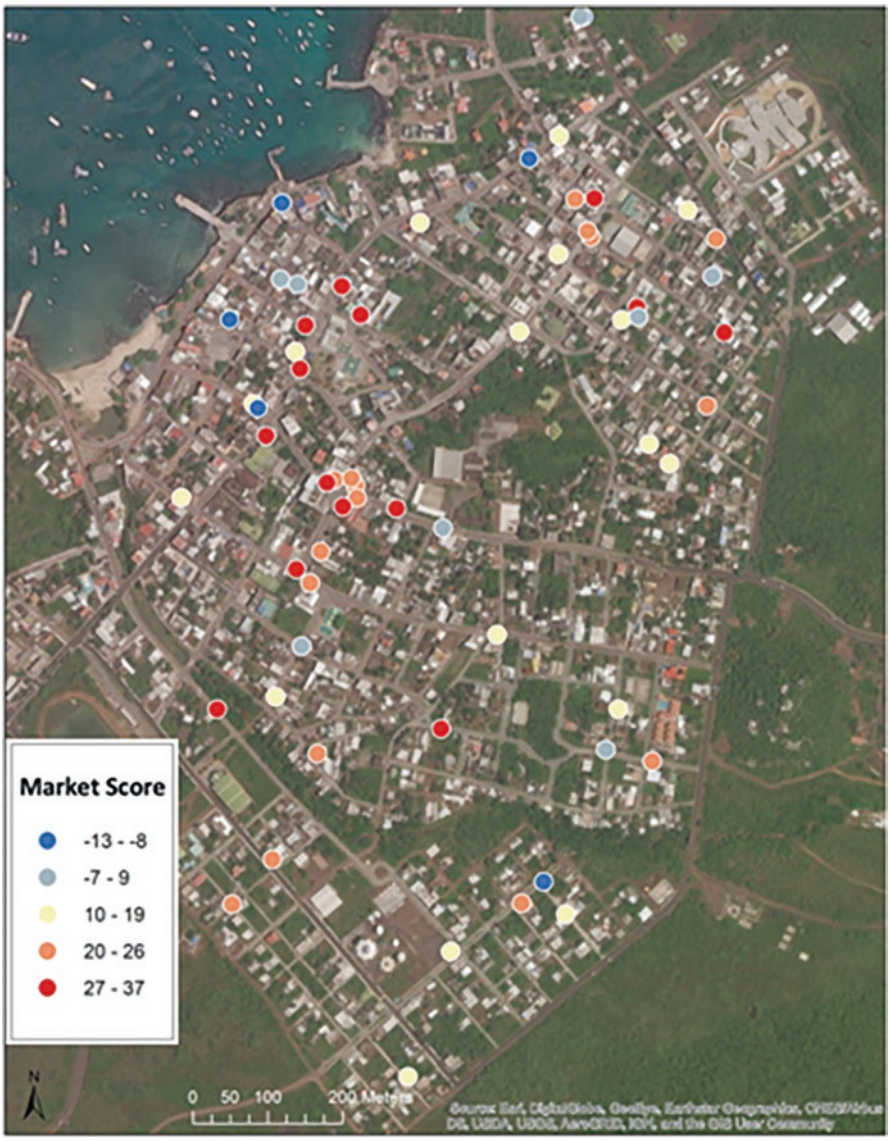

Fig. 8.1 Market locations and their NEMS-S scores in Puerto Baquerizo Moreno, San Cristóbal Island

Table 8.2 Food purchasing behavior survey questions and household responses

Food purchasing behavior elements
Which is the *most* important to you?
Market proximity to house. Market proximity to work. Low food cost. High-quality products. Reliably stocked markets.
What are the primary foods you purchased? Produce (fruits and vegetables). Beans. Meat/eggs. Complex carbs (e.g., whole grains). Simple carbs (e.g., white bread/rice). Sweetened drinks. Snacks/candies/fried foods.
How many times per week does your family eat out at restaurants or street vendors? Four or fewer times. Five or more times.
How many times per week does your family consume (snacks/drinks) outside of home? Four or fewer times. Five or more times.
Where does your family usually eat lunch? Home. Outside of home.
What do you do if your market does not have in stock the foods you are seeking? Seek another market that stocks it. Make do with what is available.
Scenario modeling suite of questions: Given reduced financial and transportation barriers, would you travel farther or spend more to obtain healthier food items?

8.2.2 Analytic Methods

The geocoded market locations were used to create a food environment surface map as a function of distance. Spatial interpolation using NEMS-S market scores was used to create a food environment quality surface map. Finally, we calculated a composite food environment score by combining the *quality* in the food environment with *access* as measured by distance. Because markets are virtually the sole source of food items for most residents, we used these composite food environment scores to interpolate a food environment surface map across the entire town.

8.2.3 Results

8.2.3.1 Spatial Approach

The food environment access map showing proximity to local markets is presented in Fig. 8.2. In the map, red regions have many nearby markets, while blue regions have few local markets nearby. The zones with the greatest density of markets are the area surrounding the large municipal market (in the northwest) and the neighborhood near the local hospital (in the northeast). The municipal market is housed in a large two-story building where vendors sell mostly fruits, vegetables, and meats.

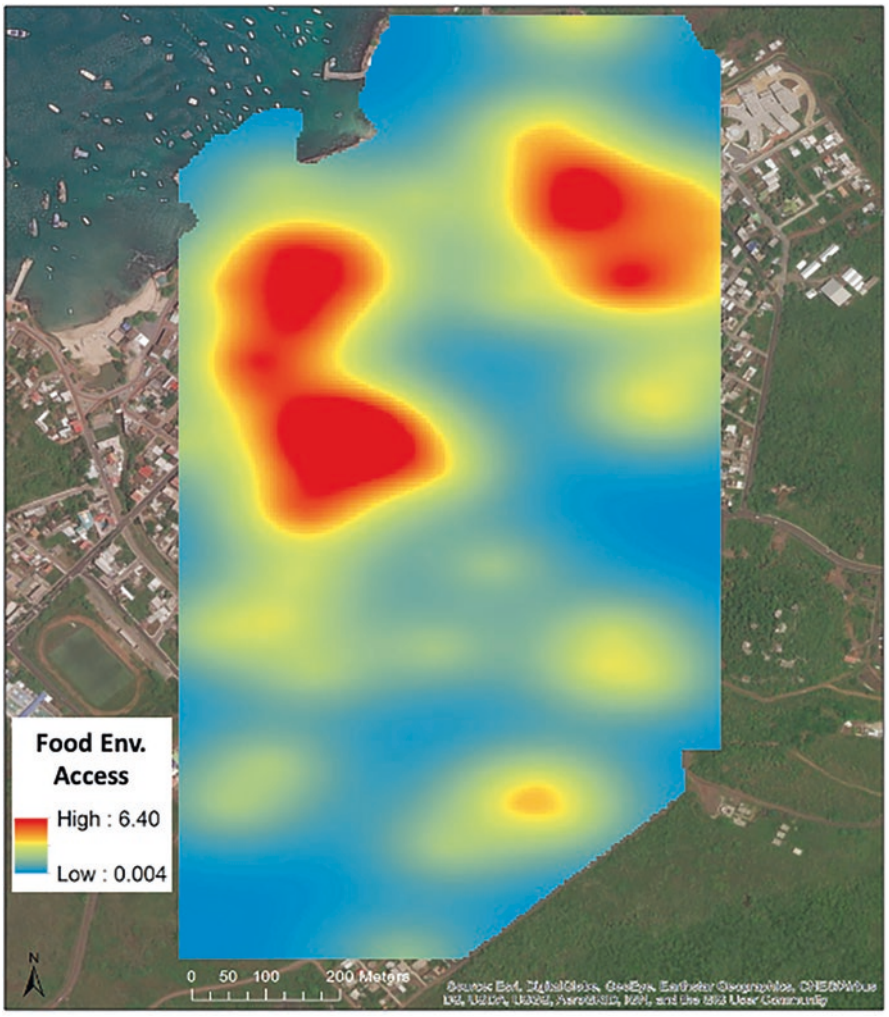

Fig. 8.2 Food environment access map depicting proximity to markets by location

This building did not receive a NEMS-S score, because it is not a neighborhood bodega. Areas immediately near and on the Malecón, the coastal boardwalk, have low market access, likely because these are tourist-heavy areas in which restaurants predominate over local markets. However, neighborhoods with local residents farthest away from the tourist-dense seaside appear to have the lowest market density.

The composite food environment surface map based on food environment quality and access to markets is found in Fig. 8.3. The strongest red zones (areas of high

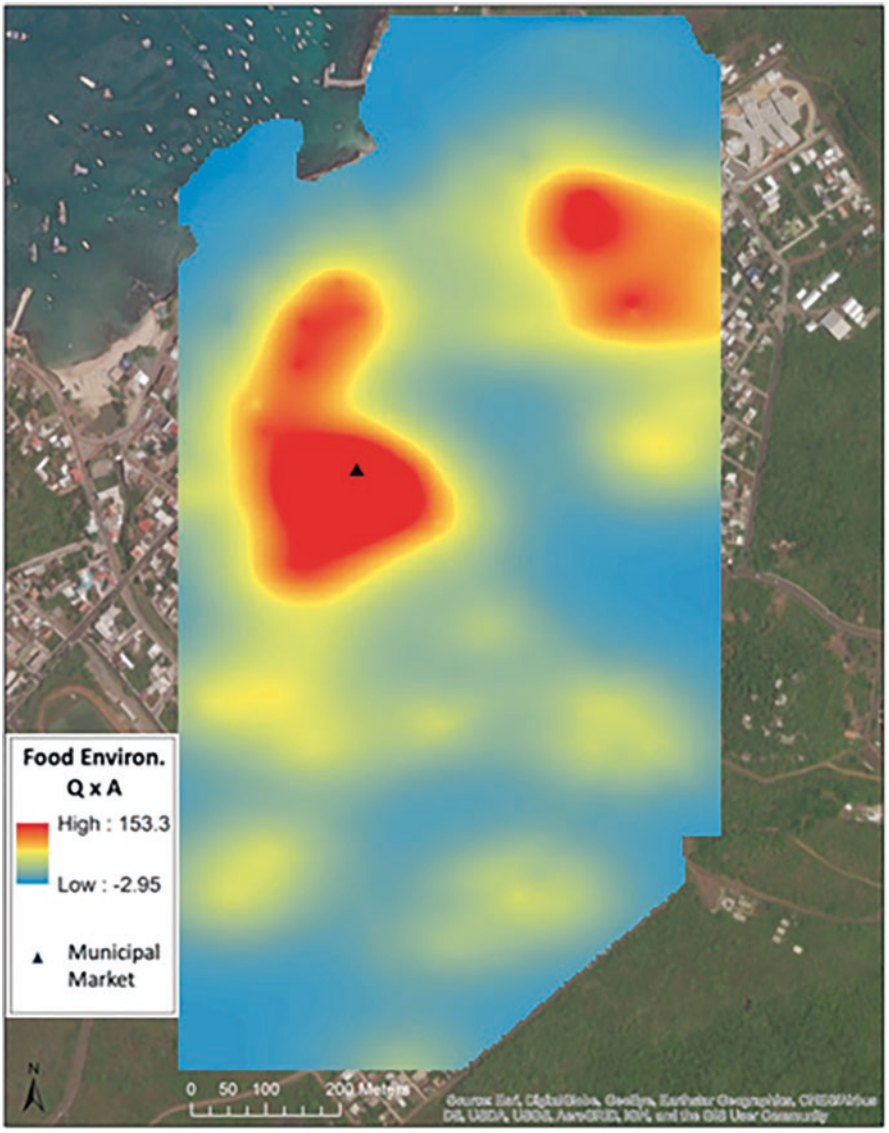

Fig. 8.3 Food environment surface map showing food quality and access to markets

quality and access) are located in the areas surrounding the outdoor municipal market, where vendors sell locally grown and imported fruits and vegetables. While there are several strong red zones in the study area, there are no strong blue zones. Strong blue zones occur when areas with high access to unhealthy markets compound the low NEM scores at these markets. This indicates that there is clustering of markets selling plentiful and healthy foods but not clustering of markets selling unhealthy foods in Puerto Baquerizo Moreno.

8.2.3.2 Observational Approach

In the food purchasing survey, we found that the single largest contributor to market choice was distance to work and home with 42% of households (n = 49) reporting distance as one of the most important factors. Cost was also a significant contributor to market choice with 40% of households (n = 46) listing affordability as a significant contributor to market choice. A sizeable minority, 11% of households (n = 13) listed the ability to purchase groceries on credit as the primary factor that determines which market they shop at.

We also found evidence of priority setting in survey responses. Compared to households that did not list having high-quality foods as a key contributor to their decision-making, households that did list food quality were nearly twice as likely to be willing to pay more or travel farther to reach better markets. These households are willing to spend on average $1.80 more (roughly the cost of two taxi rides) and 12 min more. These preferences are not inconsequential in the context of an island setting where two taxi rides or a 12-min commute brings most markets within reach. Households that chose quality or having a reliable variety of foods as their first choice for what determines market choice reported currently spending nearly 3x as much money in travel to their preferred market compared to other households.

These food purchasing behavior findings sit within the overarching framework for food environments based on five dimensions of access. For *availability*, 26% of households (n = 30) reported having reliable availability of foods as a key contributor to market preferences, and these households spend more money to travel to suitable markets. For *accessibility*, 42% of households (n = 49) reported market proximity as a primary contributor when food shopping. This represents the most commonly shared factor across households, underscoring the perceived importance of distance to markets. For *affordability*, 40% of households (n = 46) reported cost as a primary contributor to their food purchasing decisions. For *acceptability*, in response to the question "what would be your ideal location where you purchase food items?", 49% of households (n = 53) identified mainland Ecuador, 45% (n = 49) specified local production in the Galápagos, and 6% (n = 7) specified no preference. Among those who specified local production, several further specified the need for increased variety, lower prices, and higher quality. In other words, while some households are unhappy with the food system in Galápagos and exclusively want food imported from abroad, others seek island self-sufficiency, and others still view self-sufficiency alongside improved variety and quality as necessary

for an acceptable food environment. Finally, for *accommodation*, in open-ended survey questions about additional food purchasing considerations, a sizeable minority (11%) of households explicitly listed the ability to purchase groceries on credit as a key contributor to food purchasing behavior. Some households also listed their familiarity with storeowners as primary reasons for their market preferences.

8.2.4 Discussion

Key spatial food environment findings in Puerto Baquerizo Moreno are threefold: (1) Food environment scores are highest nearest the large outdoor municipal food market, (2) food environment scores are low on the coastal Malecón where food outlets cater to tourists' needs instead of residents', and (3) food environment scores within the city decrease with increasing distance away from the coast. These findings suggest an underlying distribution network potentially associated with the municipal market. It also suggests that some neighborhoods may experience food environments that are more or less conducive to health, namely, through access to fresh fruits and vegetables.

From a spatial perspective, these findings raise several important issues. Firstly, despite its relatively small size, it is clear that food environments in Puerto Baquerizo Moreno exhibit an underlying spatial pattern. This is significant in that it suggests that the built food environment (markets and where they are located) may contribute to the food options to which residents are exposed. For example, while households in the Algarrobos neighborhood in the southwest part of town have access to a select few markets and households near *La Concha*, the public square, are located next to the municipal market and an abundance of markets, households farther east have significantly fewer food outlets available. If we consider barriers to healthful diets as dependent on such factors as food availability, variety, cost, quality, and convenience, then we may conclude that the observed spatial variation in food environments helps shape adoption to healthful diets.

Although the food environment scores on which these surface maps are based depend strongly on the NEM-S market scores, the spatial patterning (i.e., the spatial dependency observed at neighborhood levels) is strongly influenced by "access." As defined in our spatial algorithm, access is a distance-based metric which considers where each point in the map is with respect to all of the markets. In access-only surface maps (Fig. 8.2), the patterns previously identified (such as high food environment scores surrounding the municipal market) are also apparent. Areas with high access scores (areas in close proximity to multiple markets) coincide with areas with high food environment scores. This suggests clustering of healthy markets but not of unhealthy markets. This has beneficial implications for residents of Puerto Baquerizo Moreno at the time of this study. However, these findings may not carry over to other islands or other times. Isabela and Santa Cruz islands have different community landscapes, market varieties, and municipal markets. Similarly, these findings are also a function of time. Depending on shipment schedules,

markets may stock different ratios of fresh produce to processed, shelf-stable foods. We might imagine that a long shipment delay in fresh produce from mainland Ecuador may lead to a relative increase in the demand for and sale of processed, shelf-stable foods in which case market surveys at that time point would be different. Future studies must consider how geographic and temporal differences across the archipelago shape food environments.

Key food purchasing behavior findings are as follows: (1) Distance to markets and cost are the number one and two most significant contributors to households' market decisions, respectively; (2) in scenario modeling questions, households that prioritize food quality and variety are more willing to spend more money and time to arrive at suitable markets than households that do not rank these factors; and (3) *acceptability* (food sourcing) and *accommodation* (markets that offer credit) feature prominently in households' decision-making process.

Findings from food purchasing behavior household questionnaires suggest that proximity and cost are the two most important factors under consideration when deciding which market to shop at, which has also been observed in other contexts (Caspi et al. 2012; Furey et al. 2001; Rose and Richards 2004). Yet these findings are especially insightful given the small size of Galápagos towns. Puerto Baquerizo Moreno, for example, can be traversed on foot across town in roughly 30 minutes. Despite this proximity, residents still reported distance to markets as the most important consideration for market selection. This may be partially driven by transportation options. In Galápagos, many residents use taxi services for short distances, especially if purchasing large quantities of foods from the municipal market. Some households have motorized scooters which increases their travel range. Most households use a bicycle or travel on foot, which may increase the perceived barriers to traveling farther when the local market is across the street. Lastly, cost was the second most frequently reported consideration for market selection. Not only does "cost" capture prices (market-level) and purchasing power (consumer-level), but it also reflects a general perception of high food prices shared by many community members.

Cost and proximity are not the only contributors to market selection. A surprising proportion of households (11%) specifically listed the ability to purchase from markets on credit as a leading consideration. Others specified preferences for certain food sources. While 49% of households noted a preference for food imported from mainland Ecuador, 45% specified a preference for local production. An emphasis on local production has not often been practiced. This is partly due to the archipelago's commitment to conservation and that 97% of the land is Galápagos parkland. Additionally, the prospect of a self-sufficient local agricultural sector is under threat as local farmers are enticed toward more lucrative professions in the tourism industry (Sampedro et al. 2018). Currently, 75% of food consumed in Galapagos is imported, and models predict that this will rise to 95% in the absence of any food policies (Sampedro et al. 2018). Additional work is to identify opportunities to unite community support of local food production with investment in the agricultural sector.

Scenario modeling survey questions identified the commitment that households have to adhering to their self-reported priorities for market selection. Households that cited food quality is a key contributor to market selection were nearly twice as likely to be willing to spend more time and pay more money to obtain their preferred foods. They were willing to spend $1.80 and 12 minutes more than households who did not list food quality as a major priority. This willingness to spend more and travel farther to obtain foods that are in line with personal preferences is important, because it may alter the influence of local food environments.

8.2.5 Conclusion

The Galápagos food environment is a highly complex, multi-dimensional contributor to diets and health. Local food environments not only are a function of place, space, and time but also have varying degrees of impact depending on how individuals interact with their environment. Each of these levels (place, space, time, and behavior) have Galápagos-specific implications. For instance, the amount and quality of fresh fruits and vegetables available in Galápagos markets may vary depending on seasonality, weather, or even shipment scheduling. Similarly, the influence of local food environments may differ across the different islands in the Galápagos. In Puerto Ayora on Santa Cruz Island, where taxi rides across the city may take 20 min, the characterization of neighborhood-dependent food environments may differ compared to those in Puerto Villamil on Isabela Island, where there are fewer than 20 markets.

Given anticipated changes in global food systems, climate change, increasing market liberalization, and Westernizing diets, the nature of Galápagos food environments may change drastically in the coming years. Considering the rising obesity rates in the Galápagos, as more imported, processed foods and sweetened beverages are adopted in favor of fresh fruits and vegetables, assessing local food environments will remain important for the future health and well-being of Galápagos residents.

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Part III
Environment, Animals and Human Health

Chapter 9
One Health in the Galapagos Social-Ecological System: Not Just the Absence of Disease

Alyssa Grube and Jill Stewart

Abstract The One Health approach recognizes the intrinsic connectivity between the health of humans, animals, and the environment. The Galapagos Islands are ideal for One Health studies due to the physical overlap of humans, domestic animals, and wildlife within a shared, fragile ecosystem. Researchers have long acknowledged the islands as a prime example of the tension between conservation and development, describing the "Galapagos Paradox" as the competing interests between preserving the islands and marketing them for tourism. The Galapagos Paradox implicitly recognizes the connection between human, animal, and environmental health by describing how actions in one sphere (human development) compromise the others (wildlife and environment). As such, much of the research conducted in the Galapagos has been influenced by the One Health paradigm, if not explicitly by name, at least in practice. This chapter will explore examples of One Health research in the Galapagos, with a particular emphasis on using the framework to understand environmental antibiotic resistance in relation to anthropogenic influence.

Keywords One Health · Antibiotic resistance · Tourism · Anthropogenic change · Galapagos Paradox

9.1 Introduction

The One Health approach recognizes the intrinsic connection between the health of people, animals, and the environment. This multidisciplinary framework has been endorsed by governments and organizations at local, national, and global levels to

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address challenges like zoonotic disease transmission, food safety, and antimicrobial resistance. This chapter explores examples of research conducted in the Galapagos under One Health principles, if not explicitly by name, at least in practice. Moreover, this chapter aims to move beyond application of One Health principally in preventing disease transmission between humans and animals, using the significant value placed on conservation in the Galapagos as an example of how to better include the environment in the One Health approach. Finally, this chapter proposes a more holistic understanding of One Health as sustainable well-being and considers the specific challenges of balancing human, animal, and environmental interests in the Galapagos social-ecological system.

9.2 The One Health Approach

The US Centers for Disease Control and Prevention (CDC) defines One Health as, "a collaborative, multisectoral, and transdisciplinary approach — working at the local, regional, national, and global levels — with the goal of achieving optimal health outcomes recognizing the interconnection between people, animals, plants, and their shared environment" (CDC 2018). Articulation of One Health as a concept serves two purposes: First and most fundamentally, it formally acknowledges the connection between human, animal, and environmental health. While this idea may seem straightforward, historical divisions in the practice and philosophy of these fields – along with our tendency to prioritize problems of human concern – have led practitioners to work in isolation on intrinsically multidisciplinary problems. Second, by making clear the connection between human, animal, and environmental health, One Health compels practitioners to work synergistically to accomplish greater health outcomes than could be achieved working in the historical divisions between fields.

Since its conceptualization, One Health principles have been applied to areas such as zoonotic disease transmission, food safety, and antimicrobial resistance. Coordinated reporting of rabies in domestic animals and humans in the United States (Ma et al. 2018) and surveillance of emerging zoonotic viruses in African bushmeat (Mwangi et al. 2016) are excellent examples of One Health in practice. The One Health paradigm is also featured in global agreements and efforts including the Sustainable Development Goals, the International Health Regulations, the UN Political Declaration on Antimicrobial Resistance, and the UN Paris Agreement on Climate Change (Essack 2018). While the One Health approach intends to maximize health outcomes for people, animals, and the environment, in practice, the framework has typically focused on improving human and animal health with little emphasis on the environment beyond its role in a particular disease transmission pathway (Destoumieux-Garzón et al. 2018). Zinsstag et al. (2011) explain this as a reflection of the movement's history: One Health was born from the "One Medicine" concept which aimed to synchronize clinical efforts in human and veterinary medicine. This concept grew to One Health in the early twenty-first century following

declaration of the Manhattan Principles on "One World, One Health" in 2004, which explicitly recognized the importance of ecosystem health, biodiversity conservation, and sustainable development in human and animal health (Cumming and Cumming 2015). Despite the shift toward integrative thinking that inspired conceptualization of One Health, significant focus remains on the human and animal dimensions (Lerner and Berg 2017). The remainder of this chapter explores examples of research in the Galapagos that reflect One Health principles and builds a case for what One Health can learn from operating in this unique social-ecological system.

9.3 Examples of One Health Principles in Galapagos

The Galapagos Islands provide a unique setting for One Health studies due to the physical overlap of humans, domestic animals, wildlife, and endemic plant species within a shared, fragile ecosystem. Researchers have long recognized the islands as a prime example of the conflict between development and conservation (Gonzalez et al. 2008, Walsh and Mena 2013), describing the "Galapagos Paradox" as the tension between preserving the islands and marketing them for tourism (Villacis and Carrillo 2013). The "Galapagos Paradox" implicitly recognizes the connection between human, animal, and environmental health by describing how actions in one sphere (i.e., human development) affect the others (i.e., environmental quality). In turn, declines in environmental quality can negatively affect both human and animal health (i.e., contaminated water) and economic stability (i.e., tourism and fishing). Recognition of these pathways and feedback loops parallels the One Health principle of interconnectedness.

While Galapagos researchers have investigated these complicated relationships from a variety of angles, many have focused on measuring anthropogenic impacts on the natural environment, particularly in relation to the health of native plant and animal species. Chief among these concerns is the introduction of invasive species, whether intentional or unintentional. Invasive species remain the biggest threat to biodiversity conservation in the Galapagos (Wikelski et al. 2004; Toral-Granda et al. 2017; Cisneros-Heredia 2018). Some well-studied examples include cats preying on lava lizards and birds (Konecny 1987; Carrión and Valle 2018); landscape destruction by introduced goats (Schofield 1989), which jeopardized giant tortoise habitats and led to an expensive eradication effort (Carrion et al. 2011); and the spread of invasive guava across the archipelago, its dispersion facilitated in part by introduced cattle and pigs (Phillips et al. 2012). Introduced species not only disrupt ecosystems by competing for resources, changing landscapes, and hunting vulnerable prey, but also pose an invisible threat in the form of pathogens. Cunningham et al. (2003) describe "pathogen pollution" as the expansion of a pathogen beyond its normal geographic or host-species range. Isolated island systems like the Galapagos are especially vulnerable to foreign pathogens, as endemic species are immunologically naïve and exhibit low genetic heterogeneity (Wikelski et al. 2004). Endemic bird populations in the Hawaiian Islands, for example, have suffered

significant declines following the arrival of avian pathogens such as avian poxvirus and avian malaria (Samuel et al. 2015). The Galapagos National Park and Agencia de Bioseguridad take careful measures to avoid the introduction of outside species and pathogens, such as by inspecting incoming passengers, goods, and cargo; fumigating overhead bins with an insecticide on incoming flights prior to landing; and quarantining livestock before transport to or between the islands. However, the threat of invasive species remains.

9.3.1 Domestic Animals and Disease Transmission

On human-inhabited islands where dogs and sea lions can be observed sharing the same beach (Fig. 9.1), it is not difficult to imagine the potential for disease transmission between domestic and wild animals. Significant work has been done to characterize diseases in cats and dogs and evaluate the potential for spillover into wild animals. For example, Gingrich et al. (2010) detected numerous parasites among dogs on Santa Cruz, San Cristobal, and Isabela, and recommended parasite prophylaxis to prevent spread to humans and Galapagos wildlife. Similarly, Levy et al. (2008) surveyed cats and dogs on Isabela Island for a range of infectious disease agents. Antibodies against parvovirus and parainfluenza were detected in 100% of dogs, while evidence for prior infection with adenovirus 1/2 (66%) and canine distemper virus (22%) was also common. More recently, Diaz et al. (2016) conducted

Fig. 9.1 Sea lions share the beach with a stray dog in Puerto Baquerizo Moreno on San Cristobal (Author's photo)

a similar survey of dogs on Santa Cruz and found 36% of dogs were seropositive for canine distemper virus (CDV), more than the 2008 study on Isabela. CDV has been shown to infect California sea lions (Barrett et al. 2004), and six tissue samples from pup carcasses from Puerto Baquerizo Moreno on San Cristobal tested positive for canine distemper viral RNA in 2011–2012 (Denkinger et al. 2017). Collectively, these reports on high levels of canine distemper virus among dogs paired with concern for transmission to wildlife motivated passage of Resolution D-ABG-028-03-2017 by the Agencia de Bioseguridad in 2017, which for the first time allowed vaccination of domestic dogs (Padilla et al. 2018).

Feline diseases also threaten Galapagos wildlife. Levy and colleagues surveyed cats in their 2008 study on Isabela and detected antibodies for *Toxoplasma gondii*, the causative agent of toxoplasmosis, in 63% of felines. Examples of spillover into other species include detection of *T. gondii* antibodies in domestic chickens (Gottdenker et al. 2005) and the Galapagos hawk (Deem et al. 2012). Deem et al. (2010) looked for evidence of exposure to *T. gondii* in penguins and flightless cormorants on Isabela and Fernandina. The authors hypothesized that antibody detection would be higher on Isabela, an island with a significant number of cats, compared to Fernandina, where cats are absent. Overall, detection of *T. gondii* antibodies was low among both bird species, with 2.3% of penguins and flightless cormorants testing positive. Surprisingly, antibody detection was higher among penguins on Fernandina (8%) compared to Isabela (1.2%). The trend was opposite among flightless cormorants, with higher detection on Isabela (4%) compared to Fernandina (1.2%), though the result was not significantly different. As a follow-up to this work, the authors explored the possibility of *T. gondii* oocyst transmission via marine water, hypothesizing that freshwater runoff from islands with cats could spread *T. gondii* to islands without cats (Verant et al. 2014). Among water samples collected from San Cristobal, Santa Cruz, Isabela, and Fernandina, overall detection of *T. gondii* oocyst-like structures was low, with only two of 100 membranes containing a total of three suspect structures. These three suspect structures could not be confirmed as *T. gondii* by molecular methods. Nonetheless, this study represents an important step toward integrative thinking about the role of the environment in disease transmission dynamics.

9.3.2 Avian Diseases from Poultry, Migratory Birds, and Vectors

Avian diseases represent another significant body of One Health research in the Galapagos through the lens of pathogen pollution. Historically, researchers and conservationists have been concerned with the introduction of avian diseases from introduced livestock animals, following reports of Marek's disease in chickens on San Cristobal in 1995 (Vargas and Snell 1997). Subsequently, Gottdenker et al. (2005) surveyed chickens on Santa Cruz and San Cristobal for a panel of infectious

diseases, confirming the presence of Marek's disease as well as a host of other pathogens and parasites. The authors pointed to detection of Newcastle disease (avian paramyxovirus-1), *Mycoplasma gallisepticum*, and *Dispharynx* sp. parasites as diseases of eminent concern to endemic avian birds, particularly those with small population sizes. Several years later, another team compared pathogen carriage among backyard and broiler chickens as well as 12 different species of wild birds on San Cruz (Soos et al. 2008). Seroprevalence of avian paramyxovirus-1, infectious bursal disease, avian encephalomyelitis virus, and avian adenovirus were high among both groups of chickens. Compared to broiler chickens, backyard chickens were more likely to test positive for *Mycoplasma gallisepticum*, infectious laryngotracheitis virus, infectious bronchitis virus, avian reovirus, and Marek's disease. Interestingly, none of these diseases were detected in the 12 species of wild birds surveyed, indicating that spillover into wildlife had not yet occurred or was undetectable in the sample size. Later work by Whitehead et al. (2018) provided an expanded survey of infectious diseases including parasites among broiler chickens on Santa Cruz and San Cristobal. In contrast to earlier work, broilers in this study tested negative for *Mycoplasma gallisepticum*. Broilers also tested positive for bursal disease, infectious bronchitis virus, paramyxovirus-1, and intestinal parasites. Deem et al. (2012) placed transmission of poultry diseases to wildlife within the context of reintroducing the Floreana mockingbird. This work assessed the pathogen status of 175 chickens and 274 wild birds from eight species on Floreana island. Chickens tested positive for paramyoxovirus-1 (30%) and adenovirus (11.3%), in addition to other pathogens. In what constitutes the first report of spillover of these diseases into Galapagos wildlife, paramyoxovirus-1 was observed in 3% and adenovirus in 2.5% of wild birds. Collectively, these studies point to poultry as a potential source of pathogens to Galapagos wildlife and justify continued surveillance of such agents among both chickens and wild birds in their vicinity.

General avian diseases introduced through human movement, migratory birds, and vectors represent another form of pathogen pollution. Reports of *Avipoxvirus* (avian pox) among yellow warblers surfaced in the early 1980s (Duffy and Harcourt 1981), with subsequent reports in Galapagos mocking birds and Darwin's finches (Vargas 1987). However, careful forensic investigation of avian specimens collected in the Galapagos between 1891 and 1906 placed the arrival of the *Avipoxvirus* in the late 1890s, coincident with early inhabitation of the islands by humans (Parker et al. 2011). More recently, avian pox has been detected in Darwin's finches on Santa Cruz (Zylberberg et al. 2012) and the Waved Albatross, a critically endangered species on the uninhabited island of Española (Tompkins et al. 2017). In this study, the outbreak appeared to be specific to nestlings and was associated with increased mortality, as 6 of the 14 affected nestlings died during the course of observation.

In addition to avian pox, avian malaria caused by *Plasmodium* represents another infectious disease concern for wild birds. *Plasmodium* lineage A parasites were first detected in the Galapagos in penguin blood samples collected between 2003 and 2005 (Levin et al. 2009). Follow-up work by these authors examined samples from 3,726 birds across 22 species to find *Plasmodium* spp. in 0.51% (15/2,923) of passerine birds and 6% (13/209) of penguins but undetected in 594 cormorants (Levin

et al. 2013). Lineages A, B, C, and D were represented among the positive samples. To explore the possibility of introduction from migratory birds, these researchers also examined blood samples from North American breeding bobolinks that pass through the Galapagos, finding *Plasmodium* lineages B and C. In this and their previous work (Levin et al. 2009), the authors speculated about the role of the mosquito *Culex quinquefasciatus*, a vector for both avian malaria and West Nile Virus, in *Plasmodium* transmission in the Galapagos. Bataille et al. (2009) demonstrated ongoing introduction of *Culex quinquefasciatus* to and between the islands as a product of transport and travel. While West Nile Virus has yet to be detected in the Galapagos (Eastwood et al. 2014), the example of *C. quinquefasciatus* introduction to the Galapagos speaks to the connectivity between human movement and disease vectors with consequences for both wildlife and humans. As West Nile Virus has a broad host range, its emergence in the Galapagos could threaten not only wild animals but also the health of human residents and tourists.

9.3.3 Antimicrobial Resistance

Recently deemed the "quintessential One Health" issue (Robinson et al. 2016), the spread of antimicrobial resistance (AMR) among microorganisms exemplifies the connection between humans, animals, and the environment at the molecular level. Figure 9.2 places the challenge of antibiotic resistance within a One Health framework, illustrating key relationships and proposed directionality of transmission of AMR bacteria and their genes. While antimicrobial resistance is an ancient phenomenon resulting from millennia of molecular evolution between bacteria that naturally synthesize antibiotics and their intended targets (D'Costa et al. 2011), humans have accelerated the pace of resistance selection through clinical medicine, application in livestock, and poor disposal practices (Davies and Davies 2010). Analogous to the concept of "pathogen pollution" described above, antibiotic-resistant bacteria and their genes are now considered environmental pollutants (Gillings et al. 2015). While we now appreciate the scale of pollution with AMR bacteria and their genes to be extensive, significant questions remain regarding their fate and significance in environmental systems.

The Galapagos Islands provide an unmatched model system to help fill some of these knowledge gaps using the One Health approach. First, geographic restriction of human settlements to 3% of the landmass allows for comparison between areas under intense anthropogenic influence to protected, uninhabited areas over a short geographic range. It would be difficult to find a comparable system in highly developed settlings, where the boundary between anthropogenic activities and the environment is unclear if not non-existent. For example, the presence of a wastewater treatment facility on the inhabited side of San Cristobal in relation to the uninhabited side of Puerto Chino allows for the comparison of heavily impacted receiving waters to a protected beach over the span of a few dozen kilometers. Studies designed to characterize AMR along this gradient could facilitate disentanglement

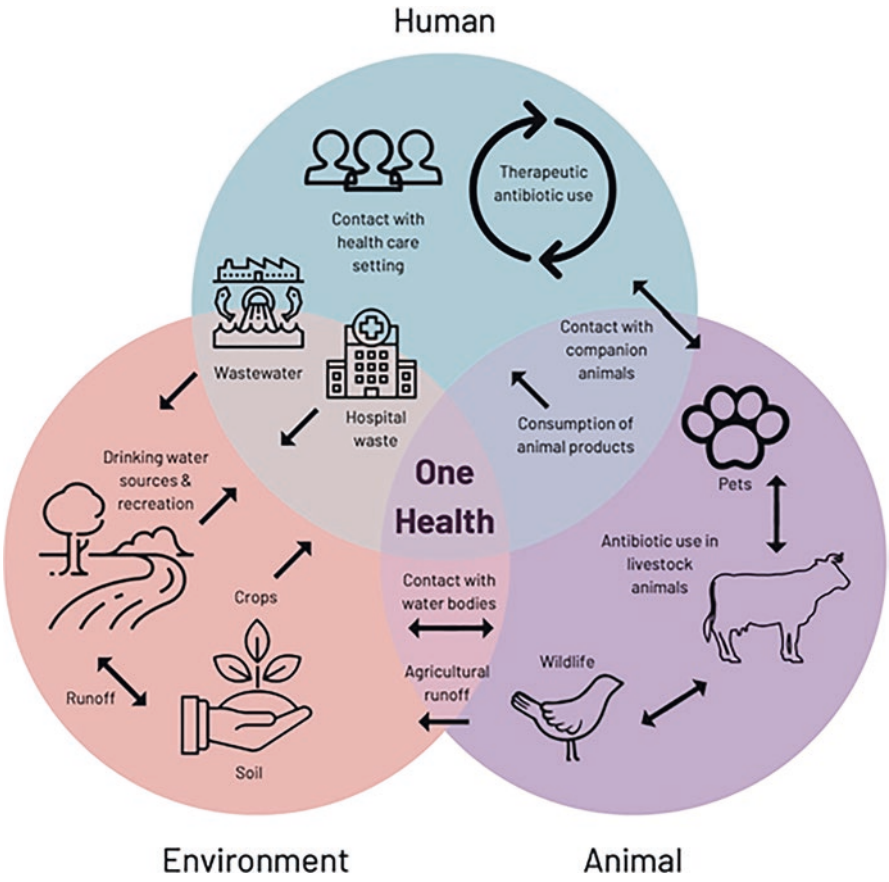

Fig. 9.2 AMR in a One Health world. The intrinsic connectivity between human, animal, and environmental spheres makes AMR a One Health challenge

of human-mediated versus naturally occurring sources of antibiotic resistance in the environment, which is currently a challenge in the field (Ashbolt et al. 2013; Larsson et al. 2018). Smalla et al. (2018) warn that we may have few to zero "pristine" environments left on earth to serve as baselines for understanding natural AMR. However, the protected areas of the Galapagos, even if not 100% pristine per the definition of Smalla et al. (2018), can serve as useful representations of very minimally impacted areas.

Second, we hypothesize that the human colonized areas of Galapagos may represent intense hot spots for AMR introduction. While still restricted to 3% of the land mass, the resident population has grown exponentially over the last several decades in concert with the expanding tourism industry, with the local population now estimated to near 30,000 residents between the four inhabited islands (Walsh et al. 2010; INEC 2017) compared to 4,078 in 1974 (Epler 2007). At the same time, the number of tourists visiting the Galapagos jumped from 17,000 in 1980 (DPNG

2018) to 271,238 in 2019, corresponding to an average annual growth rate of 6.42% (DPNG 2020). Notably, San Cristobal is the only inhabited island with a wastewater treatment plant, and work by Overbey et al. (2015) demonstrated a higher prevalence of antibiotic resistant *E. coli* in coastal waters receiving wastewater effluent than background beaches. We speculate that the tourist population in particular represents a source of AMR organisms and genes into the Galápagos ecosystem. Others have proposed the human gut to be a transporter of ARGs across international borders (Bengtsson-Palmee et al. 2015), and metagenomic surveys of human gut samples from across the globe note significant differences in ARG profiles from different geographical regions (Feng et al. 2018). Paired with the observation that travelers often carry antibiotics to take prophylactically or therapeutically, this suggests that tourists could be introducing antibiotics or AMR organisms particularly through wastewater. For example, the CDC guidance page for travel to Ecuador and the Galápagos recommends antibiotics for traveler's diarrhea on a standard packing list (CDC 2019).

Finally, conducting One Health studies of AMR in the Galapagos may provide insight into the significance of finding resistant organisms and genes in wildlife. There is a growing consensus that detection of AMR in wildlife signals anthropogenic pollution (Allen et al. 2010; Vittecoq et al. 2016). On the surface, antibiotic resistance would seem to be of little consequence to wildlife, since they are generally not administered antibiotics. However, finding AMR bacteria and genes in wildlife could indicate exposure to low levels of antibiotics in the environment, which might disrupt the structure and function of the animal's natural gut microbiome. Moreover, the presence of antibiotic resistance in wildlife could reflect the potential for zoonotic disease transmission in general. Finally, examining AMR in wildlife could help elucidate naturally occurring, rather than anthropogenically selected, forms of resistance.

Several research groups have examined Galapagos wildlife for carriage of antibiotic resistant bacteria. Thaller et al. (2010) cultured bacteria from land iguanas on Santa Fe, an uninhabited island, and tested isolates for antibiotic resistance. With the exception of two *Escherichia coli* isolates resistant to nalidixic acid and gentamicin, resistance profiles of the isolates were consistent with the intrinsic resistance profile for the dominant bacterial species identified in the sample. The authors interpreted these two *E. coli* isolates as examples of acquired antibiotic resistance and pointed to the land iguanas' proximity to a site accessed by fisherman and film crews as a possible exposure source. Several years later, Wheeler et al. (2012) expanded upon this work by culturing *E. coli* and *Salmonella enterica* from the feces of marine iguanas, land iguanas, and giant tortoises in addition to marine water at sites under various levels of human influence across the archipelago. This group found that antibiotic resistance was more common among *E. coli* (18/59 isolates) than *S. enterica*, with only 5 of 46 isolates showing an intermediate resistance profile and no clinical resistance detected. The majority of the 18 *E. coli* isolates that exhibited antibiotic resistance came from Punta Carola marine water samples, with several also collected from giant tortoises at La Galapaguera on San Cristobal and from land iguanas and marine iguanas on Plaza Sur. Notably, isolates collected

from water and iguana samples on Fernandina, as well as those collected from the feces of iguanas on Santa Fe and La Loberia on San Cristobal, were susceptible to all antibiotics tested. Collectively, these results indicate increasing antibiotic resistance among *E. coli* isolates with increasing proximity to human settlements, with the highest multidrug resistance observed at Punta Carola, in agreement with later work by Overbey et al. (2015).

More recently, Nieto-Claudin et al. (2019) used a culture-independent approach to survey the gut microbiomes of 30 giant tortoises on Santa Cruz for antibiotic resistance genes (ARGs). Specifically, this group tested the DNA extracted from giant tortoise fecal samples against a panel of 21 antibiotic resistance genes. Thirteen of these 21 genes could be detected in at least one sample, and genes for tetracycline resistance (*tetQ* and/or *tetW*) were present in 100% of samples. Genes thought to confer resistance to aminoglycosides, beta-lactams, and quinolines were also common, with genes corresponding to these antibiotic classes detected in 42.9, 32.1, and 28.6% of samples, respectively. Detection of the *mecA* gene, which confers resistance to beta-lactam antibiotics such as methicillin and penicillin, may be cause for concern even at the low detection level of one sample due to the widespread use of this antibiotic class to treat a range of infections. While it is important to note that detecting ARGs in wildlife gut microbiomes does not confirm the direction of transmission, the migratory routes of these free-ranging tortoises through agricultural and human-associated areas do suggest the possibility for ARG acquisition from human activities. On the other hand, these ARGs may reflect "natural" sources of resistance in the environment, pointing to wildlife as reservoirs for antibiotic resistance. In either case, much remains to be discovered about the ecological role of ARGs and the bacteria carrying them in wild animal populations. We are currently conducting a broader survey of ARGs in wildlife gut microbiomes and environmental reservoirs using a metagenomic sequencing approach. This study includes samples from giant tortoises, marine iguanas, land iguanas, sea turtles, red-footed boobies, sea lions, and water, as well as human children resident in the Galapagos. There is also work planned to link ARGs to their bacterial host in giant tortoise gut microbiomes. We hope that results from this study will expand our understanding of the ecology of ARGs in Galapagos wildlife and environmental matrices.

9.3.4 Non-infectious Diseases at the Human, Animal, and Environmental Interface

While the examples of One Health research discussed so far deal with disease transmission and pathogen pollution, there are also examples of non-infectious disease health outcomes at the human, animal, and environmental interface. For example, French et al. (2010) observed higher levels of the stress hormone corticosterone in marine iguanas living on beaches visited by tourists compared to marine iguanas

living on undisturbed beaches. Here, the physical overlap of humans and marine iguanas has consequences for their immune status and fitness.

In an example of the connection between environmental quality and animal health, others have assessed chemical exposures in sea lions. Alava et al. (2009) looked for persistent organic pollutants (polychlorinated biphenyls and polybrominated diphenyl ethers) in Galapagos sea lions. Fortunately, overall detection levels were low with polybrominated diphenyl ethers detected in trace amounts in only one pup. Similarly, polychlorinated biphenyls were detected below immunotoxic and endocrine-disrupting levels. Subsequently, this group measured DDT levels in tissue from Galapagos sea lions collected in 2005 and 2008 (Alava et al. 2011). Overall, DDT levels were comparable to or lower than pinnipeds measured elsewhere in the world, but 8–9% of individuals showed levels of the DDT metabolite p,p'-DDE above the immunotoxic threshold.

Finally, there are significant ongoing efforts by researchers associated with the Galapagos Science Center, Galapagos Conservation Trust, and others (Alava et al. 2014; Sebille et al. 2019; Schofield et al. 2020) to understand the effect of plastics on health in the Galapagos. Globally, it is well understood that plastic pollution threatens wildlife through ingestion and strangulation. Plastics, and microplastics in particular, exemplify the One Health principle of connectivity due to their capacity to bioaccumulate in the food web, posing consequences for wildlife and humans alike (Barboza et al. 2018). Locally, the Galapagos government is taking steps to reduce plastic pollution by banning single-use items like plastic straws and bags through passage of Resolution 05-CGREG-2015 (Consejo de Gobierno de Regimen Especial de Galápagos 2018), but arrival of plastics by ocean currents remains an ongoing problem.

9.4 What Can One Health Learn from the Galapagos?

While One Health in theory operates synergistically to improve the health of humans, animals, and the environment, in practice, the research and policies made under this approach have historically focused on human and animal health, with consideration of the environment primarily for its role in disease transmission. In contrast, research and policies in the Galapagos reflect the significant value that Ecuador has placed on conserving biodiversity and ecosystem integrity, most notably through passage of the Special Law of 1998 (Hoyman and McCall 2013). This legislation established clear prioritization of the environment in Galapagos and called for sustainable human development within an agenda of conservation. As Hoyman and McCall (2013) explain, "the scope of the Special Law's legislation is so sweeping that it represents a rare find in the public policy realm—few governments would go this far in the name of sustainability." The Galapagos Islands represent perhaps one of the few places on earth where the balance between competing human, animal, and environmental interests leans toward the environment – in contrast to the traditional One Health paradigm that leans unbalanced in the direction of

human and animal interests. One Health can learn from this example of regarding the environment for its intrinsic value and accepting the responsibility to care for nature. Local and international actors advocate for conserving the unique flora and fauna of Galapagos for both their own right to continue existing with minimal human influence and for their societal, scientific, and educational value.

One Health also stands to learn from the Galapagos example of engaging professionals and researchers from historically separate fields. For example, significant progress has been made in the Galapagos to join the efforts of veterinary medicine and conservation biology to promote the health of wild bird species (Deem et al. 2008). The authors attribute the success of these partnerships to strong communication and respect for each institution's values and goals. As Deem and colleagues explain, "We believe that one key to success of this collaboration has been the continuous attention paid to the involvement and satisfaction of each partner institution. Constant communication has been vital to assure that each partner feels 'ownership' in their portion of the program. We recognize that the value systems of universities, zoos, national park headquarters, and scientific advisory groups may differ, and thus our collaboration was structured in a manner that maximized the currency of value accruing to each partner, while minimizing competition among them." In this way, emphasizing equal ownership in One Health projects would also achieve better representation of environmental interests, as discussed above.

9.5 Not Just the Absence of Disease: The Challenges of Balancing Human, Animal, and Environmental Interests

As the story of development in Galapagos has demonstrated, equally valuing human, animal, and environmental interests is more easily said than done. The Galapagos has long grappled with how to balance development and conservation, in part because of their interrelatedness through the Galapagos Paradox. Gonzalez et al. (2008) and others (Walsh and Mena 2013) have classified the complex relationships and feedback loops between human activities and ecosystem integrity in the Galapagos as a social-ecological system. Analogous to the One Health idea of connectivity, conceptualization of a social-ecological system seeks to break the dichotomy in which humans and nature are separate, competing entities and instead recognize their interrelatedness (Gonzalez et al. 2008). These feedback loops operate on a range of outcomes from physical health to economic activities. For example, it is easy to understand how tourism and fishing industries depend on the integrity of marine and terrestrial ecosystems. Still other examples are more complicated with interwoven health and economic outcomes: Expansion of human settlements without adequate sewerage infrastructure results in fecal contamination in the environment (Walsh et al. 2010), which not only renders human populations vulnerable to disease but can also be a source of zoonotic pathogens and antibiotic

resistance genes to wildlife. In turn, reports of poor water quality may discourage some tourists from visiting the islands, resulting in decreased economic opportunities for locals. Another complex relationship involves young generations of farmers leaving agriculture for more lucrative jobs in the tourism industry, rendering the abandoned land vulnerable to invasive species (Walsh and Mena 2013; Sampedro et al. 2018). From another perspective, this tourism-driven change also affects the nutrition of locals by decreasing food stability and increasing dependence on foods imported from the mainland (Sampedro et al. 2018).

Collectively, these examples describe feedback loops often initiated by an action or value in the human sphere, which in turn decreases environmental quality in a way that compromises economic opportunities and/or the health of humans and animals. But there are also examples in which prioritizing environmental conservation has come at the cost of the health and well-being of Galapagos residents. For example, agricultural restrictions put in place to discourage the introduction of invasive species affect the alimentary options available to resident Galapagueños. While eradicating all introduced agricultural species would in theory help protect local flora and fauna from invasive species and pathogens, these animals and crops represent an important source of economic activity and nutrition for local residents (Padilla et al. 2018). Instead, residents are increasingly dependent on foods shipped or flown in from the mainland, with supply inconsistent and at times unreliable, resulting in food insecurity (Sampedro et al. 2018; Pera et al. 2019). A second example relates to efforts to curb population growth by restricting in-migration to the islands from the mainland through the Special Law of 1998 (Hoyman and McCall 2013). While this law was necessary in light of seemingly uncontrolled population growth in response to tourism, it may also in part explain shortcomings in the healthcare infrastructure. Medical professionals are technically allowed to bring their families to the Galapagos, but the immigration process is complicated. Moreover, some specialists are unwilling to work in such a remote setting where their compensation for serving a relatively small population would be less than in large mainland cities.

Examination of the complex relationships and feedback loops in the Galapagos social-ecological system reveals an important opportunity to expand how the One Health approach operates in practice. This relates not only to better including the environment as described above but also to moving toward understanding health as holistic well-being. In practice, One Health frequently operates to prevent disease transmission between humans and animals. Accordingly, the examples of One Health research in Galapagos discussed above primarily deal with disease transmission and pathogen pollution. However, drawing from the World Health Organization's 1948 definition, "health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity." In complex social-ecological systems like Galapagos, the connections (and trade-offs) between the well-being of humans, animals, and the environment are abundantly clear. Employing the WHO definition of health, One Health could be understood as a balance in a social-ecological system (Cumming and Cumming 2015; Mi et al. 2016). While the earth and all its human, animal, and plant inhabitants could also be

classified as a social-ecological system, developing a framework that describes balance on a global scale would require something resembling a theory of everything (Lerner and Berg 2017). Instead, protected areas like the Galapagos – where these connections are amplified in significance but take place over a finer spatial and temporal scale – can be an excellent model system for deciding and testing what health looks like in social-ecological systems. In discussing how to apply the One Health approach in protected areas of Africa, Osofosky and colleaguges (2005) advocate that, "adopting an ecosystem approach to health issues related to protected areas and the communities that live close to or in these areas represents an attempt to bridge the gaps that exist between the different disciplines and create an enabling environment for expanding benefits to both protected areas and local people."

Lessons learned in the Galapagos, in turn, can inform our broader understanding of health in social-ecological systems. In recommending a roadmap for how to apply the One Health approach toward realization of the United Nations Sustainable Development Goals, Queenan (2017) underscore the need for humanity to understand its place in the broader ecosystem, with human health and development directly dependent on environmental quality. By combining the multidisciplinary collaboration that One Health inspires with an expanded understanding of health as holistic well-being, we have the opportunity to improve balance in social-ecological systems in the Galapagos and beyond.

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Chapter 10
A One Health Approach to Understanding Human-Companion Animal Interactions and Parasitic Infections in San Cristobal, Galapagos Islands

Leigh-Ellyn Preston, Colon J. Grijalva, and Enrique Teran

Abstract The Galapagos Islands are a popular tourist and nature research destination, but human health needs have been under researched. Data obtained directly from physicians on San Cristobal Island in 2014 indicated that approximately 30% of the population of the island were diagnosed with gastrointestinal infections. Due to this indication, our team worked directly with personnel at Hospital Oskar Jandl to gather more information on the epidemiology of these infections. Hospital records indicated that in the first 6 months of 2018, 314 patients were seen in the hospital for diarrheal disease, and 199 (63%) of those patients tested positive for parasitic infections, most commonly *Entamoeba histolytica*, *Entamoeba coli*, or *Giardia lamblia*. In order to determine possible environmental or zoonotic exposures, our team collected water, soil, and environmental animal fecal samples to be tested by polymerase chain reaction for the presence of the commonly identified parasites. Data obtained from government census overlaid with data on incidence of infection indicate a possible association between lower socioeconomic status and infection. While our laboratory analysis of environmental samples is ongoing, we anticipate finding the implicated parasites in most of the tap water samples due to infrastructural problems highlighted to us by local physicians.

Keywords One Health · Parasitic infections · Domestic animals · Zoonoses · Water quality

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10.1 Introduction

The Galapagos Islands are an archipelago of 21 volcanic islands approximately 1000 kilometers off the western coast of Ecuador. The rich ecology of the islands draws many tourists and wildlife and environmental researchers to the islands; however, approximately 25,000 Ecuadorians inhabit four of the islands in the archipelago, with the most populous island being Santa Cruz, situated near the center of the archipelago. Additionally, a fifth island is home to Ecuadorian military personnel. The United Nations Educational, Scientific and Cultural Organization lists the Galapagos Islands as a World Heritage natural site based on their beauty, ecology, history, and conservation efforts (United Nations Educational, Scientific and Cultural Organization, 2019).

Human–Animal Interactions as a Source of Disease Transmission The tourism industry contributes a large portion of the economy of the islands, and as a result, the Ecuadorian government has had to enact policies to limit the number of people visiting and inhabiting the islands as a means to preserve the natural flora and fauna that make the islands unique. Due to the expanding population and the difficulty of transporting goods to the islands from mainland Ecuador, local resources have been exploited through mining and deforestation. Researchers have reported a positive correlation between the increase of the number of tourists visiting the archipelago and the number of introduced species (Toral-Granda et al. 2017)

Estimates calculated by the Ministry of Public Health indicate that the population of San Cristobal, located approximately 960 kilometers from mainland Ecuador, was 6116 in 2017. The majority of the population, around 6000 people, live in the urbanized city limits of Puerto Baquerizo Moreno, and approximately 79% of inhabitants consider their ethnicity to be mestizo. 94% of the population of San Cristobal is under the age of 65. San Cristobal is divided into 17 neighborhoods, with 13 being located in the urbanized area of the island, and 4 in a rural setting not far from the urbanized area.

Dogs were initially introduced to the Galapagos Islands in the early seventeenth century by the presence of sailors and whalers in the archipelago (Kaiser 2001). In 1981, the Galapagos National Park, along with other international institutions, initiated a successful effort to eradicate feral dogs in Isabela Island followed by a similar activity in Santa Cruz Island (Barnett and Rudd 1983) (Barnett 1986) (Marquez et al. 2004). Nevertheless, these efforts were diluted by the arrival of new dogs produced by the migration of colonists from Ecuadorian mainland as a consequence of the tourist boom of the 1970s and 1980s (Marquez et al. 2004) (Ospina 2006). In 1998, the special law for the Galapagos region prohibited the introduction of any potential invasive or harmful organism that does not belong to the historical ecosystem of the islands. The ban included the entry of any domestic animal except for 1-day-old chick. Other prohibited items were biological products included vaccines for dogs ban lifted by Galapagos authorities in March 2017 (Agencia de Regulación y Control de la Bioseguridad y Cuarentena para Galápagos 2017) (Asamblea Nacional República del Ecuador 2015).

Despite the prohibition, it is known that dogs are smuggled from mainland Ecuador to the islands because of the demand that exists from the colonists; the same happened with dog vaccines when they were prohibited (Brock 2012).

Cats are the most widely spread terrestrial carnivore on the globe. *Felis catus* has been found from 55°N to 52°S (Duffy and Capece 2012) (Konecny 1987) (Lohr and Lepczyk 2014). Nevertheless, the date of arrival of cats to the Galapagos Islands is not well documented. One of the hypotheses that exist is that this species was introduced by pirates and whalers as they kept cats for rodent control on their ships. However, it is more likely that cats were introduced during the early human colonization period of each island. The presence of cats has been reported in many islands including the inhabited islands (Isabela, Santa Cruz, San Cristobal, Floreana), the military base in Baltra, and the unpopulated islands of Venecia, Santiago, and Las Bayas Grande y Pequeña. Nevertheless, the last report of cat presence limits their occurrence to the four populated islands (Fundación Charles Darwin (FCD) and WWF-Ecuador 2018) (Phillips et al. 2012).

Irresponsible owned and stray companion animals can be a potential health threat to the Galapagos citizens. Although the Galapagos archipelago is free of rabies, academic researchers have reported the presence of pet parasite species, some of them potentially zoonotic. A study in dogs presented to high-quality high-volume spay neuter clinics in Isabela, San Cristóbal, and Santa Cruz reported the isolation of *Ancylostoma caninum*, *Toxocara canis*, *Giardia* spp., *Isospora canis*, *Sarcocystis canis*, and *Cryptosporidium* spp. (Gingrich et al. 2010). Other study using a randomized sample of households in urban and rural areas of Santa Cruz Island reported *Ancylostoma caninum* as the most frequent parasite in dogs, followed by *Toxocara Canis*, *Giardia* spp., *Isospora Canis*, *Sarcocystis canis*, and *Cryptosporidium* spp. (Diaz et al. 2016). On the other hand, a study implemented in Isabela Island reported a prevalence of 63% of cats positive to *Toxoplasma gondii* from a sample of 52 cats presented to a spay neuter clinic (Levy et al. 2008). Other study in the western part of the archipelago described a presence of *Toxoplasma gondii* antibodies in Galapagos penguins and flightless cormorants (Deem et al. 2010). Cats (Felidae family) are the only hosts that permit the sexual reproduction of *Toxoplasma gondii* becoming the only definitive host for this parasite and its main reservoir (Hadfield and Guy 2017).

In a random sample of residents of San Cristobal that we collected in 2018, 71% reported caring for a pet, and 31% of animal caretakers report that their animals receive regular veterinary care. In addition to domestic animals, island inhabitants share a unique relationship with the rich wildlife on the island. Examples of this include sunbathing and swimming with sea lions, sharing meals with finches, and hiking past sunning iguanas. This close relationship and irresponsible pet ownership can be a threat to the archipelago native species. Predation from companion animals to puppy sea lions and marine iguanas has been reported (Kruuk and Snell 1981; Trillmich 2015). Also, there is a potential transmission of diseases such as leptospirosis, toxoplasmosis, and canine distemper virus (Deem et al. 2010) (Denkinger et al. 2017)

Water as a Source of Disease Transmission Tap water in the Galapagos Islands typically originates from natural sources, such as rivers, streams, and lakes fed by rainwater. Although there are water treatment facilities on the islands, fresh water sources in the Galapagos Islands are often contaminated by saltwater due to overpumping for consumption and by human waste (Walsh et al. 2010). This often contaminated tap water in Galapagos is provided as a public service paid for by residents, but due to the quality of this tap water, drinking water must be shipped from mainland Ecuador and purchased from private companies (Walsh et al. 2010). Documents provided by the Ministry of Public Health on San Cristobal list the island's three water catchment locations to be in the upper sector of the island and the two water treatment plants to be just on the edges of the inhabited area in the southwest portion of the island (Fig. 10.1) (Pertuz et al. 2016).

Water is transported from the catchment locations to the treatment facilities and from treatment facilities to homes through a system of pipes that are often subject to breakage, allowing ambient pathogens access to the water intended for human consumption. Several studies have been conducted on the water quality of the water delivered to homes in the inhabited areas of San Cristobal (Pertuz et al. 2016; Gerhard et al. 2017). Repeatedly, these studies have found fecal coliforms in water intended for human consumption. Each of these pathogens can be transmitted to humans and cause disease. The Ministry of Public Health recognizes that improving the quality of the water intended for human consumption will require a combination of interventions including both improved sanitation and improved infrastructure (Pertuz et al. 2016; Gerhard et al. 2017).

Recently, it has been also reported that perceptions of water quality and household practices influenced exposures to contaminated tap water. A minimal change was found in drinking water sources with 85% of mothers sampled before the new drinking water treatment plant and 83% sampled after using bottled water, while

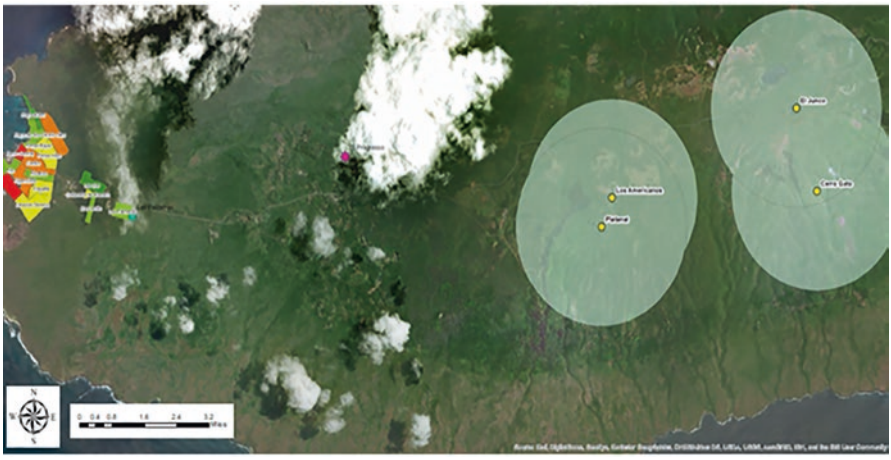

Fig. 10.1 Water catchments and treatment facilities

>85% from the pooled sample used tap water for cooking and hygiene practices. The new drinking water treatment plant opening was associated with lower odds of fecal contamination in tap water, reported urinary infections, and community level rates of urinary and gastrointestinal infections. The household practice of recently washing the cistern contributed to higher contamination levels after the new drinking water treatment plant opened. To ensure access to clean water, public health workers need to consider how household perceptions and practices influence tap water use and quality, in addition to infrastructure improvements. Exposures to contaminated tap water contribute to the burden of infectious disease in environments with inadequate water infrastructure (Houck et al. 2020).

Morbidity in San Cristobal The leading causes of morbidity on San Cristobal are reported as acute respiratory illness (32%), followed by gastrointestinal illness (13%) and musculoskeletal disorders (9%). Healthcare on the islands is restricted to what Ecuadorians refer to as "second-level" facilities that are capable of handling emergencies, general obstetrics and gynecology, pediatrics, and internal medicine. The hospitals are located in cities and are difficult for residents of rural areas to reach. Because of the healthcare barriers facing residents of the rural neighborhoods, small clinics have been established in these areas to attempt to meet the healthcare needs of families in rural areas. These small clinics are not affiliated with the larger, government-run hospital on the island, so the quality of care in these facilities is not well-known.

Hospital data obtained directly from doctors on San Cristobal, Santa Cruz, and Floreana Islands from 2014 indicate that the yearly prevalence of gastrointestinal infections is approximately 30% on each island. On San Cristobal, the majority of the infections fall into a category labeled "infection" (17%), followed by macroparasites (8%) and amoebas (3%). Santa Cruz data shows that the majority of infections are caused by macroparasites (11%), followed closely by amoebas (10.5%), and "infection" (5%). On Floreana, the majority of infections are caused by "infection" (22%) followed by macroparasites (9%). The data provided by hospitals is not very specific as far as the pathogen, which makes intervention programs difficult to create.

Due to the complex nature of possible transmission cycles of intestinal pathogens, epidemiological investigations to determine contamination sources and inform educational campaigns are a vital necessity. One of the main objectives of our research was to pilot one such epidemiological investigation to narrow the scope of possible transmission cycles for the leading causes of intestinal illness in San Cristobal, in anticipation of expanding the process to other inhabited islands in the Galapagos archipelago.

Methods of Investigation Working with collaborators at Hospital Oskar Jandl in San Cristobal, we collected and analyzed laboratory results from fecal samples and approximate location of residence of patients consulting the hospital physicians from January 2018 to May 2018. Using the complete records of all gastrointestinal consultations, we determined the top three pathogens associated with gastrointesti-

nal disease in San Cristobal during the study period, as well as demographic factors of those cases. Collaborators at Hospital Oskar Jandl then worked to identify the neighborhoods from which the patients originated. We then consulted government documents to define the boundaries and population size of the neighborhoods in San Cristobal and used this information, combined with the case location information, to calculate approximate, neighborhood-specific, incidence rates of gastrointestinal infections with the identified organisms. To visualize this data, we defined neighborhoods in ArcGIS 10.6 (ESRI, Redlands, CA) and initially created choropleth maps of population density (Fig. 10.2) and then added addition layers showing the calculated incidence rates for each neighborhood (Fig. 10.3).

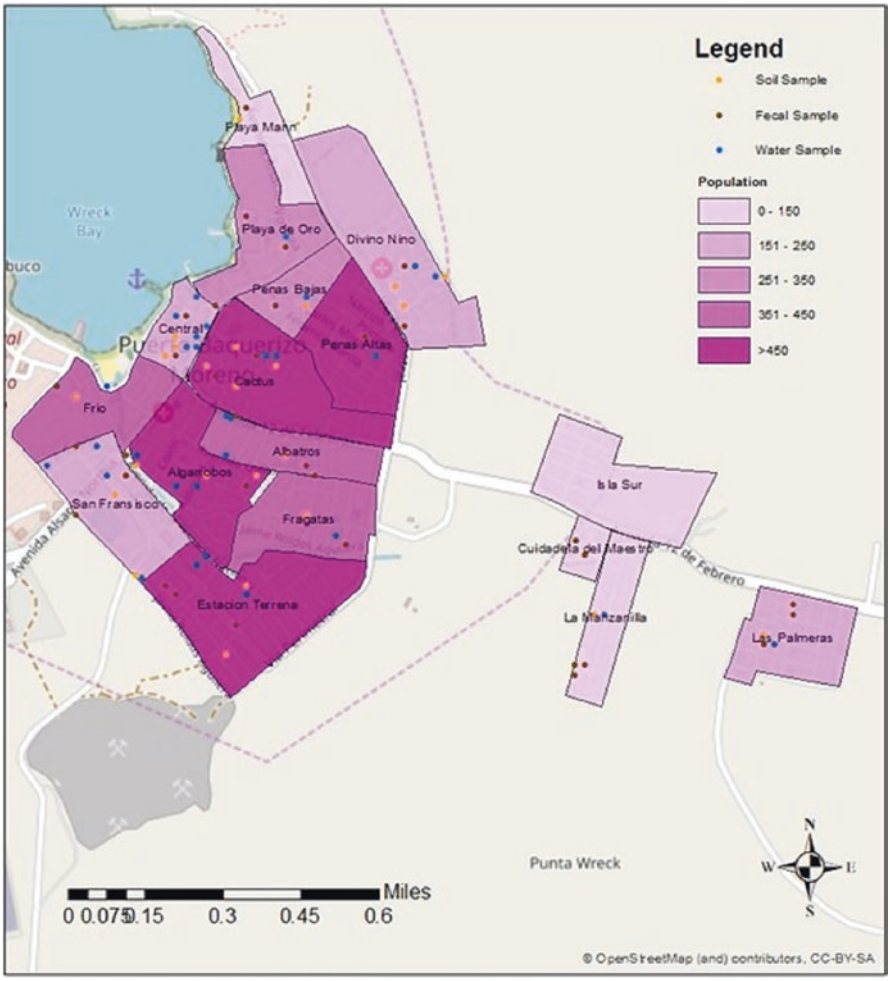

Fig. 10.2 Population by neighborhood

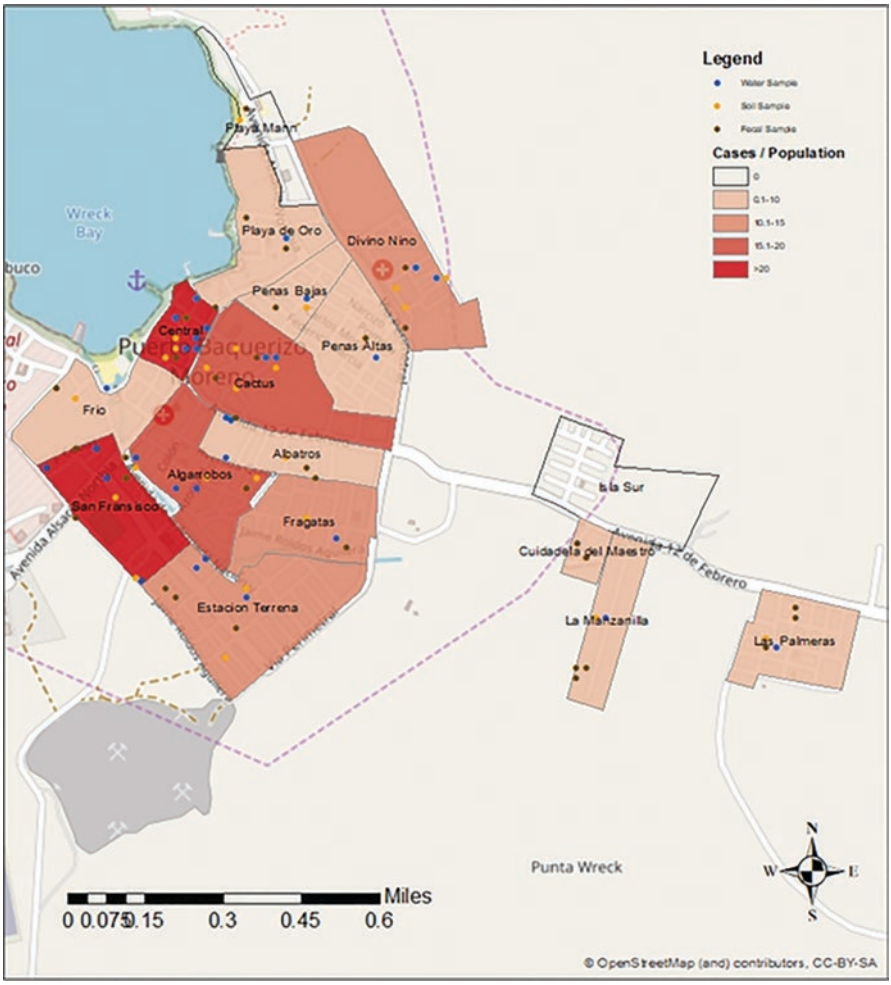

Fig. 10.3 Incidence by neighborhood

Once we had identified the top three pathogens associated with infection, and visualized the neighborhood-specific incidence rates, we used the incidence rates to decide upon the number of environmental samples to collect from each neighborhood. There were collected soil, water, and animal fecal samples from neighborhoods reporting cases of gastrointestinal infections associated with our pathogens of interest. Soil samples were taken from areas where human activity would be most likely, such as playgrounds, near the fire station, or high traffic areas like shops or restaurants. Water samples included samples of tap water and drinking water, and animal fecal samples were taken from feces found in the environment in each neighborhood. The GPS coordinates of the location of each sample were recorded and then entered into the map to track samples that were positive or negative for the

organisms of interest. The number of water and soil samples was determined according to the neighborhood-specific incidence rates and stored properly at the UNC/USFQ Galapagos Science Center in San Cristobal and then shipped to the School of Medicine at the Universidad San Francisco de Quito in Quito, Ecuador, for further analysis. Three environmental animal fecal samples were collected from each neighborhood and evaluated at Hospital Oskar Jandl using microscopy to detect our pathogens of interest and then stored with the water and soil samples and shipped to Quito for further analysis. All samples were analyzed using polymerase chain reaction (PCR) to detect the DNA of our organisms of interest.

Briefly, the environmental samples from the Galapagos Islands were stored at -80°C until DNA extraction. DNA was extracted from 500 mg of material using FastDNA™ SPIN Kit for Soil (MP Biomedicals, USA), following the kit protocols. At the end of the extraction protocol, 70 ul of DNA was collected, which was stored at −20 °C until the PCR amplification protocols are performed. The DNA concentration and quality were measured based on absorbance at 260 and 280 nm with the BioTek EPOCH spectrophotometer (BioTek® Instruments, Inc., USA).

For the detection of *Giardia duodenalis* in environmental samples, primers were used for amplification based on nested PCR of the β-giardin (bg) gene, an essential protein for the identification of this parasite (Gil et al. 2017). The sequence of the primers is presented below: G7eF (AAGCCCGACGACCTCACCCGCAGTGC), G759eR (GAGGCCGCCCTGGATCTTCGAGACGAC), G99iF (GAACGAACGAGATCGAGGTCCG), and the G609iR (CTCGACGAGCTTC). For the amplification of the β-giardin gene (511 bp), the protocol of Gil et al. (2017) was used with some modification. The PCR reactions consist of 1 ul of the DNA sample, 10 uM of each first (first reaction with primers, G7eF/G759eR; second reaction, G99iF/G609iR) 12.5 ul of Platinum™ Hot Start PCR 2X Master Mix (Invitrogen). The first reaction was based on the following protocol: an initial denaturation step at 94 °C for 5 min, followed by 40 cycles of 94 °C for 30 sec, 65 °C for 30 sec, and 72 °C for 40 sec, with a final step of 72 °C for 7 min. The conditions of the second PCR were the same except at the annealing temperature, which was changed to 55 °C.

All PCR reactions were carried out with positive controls on *G. duodenalis*, provided by the Institute of Microbiology of the San Francisco University of Quito in an Applied BioSystems Thermocycler. The amplicons obtained were visualized on 1.5% agarose gels (Invitrogen) stained with SYBR Safe (Invitrogen).

For detection of *Entamoeba histolytica*, the sequence of primers and amplification conditions were based on a previous study, where they propose the amplification of the 16S rRNA gene based on a nested multiplex PCR assay, first amplifying species regions of *Entamoeba* and in a second instance specific regions for *E. histolytica* (Khairnar and Parija 2007). The sequence of the primers is described below: Primers for *Entamoeba* species E-1 5 'TAAGATGCACGAGAGCGAAA 3' (forward first) E-2 5 'GTACAAAGGGCAGGGACGTA 3' (reverse first) and for *E. histolytica* EH-1 5 'AAGCATTGTTTCTAGATCTGAG 3 '(forward first) EH-2 5' AAGAGGTCTAACCGAAATTAG 3 '(reverse primer). The amplification reactions

of the 16S rRNA gene from *Entamoeba* species consisted of 1 ul of the DNA sample, 10 uM of each first (first reaction with primers, E1/E2; second reaction EH-1/EH-2) 12.5 ul of Platinum™ Hot Start PCR 2X Master Mix (Invitrogen). The conditions for the first reaction were initial denaturation step at 96 ° C for 2 min, followed by 30 cycles of 92°C for 60 sec, 56°C for 60 sec, and 72°C for 90 sec, with a final step of 72°C for 7 min. The conditions of the second PCR were the same except at the annealing temperature, which was changed to 48°C. Similarly, all reactions were carried out with *Entamoeba histolytica*-positive controls, provided by the Institute of Microbiology of the San Francisco University of Quito, in Applied BioSystems Thermocycler. The amplicons obtained were visualized in 1.5% agarose gels (Invitrogen) stained with SYBR Safe (Invitrogen).

The detection of the *Cryptosporidium parvum* was previously described (Yu et al. 2009), where they identify the *Cryptosporidium* oocyst wall protein (COWP) gene utilizing a nested PCR. The pre-amplification was based on the Cry-153 (5′-GTAGATAATGGAAGAGATTGT G-3′) and Cry-93 (5′-GGACTGAAATACAGGCATTATCTTG-3′) primers. The amplification included cowpnestF13 (5′-TGTGTTCAATCAGACACAGC-3′) and cowpnestR23 (5′-TCTGTATCCCCTGGTGGGC-3′) primers. The reactions were performed in the same manner previously described. The conditions for the first reaction were initial denaturation step at 94 °C for 5 min, followed by 30 cycles of 94 °C for 50 sec, 52 °C for 30 sec, and 72 °C for 50 sec with a final step of 72 °C for 10 min. The conditions of the second PCR were the same except at the annealing temperature, which was changed to 60 °C. All reactions were performed with positive controls of the *Cryptosporidium parvum*, provided by the Institute of Microbiology of the San Francisco University of Quito, in an Applied BioSystems Thermocycler. The amplicons obtained were visualized in 1.5% agarose gels (Invitrogen) stained with SYBR Safe (Invitrogen).

We also chose to incorporate information on chronic conditions of residents of each neighborhood, including hypertension, diabetes, and obesity, and information on socioeconomic status, as these factors can affect the likelihood of disease incidence and severity. The information on chronic conditions and socioeconomic status were obtained from the Ministry of Public Health and added to our neighborhood maps. Additional information on water catchment locations was also added to the maps in order to visualize the flow of water from catchment location to homes.

When collecting environmental samples, we also collected information from residents of the neighborhood. We gathered information on the type of drinking water used in their homes, including the type of filtration method, if any, used, information on where they purchased fruits and vegetables and how they prepared them for consumption, where residents stored waste, and the number and type of animals, if any, owned by the residents. If residents owned animals, additional questions were asked regarding the habitat of the animals and veterinary services utilized. All information from residents was collected by affiliates of Hospital Oskar Jandl, deidentified, and then analyzed.

Results of Our Investigation During the period of January 2018 to May 2018, 313 unique patient records were identified to have been seen by physicians at Hospital Oskar Jandl for gastrointestinal illness. 199 of those patients tested positive for gastrointestinal infections. From those records, the top three organisms associated with disease were *Giardia lamblia* (16%), *Entamoeba histolytica* (72%), and *Entamoeba coli* (20%). Twenty-five (13%) of the patients in our study were co-infected with *E. histolytica* and *E. coli*, so it is likely that they were infected with an undetected pathogenic organism. The age of patients positive for infection ranged from 7 months to 94 years, with an average age of 32 years. Only 22% of the patients were under the age of 18. Neighborhood information available at the Hospital Oskar Jndl was unfortunately only for 70 of the 199 patients.

Neighborhoods with the highest incidence of gastrointestinal disease were Barrio Central (3%) and San Francisco (3%). These two neighborhoods also were of lower socioeconomic status, though were not the neighborhoods with the lowest socioeconomic status (Manzanillo, Peñas Altas, and Fragatta) (Fig. 10.4). Barrio Central had the highest prevalence of hypertension (15%), followed by Frio (12%). San Francisco had the highest prevalence of diabetes at only 5%, and Ciudadela del Maestro had the highest prevalence of obesity (10%), followed by Manzanillo (9%).

A total of 101 soil and water samples, 67 water and 34 soil, and 48 fecal samples were collected. All fecal samples were negative upon microscopy inspection and PCR analysis, but the soil and water samples are currently being evaluated by PCR analysis at Universidad San Francisco de Quito.

Three households from each neighborhood were randomly chosen by our collaborators at Hospital Oskar Jandl to respond to survey questions, which resulted in 45 completed surveys. All respondents reported having reliable electricity more than 20 hours of the day, and 96% reported having running water in their residence. When asked about the source of their drinking water, 40% of residents responded that they drink untreated tap water, and 4% reported drinking rainwater that they had collected in tanks near their home. The majority of respondents (82%) lived in neighborhoods with paved or asphalt roadways, and 80% reported utilizing trash cans to dispose of waste.

As reported above, 71% of surveyed residents stated that they owned a companion animal, or animals that they cared for. Of those, 63% owned at least one dog, 44% owned at least one cat, and 16% owned at least one chicken. Thirty-eight percent of residents with companion animals or pets reported that their animals roamed the streets.

However, in a study developed between June and July 2016 and 2017, the population of stray dogs was estimated using a mark-recapture method in 6/17 randomly selected urban neighborhoods. There were 215 stray dogs in those transects in 2016 (95% CI 162–309) that was similar to the one calculated in 2017 (168, 95% CI 138–220). During the same period, a random sample of households was collected to identify demographic factors of dogs in urban and rural San Cristóbal Island. In 2016 54/142 (38%) households reported to have at least one dog compared to 68/141 (44%) in 2017. Nevertheless, the prevalence of households that allowed

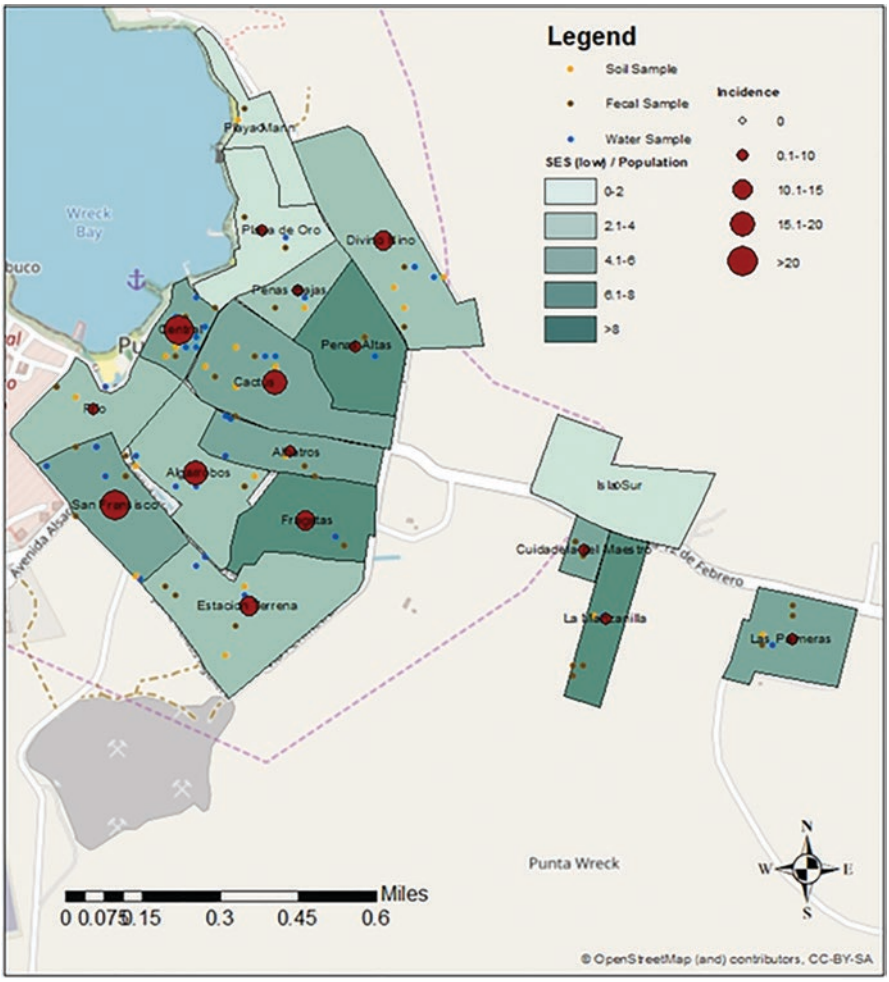

Fig. 10.4 Incidence by neighborhood and socioeconomic status

their dogs to free roam was lower in 2017 (28%, 95% CI 21–36%) compared to 2016 (44%, 95% CI 36–54%) (Grijalva et al. 2018). A parallel study was completed to estimate the stray cat population in the same neighborhoods were the stray dog population was surveyed. Using the distance sampling method, a population density of 142 stray cats/km2 (95% CI 34–584 stray cats/km^2) was reported in 2016, similar to 109 stray cats/km2 (95% CI 49–242 stray cats/km^2) reported in 2017 (Grijalva et al. 2019).

Moreover, in the present analysis in 2019, 31 % of surveyed residents with companion animals reported that their animals received regular veterinary care, and 13% reported that their animals had recently been ill. This is probably because there is only one veterinary in San Cristobal and occasionally there is additional veterinary service from the Agency of Biosecurity and Quarantine for the Galapagos.

Parasitic infection at any age can cause dehydration and can initiate chronic conditions. The burden of parasitic infection is usually more dire, and more frequently written about in children, so finding that the majority of the patients in San Cristobal were over the age of 18 is interesting. Individuals 18 to 50 usually have healthy functioning immune systems and should be able to clear minor infections without medical treatment. Because the age range of the patients in San Cristobal is shifted to adults, this could imply a heavier parasite burden, and potentially a shift in the type of parasite causing disease, as recently suggested by Cable et al. (2017).

All of the top three organisms are spread through a fecal-oral transmission route, infecting a host when fecal particles are ingested in contaminated food or water. These parasites are commonly found in tropical environments with poor sanitation (Centers for Disease Control and Prevention 2015a, b, 2019). *G. lamblia* survives in soil and water and has a shell that permits the parasite to survive without a host for long periods of time. Although *G. lamblia* is found in soil, it is most common in water. The organisms' shell also allows them to survive chlorine water treatments, which is a common decontamination method for drinking water (Centers for Disease Control and Prevention 2015a, b). *E. histolytica* is most commonly transmitted in infected drinking water (Centers for Disease Control and Prevention 2015a, b). *E. coli* is generally not pathogenic in humans, and the presence of this parasite in stool can indicate that a patient has been exposed to fecal contamination of food or water (Centers for Disease Control and Prevention 2019).

As we were collecting data, we learned that there was one veterinarian on the island, and the practice of this veterinarian was located in a neighborhood outside of the most populous area. With 71% of surveyed residents reporting owning or caring for an animal, and the numerous animals we saw roaming the streets, this could mean that the veterinarian might not be equipped to treat all of the companion animals on the island. We are unsure of the status of the veterinary clinic, as we were unable to contact the veterinarian. Because we were unable to speak directly with the veterinarian, we are also unsure of the types of animals that are seen by the clinic. There is also intermittent high-volume spay neuter clinics in the island and a free preventive medicine service for dogs and cats registered in the government data base. The Galapagos Islands are home to a vast array of different animal species, and illness in any of those could affect human health. Further, while we know there is a vaccination schedule for companion animals in San Cristobal, we have no data on adherence to that schedule, which could affect animal health and, in turn, human health.

We faced many additional limitations. In order to more accurately draw conclusions about the sources of infection, it would be best to talk directly to patients about the potential exposures that could have led to disease. With this information, we could have done a more targeted sampling of environmental risk factors. Speaking directly with patients would also allow us to increase the sample size of patients with intestinal illness. Some patients had to be excluded from our sample due to incomplete location data. Coupled with direct discussions with patients, our study could be improved by directly sampling animal stool and water sources. This would allow us to draw more accurate conclusions about the infection rate in

animals. Additionally, it would be ideal to perform the PCR closer to the source of the sample. Because the laboratory in San Cristobal was not able to run the PCR analysis, we had to freeze the samples and have them shipped, which could have interfered with our ability to detect pathogens.

Our work had many strengths. We were able to obtain a large amount of information about socioeconomic status, chronic diseases, and morbid conditions within the population due to the survey efforts of the Ministry of Public Health. Surveillance information is regularly collected, and because of the self-contained population of the island, census data is extremely reliable. We also had very cooperative collaborative partners in Universidad San Francisco de Quito at San Cristobal and at Hospital Oskar Jandl. We had common goals of protecting the health of residents and were able to gather sizeable amounts of data in a very short time.

In the future, we would like to expand our investigation to the other inhabited islands. We would like to establish a collaborative relationship with the Agency of Biosecurity and Quarantine for the Galapagos and veterinarians of the islands to collect data directly from the veterinary clinics, as we did with the hospitals. We know that the residents of the Galapagos Islands have a very unique relationship with, not only companion animals, but with wildlife as well. In addition, the data suggest the presence of a large population of dogs and cats even though their tenancy was totally prohibited until few years ago. This relationship leaves human populations and endemic species vulnerable to zoonotic infections, which makes understanding of disease transmission cycles in animals an important step to improving human health on the islands.

We have established a relationship with the hospital in Santa Cruz and plan to investigate this population in the future. Prior to beginning data collection in Santa Cruz, we plan to finish our PCR analysis of the samples from San Cristobal. This will provide insight into the most relevant environmental exposures that should be further investigated. We would like to sample water intended for consumption at all collection points, from water catchments to treatment facilities to consumer's homes. This would give us a better picture of where contamination may be introduced and also provide insight into how best to prevent the exposure to residents.

It is very likely that these intestinal pathogens are transmitted back and forth between animals and humans, so unlocking the source of human infection will likely be closely tied to infection in animals. Our work highlights the astounding impact that animal and environmental health have on the health of inhabitants of San Cristobal. Through collaboration and increased awareness of One Health research techniques, the transmission of diseases can be identified and interrupted to improve the health of all residents in the Galapagos Islands.

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Chapter 11
Surprising Absence of Antibiotic Resistance in *Salmonella enterica* Isolates from Galapagos Marine Iguanas (*Amblyrhynchus cristatus*)

Belen Carrillo, Cristina Chavez, and Gabriel Trueba

Abstract Reptilians are known to carry *Salmonella enterica*, an intestinal bacterial pathogen (for humans and other animals) which is known to carry a cornucopia of antibiotic resistance genes. We cultured fecal matter from marine iguanas in the San Cristobal island and obtained 20 *S. enterica* isolates which lacked clinical resistance to any of the antibiotics tested. This finding is unexpected because isolates were obtained from a beach visited by tourists, close to the San Cristobal town in San Cristobal island. This island houses many domestic and peri-domestic animals known to carry *S. enterica* and antibiotic-resistant bacteria. It is important to understand whether this lack of antibiotic resistance is due to genetic isolation of *Salmonella* and these marine iguanas from those in domestic animals. We discuss the potential zoonotic transmission of strains from wildlife.

Keywords *Salmonella* · Antibiotic resistance · Marine iguanas

11.1 Introduction

Salmonella enterica infections are responsible for high morbidity and mortality specially in very young and elderly people (Bassal et al. 2012). Zoonotic transmission is linked to consumption of animal products such as dairy and meat. This bacterium has been also associated with reptiles (pets and wildlife) (Sylvester et al. 2014), and contact with these animals has also resulted in human infections (Mermin et al. 1997).

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An increasing encroachment of humans in natural habitats puts humans in contact with wildlife pathogens (Kruse et al. 2004) and wildlife in contact with pathogens from domestic animals and humans (Skov et al. 2008). These interactions also cause transmission of antimicrobial resistant commensal bacteria and antimicrobial resistance genes from bacteria in humans and domestic animals to wildlife microbiota (Swift et al. 2019; Mercat et al. 2015). Pathogenic *Enterobacteriaceae*, such as *S. enterica*, are especially able to transmit between different animal species including wildlife (Skov et al. 2008). *Salmonella* is actively engaged in horizontal gene transfer (HGT) of antimicrobial resistance genes (AMRG), a feature which has prompted its inclusion in the list of antimicrobial resistance treats (Centers for Disease Control and Prevention 2019). It has been suggested that *Salmonella*'s AMRG in domestic animals contributes to the AMRG pool in wildlife (Botti et al. 2013). *Salmonella* is also known to exchange antibiotic genes with *E. coli* (Blake et al. 2003; Card et al. 2017) which is the most abundant member of the *Enterobacteriaceae* family in the mammalian intestines (Gordon and FitzGibbon 1999).

Physical isolation of some wildlife sanctuaries may reduce the transmission opportunities of either pathogens or antibiotic resistant bacteria from humans or domestic animals to wildlife or vice versa. In the Galapagos Islands, increasing antibiotic resistance has been observed in bacteria from iguanas living in the proximity of human activity, as compared to those from more isolated areas (Thaller et al. 2010; Wheeler et al. 2012). In this report, we describe *S. enterica* isolates obtained from marine iguanas in habitats close to a town and frequently visited by tourists. Surprisingly, *S. enterica* from these animals showed no resistance to any antibiotic tested, even though the samples were obtained from a frequented beach located in the proximity of the largest town in the San Cristobal Island. We also present potential evidence of the public health risks of *S. enterica* carriage in the Galapagos wildlife.

11.2 Materials and Methods

11.2.1 Salmonella *Isolation*

As part of a study designed to investigate *Campylobacter* sp. in Galapagos marine Iguanas (*Amblyrhynchus cristatus*), we obtained 81 fresh fecal samples from the soil from a touristy beach close to the town of Puerto Baquerizo Moreno (La Lobería, 0° 55′37″ S 89° 36′43″ W, San Cristóbal Island) and carried to the laboratory. We obtained approximately 4 g of fresh fecal matter and placed in a sterile tube with saline phosphate buffer (pH 7.2). The solution was vortexed, and a 500 µl aliquot was filtered through a Millipore® membrane (0.65 µm pore size) which was located on top of o blood agar plate (Blaser and Cody 1986). After 1 h, the membrane was removed, filtrates were streaked, and plates were incubated in modified

atmosphere (using an anaerobic generator CampyGen sachet) for 48 h. The colonies were analyzed by Gram staining, oxidase test. Some of the colonies of oxidase negative Gram-negative *Bacillus* were cultured in *Salmonella-Shigella* agar, and all colonies showing the typical *Salmonella* appearance were subjected to API® 20 E Biomérieux tests. Bacterial species were confirmed by PCR amplification and DNA sequencing of the 16S ribosomal RNA gene (Lane 1991).

11.2.2 Detection of Salmonella *Serovars*

We took two colonies of each isolate, placed in 1.5 ml Eppendorf tubes containing 300 µl of sterile water and boiled for 10 min and kept at −20 °C for one night. All the extracts were diluted 1:100 in TE (Tris-EDTA). STM and STY amplification was performed as described previously (Kim et al. 2006) using 1 µl of DNA extract. The two started with denaturation at 94 °C for 5 min, followed by 40 cycles (94 °C for 30 s, 62 °C for 30 s, and 72 °C for 1 min) and a final extension at 72 °C for 5 min. The electrophoresis was carried out in a 2.5% agarose gel for 2 h at 80 V with ethidium bromide staining.

11.3 Antibiotic Susceptibility Tests

Antimicrobial susceptibility tests were performed in *Salmonella* isolates using AMP ampicillin (10 µg), TET tetracycline (30 µg), SXT trimethoprim-sulfamethoxazole (1.25/23.75 µg), GEN gentamycin (10 µg), AMC amoxicillin-clavulanic ac. (20/10 µg), CIP ciprofloxacin (5 µg), CHLOR chloramphenicol (30 µg), IMP imipenem (5 µg), CF cefazolin (30 µg), CAZ ceftazidime (30 µg), FEP cefepime (30 µg), and CTX cefotaxime (30 µg) as representatives of the most used families of antibacterial drugs in healthcare. The Kirby-Bauer test was carried out following CLSI (Clinical & Laboratory Standards Institute) guidelines using clinical settings for sensible or resistant phenotype interpretation.

11.4 Results

We isolated 21 strains of *S. enterica* from 81 fecal samples of marine iguanas in a beach very close to the town of Puerto Baquerizo Moreno. The bacterial species were characterized by biochemical reactions and 16S gene DNA sequences. None of the isolates was resistant to any of the 12 antibiotics tested.

11.5 Conclusions

These results agree with previous reports which showed low antibiotic resistance in *S. enterica* from Galapagos Islands' reptiles (Wheeler et al. 2012); however, our results disagree with the high antibiotic resistance observed in *S. enterica* isolated from domestic animals in continental Ecuador (Vinueza-Burgos et al. 2016; Sánchez-Salazar et al. 2019). These results may suggest that *S. enterica* lineages in San Cristobal Island's marine iguanas are genetically isolated from *S. enterica* in the continent, even though multiple domestic animals are introduced constantly to this island (Puente-Rodríguez et al. 2019; Padilla et al. 2018); however, previous reports of *S. enterica* isolates from Galapagos iguanas didn't show any distinct lineages when compared with isolates from elsewhere (Wheeler et al. 2012).

It is also difficult to understand why *S. enterica* from iguanas are pan-sensitive because previous studies in San Cristobal Island showed multi-antibiotic-resistant *E. coli* in marine iguana feces (Wheeler et al. 2012) and in water from beaches (Overbey et al. 2015). Furthermore, one of these studies showed that pan-sensitive *S. enterica* cohabitate with multi-resistant *E. coli* in the same iguanas (Wheeler et al. 2012); both bacteria (*S. enterica* and *E. coli*) are known to exchange antibiotic resistance genes in animal intestines (Card et al. 2017; Blake et al. 2003).

Antibiotic resistance is common in *Salmonella* from wildlife (Botti et al. 2013). However, a study in the island of Grenada (West Indies) showed also very low levels of antibiotic resistance in *S. enterica* isolated from green iguanas (Sylvester et al. 2014). It could be argued that the lack of antibiotic resistant gene transference between *E. coli* and *S. enterica* is due to the low prevalence of *E. coli* in marine iguanas (Wheeler et al. 2012); however, similar low antibiotic resistance was found in other Galapagos reptiles with high *E. coli* prevalence (Wheeler et al. 2012). The intriguing absence of antibiotic resistance in *S. enterica* isolated from wild iguanas is an important finding which may inform about possible ways to interrupt the dissemination of antibiotic resistance genes in the environment.

Finally, *S. enterica* carriage by Galapagos wildlife may be posing some risks to the human population. In July 2019, our laboratory isolated *S. enterica* from seven humans (diarrheal outbreak associated with a social event) attending the hospital in San Cristobal. Surprisingly, the isolates showed no resistance to any of the 16 antibiotics tested, which may indicate that these bacteria originated in wildlife and not from domestic animals. Although pan-sensitivity has been reported in *S. enterica* isolated from clinical cases in South America (Rodríguez et al. 2017), it is interesting that these cases occurred in Galapagos Islands where pan-sensitive strains of *Salmonella* are prevalent in wild reptilians (Table 11.1).

Table 11.1 Molecular detection of serovars using Kim et al.'s (2006) protocol. Numbers indicate the pattern of amplification

Sample	Amplification pattern		Serovar
	STM	STY	
CS5	2,5	0	Braenderup
CS7	2,3,5	1	ND
CS8	0	0	ND
CS12	2,5	1	ND
CS16	3,5	0	Hadar
CS17	5	0	ND
CS23	2	0	ND
CS31	2	0	ND
CS35	2,5	2	ND
CS36	5	0	ND
CS52	0	1	ND
CS55	2,5	0	Braenderup
CS57	0	0	ND
CS58	2,5	2	ND
CS64	2,3,5	0	Bovismorbificans
CS70	2	1,2	ND
CS71	2,5	0	Braenderup
CS73	0	0	ND
CS74	0	0	ND
CS76	2,5	2	ND

ND not determined

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Chapter 12
Mosquitoes of the Galapagos Islands: The Risk for Arboviruses Transmission and the Need for a Better Vector Surveillance and Control Program

Renato León, Leonardo Ortega-Lopez, Carolina Molina, and William F. Waters

Abstract The Galapagos Islands are best known for their biodiversity, which inspired both Darwin's theory of evolution and a significant tourism industry. But the movement of visitors and residents as well as goods increases the risk of exposure to emerging and re-emerging diseases. In particular, more than a billion people are infected, and more than one million people die every year from vector-borne diseases such as dengue fever. Three mosquito species have been identified in Galapagos, *Aedes taeniorhynchus*, *Culex quinquefasciatus*, and *Aedes aegypti*, all of which are important arbovirus (viruses transmitted by arthropods) disease vectors. The first two can transmit West Nile virus and several other arboviruses, while *Ae. aegypti* is the principal vector of dengue fever virus, chikungunya virus, Zika virus, yellow fever virus, and, potentially, Mayaro and Rift Valley fever viruses.

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Cases of dengue fever have been reported sporadically on the island of Santa Cruz since 2002, and a significant dengue fever outbreak occurred on San Cristobal in 2010. At least 26 cases of chikungunya were reported in 2015, and a few cases of Zika occurred between 2016 and 2017. The local mosquito control program currently relies on larval and adult control through source reduction and application of larvicides and insecticides, but has not been entirely successful.

This chapter provides a review of the current knowledge of the mosquito fauna in the Galapagos Islands and the potential effect of the introduction of new arboviruses, and it addresses the risk of disease burden by arboviruses in the islands with an emphasis on dengue fever. It then suggests the need to implement the Biogents Gravid *Aedes* trap (GAT) for adult mosquitoes as an economic and nontoxic surveillance alternative, which would help prevent or reduce arbovirus transmission.

Keywords Vector-borne diseases · Dengue fever · Arboviruses · Vector surveillance · Vector control · Mosquitoes

12.1 Introduction

Mosquitoes are medically important two-winged insects that are a nuisance to humans and can transmit deadly infectious pathogens through their bite. Some of these pathogens are arboviruses (arthropod-borne viruses). Every year, more than a billion people are infected, and more than one million people die from vector-borne diseases (WHO 2014). In the context of the 2020 Coronavirus disease (COVID-19) pandemic, the situation of public health systems in many tropical countries (especially in the Americas) is especially precarious (Navarro et al. 2020). Dengue virus (DENV), a mosquito-borne arboviral disease, has caused significant outbreaks in the Americas in the last decade. After a decrease in cases in 2017 and 2018, a new major epidemic started in the region in 2019 affecting over five million people by August 2020. In this period, Ecuador has reported 20,976 DENV cases (MSP, Gaceta-Vectores SE 30 2020b). By mid-2020, it was clear that the COVID-19 and DENV fever co-epidemics put the already strained national health systems on the edge (Navarro et al. 2020).

The Galapagos Islands, which constitute one of the 24 provinces of Ecuador, are located approximately 1,000 km west of the mainland and are a globally renown tourist destination. The archipelago consists of 22 islands larger than 1 km^2 and hundreds of islets and rocks; it was designated a Natural World Heritage site in 1976 and a Biosphere Reserve by UNESCO in 1984 (UNESCO 2011). It is best known for its biodiversity, which inspired Darwin's theory of evolution. The beauty of the landscape, where stunning endemic species are found in their natural habitats, ironically contrasts with urban and suburban areas in five inhabited islands, where approximately 33,000 residents (SNI 2017) struggle every day to make a living and have to face restricted job opportunities, a high cost of living, and many other limitations (Brewington 2013).

The fragile ecosystem faced by the local wildlife and the human population also hides serious public health problems. The limited availability of basic public services, lack of adequately developed health infrastructure, and poor nutritional status put the local population in a vulnerable situation (Freire et al. 2018). In addition, rapid population growth, substantial flows of tourism, and movement by visitors and residents, as well as commerce with the mainland, increase the risk of introduction of invasive species and pathogens into the islands (Toral-Granda et al. 2017). In this chapter, we address the risk of disease burden caused by arboviruses transmitted by mosquitoes in Galapagos with an emphasis on DENV. Furthermore, we discuss the implementation of vector surveillance through the use of the Gravid *Aedes* trap (GAT), an inexpensive and efficient alternative to prevent or reduce arbovirus transmission in the islands.

12.2 Mosquito Vector Species and Arbovirus Transmission

Only three species of mosquitoes (Diptera: Culicidae) are known to inhabit the Galapagos Islands: *Aedes taeniorhynchus*, *Culex quinquefasciatus*, and *Ae. aegypti*. All three have been reported elsewhere to be important disease vectors. The first two can transmit West Nile virus (WNV) and several other arboviruses, while *Ae. aegypti* is the principal vector of DENV, chikungunya virus (CHIKV), Zika virus (ZIKV), yellow fever virus (YFV), and, potentially, Mayaro virus (MAYV).

Of the three species mentioned above, only *Cx. quinquefasciatus* and *Ae. aegypti* are considered to be invasive species. Studies in the past decade on *Ae. taeniorhynchus* suggest that since its arrival into Galapagos, this mosquito has evolved into what is now considered a native species. As further described below, it may play a role as a vector of several arboviruses that are frequently a cause of disease burden in other parts of the world.

12.2.1 Aedes taeniorhynchus

This species, commonly known as the black salt marsh mosquito, was originally classified as *Ae. taeniorhynchus* (Wiedemann 1821) and reclassified as *Ochlerotatus taeniorhynchus* (Reinert 2000), but it recently regained its original taxonomic status (Wilkerson et al. 2015). This mosquito is thought to have arrived naturally in Galapagos some 200,000 years ago (Bataille et al. 2009) and is now widely distributed in the islands. Studies have shown specific adaptations to the lowlands and highlands in the islands (Bataille et al. 2010), and further molecular studies suggest that the Galapagos populations of *Ae. taeniorhynchus* have evolved into a distinct clade from those in other regions of the Americas (Bataille et al. 2009). Thus, this mosquito is currently considered a Galapagos native species; it is medically important because it is known to be a vector of eastern equine encephalitis virus (EEEV),

Venezuelan equine encephalitis virus (VEEV), WNV, St. Louis encephalitis virus (SLEV), and the dog heartworm *Dirofilaria immitis* (Labarthe et al. 1998; Ortiz and Weaver 2004). Studies on this vector have determined that the populations established in the Galapagos are possibly more competent to WNV transmission, representing a higher risk to native and endemic wildlife (Eastwood et al. 2013).

12.2.2 Culex quinquefasciatus

This species, known as the Southern house mosquito, is present in tropical and subtropical areas throughout the world, including Africa, the Americas, Asia, and Australia (Fonseca et al. 2006). *Culex quinquefasciatus* belongs to the *Culex pipiens* complex that includes six recognized species, of which only *Cx. pipiens pipiens* and *Cx. quinquefasciatus* occur in the Americas. *Culex quinquefasciatus* has been shown to be a vector of important pathogens, such as WNV, SLEV (Meyer et al. 1983; Reisen et al. 2005; Sardelis et al. 2001), Oropouche virus (OROV) (Da Rosa et al. 2017), and lymphatic filariasis and in wildlife populations, avian malaria and avian pox (Eastwood et al. 2011; Farajollahi et al. 2011). West Nile virus and SLEV are zoonotic diseases that can also be considered to be important pathogens for wildlife, which increases conservation concerns in fragile ecosystems (Kilpatrick et al. 2006). West Nile virus can develop high viremias in some birds and may elicits mortality, whereas SLEV has not been associated with avian virulence (Maharaj et al. 2018).

The first record of *Cx. quinquefasciatus* in Galapagos dates to 1985; it is thought that it was introduced from the mainland as larvae, possibly through local air travel (Whiteman et al. 2005). Currently, *Cx. quinquefasciatus* is present on Santa Cruz (STZ), San Cristobal (SCL), Isabela, and Floreana islands (Whiteman et al. 2005) and was recently found on Baltra and Santiago islands (Eastwood et al. 2019). To date, it is not known whether *Culex*-borne arboviruses circulate in Galapagos (Eastwood et al. 2014); however, statistical analyses of a potential introduction of WNV into the islands predict that its most likely introduction would be through air transport of infected *Cx. quinquefasciatus* mosquitoes (Kilpatrick et al. 2006).

12.2.3 Aedes aegypti

This mosquito, commonly known as the yellow fever mosquito for its ability to transmit YFV, also has significant medical importance due to its role as a vector in the transmission of several other arboviruses as described below. The species originated in Africa from a zoophilic form called *Ae. aegypti formosus*, which is now genetically different; both occupy a distinct ecological niche (Brown et al. 2011, 2014). It is thought that this species first spread to the New World during the slave trade and subsequently invaded other continents, occupying the tropical and subtropical areas of the world (Brown et al. 2014; Kraemer et al. 2015). *Aedes aegypti*

is a container-inhabitant species found primarily in and around urban domiciles, particularly where eggs can be laid on a surface in contact with standing water. Its immature stages (larvae and pupae) are commonly found in unattended stored water in tanks, flowerpots, spare tires, and drainage ditches (Romero-Vivas et al. 2006). It is an anthropophilic, diurnal mosquito that is probably the most important global vector of human arboviruses (Lima-Camara 2010; Scott et al. 1993). This species has been identified as the main vector of DENV, CHIKV, ZIKV, and YFV (Bhatt et al. 2013; Guo et al. 2013; Gubler 2011; Yakob and Walker 2016). Global concerns over DENV, CHIKV, and ZIKV are due to the sharp increase in incidence and the spread to new geographical locations in the last decades (Kraemer et al. 2015; Kamal et al. 2018). The lack of available vaccines or well-established vaccination programs against these arboviruses (except for YFV) currently leaves the control of *Ae. aegypti* populations as the main alternative to prevent disease transmission (Barrett 2018; Powers 2018; World Health Organization 2018).

Aedes aegypti was possibly introduced into the Galapagos in the 1990s, and DENV was first recorded in 2002, thus confirming the permanent establishment of *Ae. aegypti* (World Health Organization (WHO) 2002; Bataille et al. 2009). This species is currently present on STZ and SCL and was recently reported on Isabela (Asigau et al. 2017).

It is important to note another invasive species, *Aedes albopictus*, commonly known as the Asian tiger mosquito, which was introduced from Asia into the Americas a few decades ago. In Ecuador, this species was first recorded in Guayaquil, the main city in the coastal mainland (Ponce et al. 2018). Although not yet present in the Galapagos, its introduction is possible considering the immense flow of people and products from the mainland, especially from Guayaquil (Toral-Granda et al. 2017). *Aedes albopictus* has been shown to be an efficient vector of many viruses, including DENV, CHIKV, ZIKV, and YFV (Leta et al. 2018; Bonizzoni et al. 2013; Boyer et al. 2018; Paupy et al. 2009), and it has also been identified as a highly efficient vector of WNV under laboratory conditions, although it has not been officially connected to urban or peri-urban transmission (Turell et al. 2001, 2005a).

A few of the abovementioned mosquitoes including *Ae. taeniorhynchus*, *Ae. aegypti* and *Ae. albopictus* can also transmit Rift Valley fever virus (RVFV), which is considered to be one of the most dangerous emerging zoonotic diseases worldwide (Pepin et al. 2010).

12.3 The Burden of Disease in Ecuador and Galapagos

12.3.1 Dengue Fever

Dengue fever is undoubtedly one of the most important vector-borne diseases in the Americas and in Ecuador. After transmission of the disease in Ecuador was halted for about a decade in the 1950s as a result of an efficient vector control program (García 1953), the disease and its vector re-emerged, producing more than 80,000

DENV cases in Guayaquil in 1988, followed by a major outbreak of an estimated 800,000 cases nationwide (Badii et al. 2007). Other outbreaks occurred in 2000, 2001, 2005, 2010, 2012, and 2015 (Brathwaite Dick et al. 2012; Real-Cotto et al. 2017; Stewart-Ibarra et al. 2018; Sippy et al. 2019). There are four distinct serotypes of DENV (DENV-1, DENV-2, DENV-3, and DENV-4) that follow the human cycle; a fifth serotype (DENV-5) discovered in 2014 is related to a sylvatic cycle (Mustafa et al. 2015). The first four serotypes associated with human disease have all been recorded in Ecuador (Ramos-Castaneda et al. 2017).

In the Galapagos, DENV transmission started on STZ island after the introduction of the *Ae. aegypti* mosquito into the islands. By 2002, the first four cases of DENV occurred (WHO 2002), and that year, the first outbreak of DENV was reported in Puerto Ayora, with at least 227 cases (Ryan et al. 2019), producing an incidence of 122 per 10,000 inhabitants. In contrast, the DENV incidence at the national level was much lower, at 4 cases per 10,000 inhabitants that year (Panamerican Health Organization (PAHO) 2020). Between 2005 and 2014, at least 262 more cases were reported on STZ, peaking between 2010 and 2012. This was when the first and only major outbreak occurred on SCL island (2010), starting with a few cases in epidemiological week 14 with at least six confirmed cases and rapidly increasing to 94 cases, mostly in the neighborhoods of Peñas Bajas ($n = 23$), Algarrobos ($n = 20$), Cactus ($n = 14$), and Barrio Central ($n = 7$). A few other cases were reported in at least 12 other neighborhoods from Puerto Baquerizo Moreno, SCL island. A total of 941 cases were reported by the end of 2010 (Parra 2014). From 2002 through 2020, at least 1,800 cases have occurred in Galapagos based on data from the Ecuadorian Ministry of Public Health (Parra 2014; Ryan et al. 2019).

By August 2020, Galapagos had reported 109 cases of DENV fever in that year (MSP, Gaceta-Vectores SE 30 2020b). Combined with the COVID-19 pandemic, this new DENV outbreak significantly affected the economy and life in the archipelago. According to local information, ongoing DENV transmission occurs on both STZ and SCL, while the first cases of local transmission of DENV have occurred on Isabela island.

12.3.2 Chikungunya and Zika

In the past decade, CHIKV and ZIKV, two other imported arboviruses, produced major epidemics in the Americas (Panamerican Health Organization (PAHO) 2014; Paixão et al. 2018). CHIKV emerged from Africa and was gradually distributed globally, reaching the Americas in 2013, where it produced a substantial outbreak (Yactayo et al. 2016). In Ecuador, the number of reported cases decreased from 33,619 in 2015 to 1,860 in 2016; 196 in 2017; and only 8 in 2018 (MSP, Gaceta-Vectores SE 24 2020a). Only 26 cases of CHIKV were reported in Galapagos in the peak year of 2015 (MSP, Gaceta-Vectores SE 52 2017).

A second arbovirus, ZIKV, which also originated in Africa, spread rapidly to other regions, reaching the Americas in 2015 and producing 223,477 cumulative cases through January 4, 2018 (Panamerican Health Organization (PAHO) 2018). The first case reported in Ecuador was in 2015 and was followed by 2,947 cases in 2016, 2,413 in 2017, and ten in 2018 (MSP, Gaceta-Vectores SE 24 2020a). In Galapagos, the only five imported cases were reported between 2016 and 2017 (MSP, Gaceta-Vectores SE 52 2017).

12.3.3 Yellow Fever

The YFV is a deadly arbovirus, which in urban settings is transmitted by the *Ae. aegypti* mosquito. This dangerous arbovirus continues to be a problem in the Americas, especially in Brazil, where between 2016 and 2017, 1,987 cases of yellow fever and 282 deaths were reported (Ortiz-Martínez et al. 2017). In Ecuador, urban transmission of YFV ended in 1919 (García 1953). Subsequent outbreaks in Ecuador's Amazon basin were recorded in 1949 and 1992. In a new outbreak at this region in 1997, 44 cases were reported (Izurieta et al. 2009). The last three cases of YFV were reported from Amazonian Ecuador in 2017 (MSP, Gaceta-Vectores SE 24 2020a). Despite the potential threat of YFV epidemics, protection for 10–35 years can be given to people who get vaccinated (Monath 2005), and if regulatory mandates are applied, YFV outbreaks can be avoided (Possas et al. 2018). But unvaccinated travellers from this region or from other neighbor countries could potentially carry the virus to Galapagos, where the virus could easily spread because vaccination is not mandatory in the local population.

12.3.4 Mayaro

A new emerging pathogen, MAYV, has recently drawn attention because a total of 901 human cases have been reported in Latin America and the Caribbean (Ganjian and Riviere-Cinnamond 2020) including the first five human cases in Ecuador (MSP 2020c). Mayaro virus is also an arbovirus, which presents an enzootic cycle circulating between non-human primates and other mammals and mosquitoes in the wild. It belongs to the genus *Alphavirus* and, together with CHIKV in the Semliki Forest complex of viruses, reminds us of the past CHIKV outbreak and the persistent risk of increased disease burden in the future (Acosta-Ampudia et al. 2018; Izurieta et al. 2011). Human cases from 2015 to 2020 of the abovementioned arboviruses in Ecuador are presented in Table 12.1.

Table 12.1 Arboviral disease cases reported for Ecuador and the Galapagos: 2015–2020

	E	G	E	G	E	G	E	G	E	G	E	G	E	G
Year	2015		2016		2017		2018		2019		2020		Total	
Dengue fever	42,499	184	14,159	2	11,387	57	3,099	8	8,416	2	12,560	109	92,120	362
Chikungunya	33,619	26	1,860	0	196	0	8	0	2	0	0	0	35,685	26
Zika	1	0	2,947	2	2,413	3	10	0	0	0	0	0	5,371	5
Mayaro	0	0	0	0	0	0	0	0	5	0	0	0	5	0
Yellow fever	0	0	0	0	3	0	0	0	0	0	0	0	3	0
Total	76,119	210	18,966	4	13,999	60	3,117	8	8,423	2	12,560	109	133,184	393

Source: MSP, Gaceta-Vectores (https://www.salud.gob.ec/gacetas-vectoriales-2020/)
E Ecuador, *G* The Galapagos Islands

12.3.5 West Nile

Although WNV human cases have not been recorded in Ecuador, including the Galapagos, a recent short review indicated that according to previous serology studies, the virus circulates in equines in the coastal part of the country (Coello-Peralta et al. 2019). Hence, its introduction to the Galapagos is highly likely, and it could have unpredictable consequences, especially in endemic wildlife (Kilpatrick et al. 2006). In the past few years, WNV has circulated in North America, showing a high adaptability and ability to be transmitted and maintained over long periods of time (Andreadis et al. 2004; Turell et al. 2006). Among the main reasons of the long-term transmission of WNV in this region are the successful establishment of its vector, *Cx. pipiens pipiens*, in urban environments, the ability of the vector to transmit the virus vertically to its offspring, and the mixed host feeding behavior of the vector, affecting a wide range of vertebrates (Dohm et al. 2002; Lukacik et al. 2006; Turell et al. 2006). In environments that are similar to Galapagos, such as Hawaii, bird populations have declined, in part due to mosquito-borne diseases. In particular, it is thought that avian pox and avian malaria, both transmitted by *Cx. quinquefasciatus*, are responsible for the avifauna decline in Hawaii (Van Riper and Scott 2001; Van Riper et al. 2002). Similar effects could occur in Galapagos with the potential introduction of WNV, as local avifauna would also be susceptible to this disease (Wikelski et al. 2004; Thiel et al. 2005) and since local vectors *Cx. quinquefasciatus* and *Ae. taeniorhynchus* are already established and have shown to be competent for WNV. The main potential introduction pathway of WNV into Galapagos has been determined to be through infected mosquitoes in airplanes coming from the mainland (Kilpatrick et al. 2006). However, another route of spread of WNV is through migratory birds, which has been observed in other regions such as southern Europe, making this another pathway of introduction that should not be ignored (Rappole et al. 2000). Poultry and other domestic birds are used in seroprevalence studies of WNV (Komar 2001) and have been discarded as reservoirs that could keep the transmission cycle of WNV as they do not develop sufficient viremia and thus are considered dead-end hosts (Maquart et al. 2016). Another arbovirus that has produced devastation in Asia in the past, Japanese encephalitis virus, has essentially the same transmission cycle as WNV and SLEV (Barrett and Weaver 2012). If this virus was introduced to the Galapagos, it could well be detrimental to some of the native bird species.

12.3.6 Other Arboviruses

The equine encephalitis viruses, including VEEV, EEEV, and western equine encephalitis (WEEV) in the Togaviridae family, genus *Alphavirus*, are zoonotic viruses that persist in the Americas and are also a threat to both human and other animal populations. These viruses were all reported in Ecuador (Calisher et al.

1983) in a surveillance program carried out in the 1980s after the only well-documented large outbreak of VEEV, which was reported in Ecuador in 1969 (Gutierrez et al. 1975), when 31,000 humans and 20,000 horses were infected.

This VEEV virus circulates in enzootic cycles between small rodents and mosquito species of the *Culex (Melanoconion)*, *Aedes*, and *Psorophora* genera. North, Central, and South American strains of *Ae. taeniorhynchus* have all been shown to be competent vectors of VEEV (Turell 1993, 1999; Turell et al. 1992, 2003). This virus was also detected in patients with acute undifferentiated febrile illness in Ecuador's Amazon basin (Manock et al. 2009). The risk of new VEEV outbreaks persists in Ecuador, even after a long period of apparent epidemiological silence, since VEEV cases have been recorded elsewhere in the Americas in the past few decades (Guzmán-Terán et al. 2020).

As mentioned above, EEEV is known to be lethal in a number of bird populations. Therefore, as *Ae. taeniorhynchus* is known to be a competent vector of EEEV (Turell et al. 1994) and numerous strains of EEEV have been detected in mosquito populations in the Amazon Basin region (Turell et al. 2005a), its introduction might have devastating effects if introduced into the Galapagos.

While the introduction of RVFV into Galapagos is unlikely, should this occur, it could be devastating because RVFV can have high mortality rates in several animal species. Thus, given what has happened with CHIKV and ZIKV, it is possible that a person visiting game parks in East Africa could be bitten by a mosquito infected with RVFV. As with CHIKV, VEEV, and ZIKV, humans produce a very high viremia when infected with RVFV (Meegan 1979) and thus could bring the virus to the Americas and introduce it into the local mosquito population because both *Ae. taeniorhynchus* and *Ae. aegypti* are competent vectors (Turell 1993; Turell et al. 1985). Also, given that the Galapagos and game parks in East Africa are internationally known natural animal habitats, it is even possible for a person to plan a once-in-a-lifetime adventure including a visit to a game park in Africa and then a visit to the Galapagos, thus potentially allowing for the introduction of RVFV directly to the Galapagos.

Arboviral studies conducted in coastal Ecuador of 770,000 mosquitoes collected in the 1970s also revealed the presence of 24 virus strains of the Gamboa serogroup of Bunyaviruses, including the new Pueblo Viejo virus (Calisher et al. 1981). Three hundred seventy-nine viruses were later isolated from mosquitoes, including 11 Bunyaviruses: (the virus name is followed by the number of virus isolates in parenthesis), Maguari (243), Playas (3), Vinces (33), Tunbock (2), Abras (5), Babahoyo (3), Acana (2), Guajara (3), San Juan (6), Pueblo Viejo (3), 18 unspecified Gamboa serogroup viruses, and Palestina (7) (Calisher et al. 1983).

Finally, another virus of the family Bunyaviridae, OROV of the Simbu serogroup, has been found in febrile human cases in coastal Ecuador (Wise et al. 2020). Its transmission occurs through biting midges of the *Culicoides* genus; nevertheless, *Culex* mosquitoes (notably *Culex quinquefasciatus*, which is widely distributed in the Galapagos) have also been identified as a possible vector (Da Rosa et al. 2017). These and many other arboviruses (such as Group C Orthobunyaviruses) that circulate in the Amazonian forest (Turell et al. 2005b) share features and could produce

symptoms such as fever, headaches, and myalgias, which could confound diagnosis of the disease. Similarly, diseases caused by another pathogen could be misdiagnosed as dengue fever without appropriate laboratory testing (Aguilar et al. 2011). Information on the main arboviruses known to exist in Ecuador and Galapagos, their vectors, and references is summarized in Table 12.2.

12.4 Preliminary Studies and Data on the Surveillance of Mosquitoes in the Galapagos

Our studies of mosquitoes in the Galapagos have focused mainly on *Ae. aegypti*. The first entomological collections were conducted as part of a pilot study to assess social- ecological risk factors associated with DENV transmission and the presence of mosquitoes in households (Ryan et al. 2019). Household surveys were conducted in 50 houses on the two main inhabited islands (STZ and SCL) in order to obtain demographic information; history of DENV infection; housing conditions; and residents' knowledge, attitudes, and practices. Mosquito collections were carried out using Prokopack aspirators and standard container examination for the presence of immature stages. Data were analyzed using multi-model selection methods to derive best fit generalized linear regression models and to determine risk of DENV infection and presence of mosquitoes. Results suggested that 14% and 24% of the population of STZ and SCL, respectively, presented prior DENV infection and an increased presence of the mosquito on SCL. Breteau Indices (BI, the number of containers with juvenile *Ae. aegypti* per 100 homes) on STZ (BI = 6) were much lower than on SCL (BI = 26). Factors that we found to be associated with prior DENV infection were movement of people, income, education of the household head, number of people living per room, housing conditions, and access to piped water, whereas the presence of mosquitoes was more associated with the use of window screens, air conditioners, mosquito control measures, and perceptions of DENV (Ryan et al. 2019).

These initial results might actually have underestimated the mosquito populations on STZ because focused spraying campaigns had been conducted by the Ministry of Public Health (MSP) on STZ a few weeks before the mosquito survey. Additionally, past history of DENV exposure on SCL may have reflected the major epidemic of 2010. A subsequent longitudinal study was carried out in the dry and rainy seasons between 2017 and 2018, when mosquito populations were surveyed on Isabela and Floreana islands as well as on STZ and SCL (Fig. 12.1). Collection sites were selected based on previous information from the MSP and included houses with outdoor laundries and water storage tanks, which were examined for the presence of immature larvae and pupae. The interior of houses and peridomiciles were also surveyed for adult mosquitoes using Prokopack aspirators and BG-Sentinel traps using standard procedures. Results showed that a total of 75 of 319 (23%) of the houses sampled in the 4 islands were positive for *Ae. aegypti*,

Table 12.2 Viruses known to exist in Ecuador or the Galapagos, their vectors, and some viruses that might be introduced and cause disease

					Reported in		
	Vector species	*Ae. aegypti*	*Ae. taeniorhynchus*	*Cx. quinquefasciatus*	E	G	References
Family	Arbovirus						
Flaviviridae	YFV	X			Yes	No	García (1953) and Izurieta et al. (2009)
	DENV	X			Yes	Yes	Stewart-Ibarra et al. (2018), Sippy et al. (2019) and Ryan et al. (2019)
	ZIKV	X			Yes	Yes	Cevallos et al. (2018)
	WNV		X	X	Yes	No	Eastwood et al. (2011, 2013, 2014, 2019)
	SLEV		X	X	Yes	No	Calisher et al. (1983) and Manock et al. (2009)
	Ilheus				Yes	No	Johnson et al. (2007)
Togaviridae	CHIKV	X			Yes	Yes	Stewart-Ibarra et al. (2018) and Cevallos et al. (2018)
	MAYV	X			Yes	No	Izurieta et al. (2011)
	VEEV	X	X		Yes	No	Gutierrez et al. (1975), Calisher et al. (1983) and Manock et al. (2009)
	EEEV		X		Yes	No	Calisher et al. (1983)
	WEEV			X	Yes	No	Calisher et al. (1983)
Bunyaviridae	OROV			X	Yes	No	Wise et al. (2020)
	Gamboa serogroup				Yes	No	Calisher et al. (1981, 1983)
	Group C				Yes	No	Calisher et al. (1983) and Forshey et al. (2010)

E Ecuador, *G* The Galapagos Islands

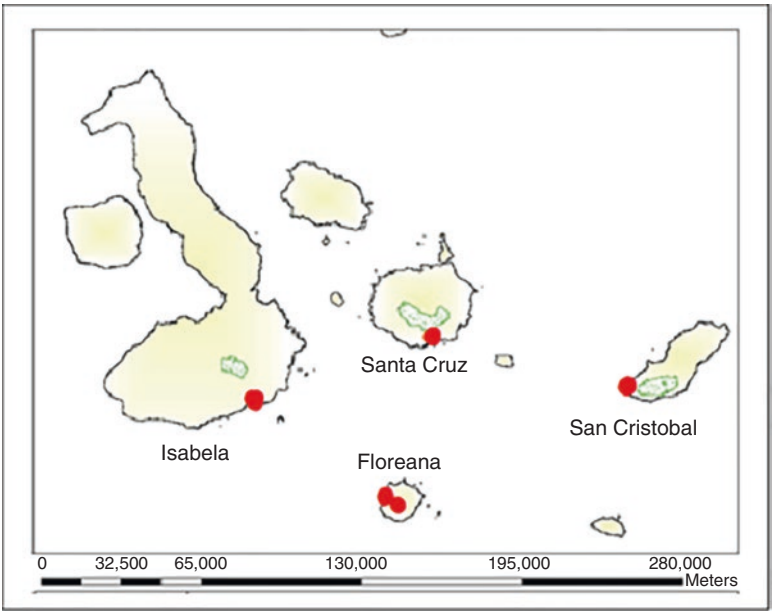

Fig. 12.1 Map of the Galapagos Islands. Entomological collections were carried out on four of the inhabited islands. Red dots indicate collection sites on each island

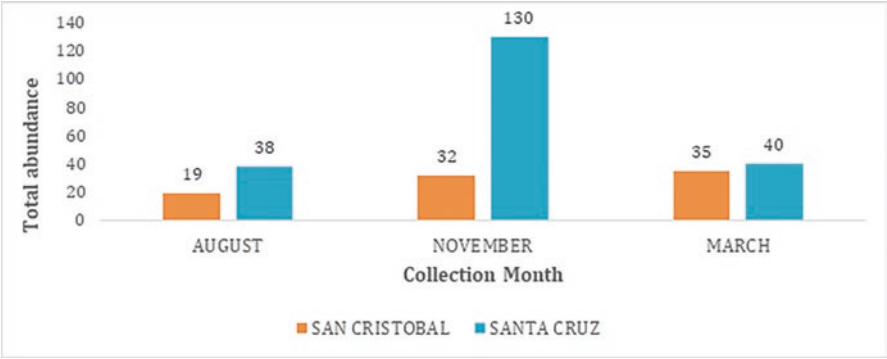

Fig. 12.2 Collections of adult *Aedes aegypti* (both males and females) on Santa Cruz and San Cristobal in relation to the entomological collection period (2017–2018)

producing a total of 299 adults and 42 immature specimens. Percentages of positive houses were 36% for STZ, 28% for SCL, and 6% for Isabela. *Aedes aegypti* was not found in Floreana Island, where only 170 permanent residents live in the town of Velasco Ibarra, which is the smallest inhabited place in the Galapagos except for Baltra, where a few scattered, intermittently inhabited buildings are found near the airport. *Aedes aegypti* was found both in STZ and SCL in all three collection periods in 2017 and 2018 (Fig. 12.2), but the number of adult mosquitoes differed

significantly between the islands and the month of sampling ($X^2 = 5.63$, df = 1, $p < 0.05$) and ($X^2 = 8.01$, df = 3, $p < 0.05$), respectively. November was the month with the greatest abundance of *Ae. aegypti* mosquitoes. These results suggest a greater abundance of *Ae. aegypti* mosquitoes on STZ than in SCL, which is not consistent with previous findings. Human population size (20,302 vs 9,667 inhabitants, respectively) and population density (133 inhabitants/km2 vs 80 inhabitants/km2) (CGREG 2016) on STZ and SCL, respectively, may influence *Ae. aegypti* abundance in the islands.

12.5 *Aedes aegypti* on Isabela Island Predicts Future Local Disease Transmission

Isabela is the largest island in the Galapagos, at 4,640 km^2. Its capital, Puerto Villamil, is the third largest town at the archipelago, with an estimated population of 3,073 in 2020 (SNI 2017). In contrast to Puerto Ayora and Puerto Baquerizo Moreno, the population in Puerto Villamil is more dispersed, at 42 inhabitants/km^2 (CGREG 2016). *Aedes aegypti* was first reported on Isabela in 2014 (Asigau et al. 2017), when four specimens were collected through CDC light trapping during an entomological assessment to study *Ae. taeniorhynchus* and *Cx. quinquefasciatus* mosquitoes. To corroborate this findings, we conducted entomological surveillance using Prokopack and BG traps in August 2017 and March 2018. In the mosquito survey in 2018, we identified five adults and seven immature *Ae. aegypti* specimens, thus confirming the presence of *Ae. aegypti* on Isabela. The island's local airport, Brisas del Mar, and Central neighborhoods, located near the coastline, were positive for the mosquito, suggesting that this invasive species probably arrived as part of the continuous air and inter-island boat transportation of people and goods. These and other factors, such as the absence of well-developed public health services and the local climate, may have also facilitated the invasion of this species as reported elsewhere in the Americas (Fonzi et al. 2015; Ramos et al. 2008; Sukehiro et al. 2013). Whether the presence of this species on Isabela is the result of a single or multiple introductions and whether local mosquito breeding is occurring remains to be determined; however, considering that adults, larva, and pupa were collected, it is likely that this species is already well established on the island.

Additional observations showed that the mosquito larvae and pupae are related to the presence of discarded tires in local school yards. The perception that neither the mosquito nor disease constitutes important problems also contributes to their persistence. The design, implementation, and maintenance of an effective and consistent long-term vector control program, under a sustainable public health strategy, involving both the government and the community, is of great importance for preventing the establishment of vector species such as *Ae. aegypti* (Morrison et al. 2008; Jansen and Beebe 2010). The challenge is urgent because unconfirmed reports suggest that up to six dengue fever cases occurred on Isabela between May and June 2020, most likely as a product of local transmission.

12.6 Entomological Surveillance Using a New Alternative: The Gravid-Aedes Trap

The Galapagos vector control program relies mostly on the treatment of standing water with the larvicide temephos (Abate®) to kill the mosquito larva and, upon request from the residents, on spraying of domiciles with insecticide (deltamethrin) to eliminate adults. The Ministry of Public Health is largely responsible for these tasks, but due to insufficient personnel and other limitations, these activities are supported by the Galapagos Biosecurity Agency (*Agencia de Regulación y Control de la Bioseguridad y Cuarentena para Galápagos*), which is responsible for the control of invasive species at the islands. The activities of these institutions are focused mostly on control. Thus, the implementation of mosquito surveillance is crucial at the Galapagos to provide with data for conducting the most appropriate vector control activities.

The determination of entomological indices of larvae and pupae, which were commonly used to predict disease burden in the past decade, has proved to be poor predictors of disease. The abundance of immature stages does not reflect the vector's abundance because not all larvae or pupae reach the adult stage and not all individuals are females, which are the only vectors of disease. Apparently, adult indices are better disease predictors. The Prokopack aspirator and the BG sentinel trap are useful devices for collecting adult mosquitoes, but their operation requires trained personnel and is quite labor- and resource-intensive. For instance, the BG trap requires connection to electric outlets or batteries, which are not always available. In contrast, the GAT trap developed by Biogents in 2012 is an attractive alternative because it is easy to use and is affordable. It does not depend on an electric outlet for its operation and is highly specific to the collection of *Ae. aegypti* mosquitoes, thus protecting other local fauna that may be affected using other collection methods (Eiras et al. 2014). Hence, it has proved to be an efficient tool for both surveillance and the control of vector populations (Eiras et al. 2018a, b). At the beginning of 2020, a pilot study was initiated to evaluate the effectiveness of the GAT traps on STZ and SCL but was temporarily suspended due to the COVID-19 pandemic. In an initial three-week surveillance period using ten GAT traps placed on each island, 13 *Ae. aegypti* females and 6 *Cx. quinquefasciatus* specimens were captured on STZ, and 4 *Ae. aegypti*, 3 *Ae. taeniorhynchus*, and 2 *Cx. quinquefasciatus* female specimens were collected on SCL, showing that the GAT trap could be a promising alternative for conducting mosquito surveillance in the Galapagos. Further data need to be obtained to corroborate the effectiveness of the GAT trap for collecting *Ae. aegypti* mosquitoes in Galapagos. The study continued in 2021 and will provide valuable data on *Ae. aegypti* populations with respect to their behavior and abundance. This study can also contribute to vector control and the implementation of ongoing government control strategies.

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Part IV
Health Problems and Services

Chapter 13
Health Across the First 1000 Days in the Galápagos Islands

Johanna R. Jahnke, Amanda L. Thompson, Norman T. Archer, Margaret E. Bentley, Kelly M. Houck, María Francisca Murgueitio Fuentes, and Juan Ochoa

Abstract This chapter investigates how early developmental health concerns arise and are contended with on San Cristóbal island, where residents live in geographic isolation with limited access to fresh food, potable water, and healthcare options. In particular, the chapter focuses on the "first 1000 days," the period between conception and a child's second birthday. This period marks a time of rapid growth that is highly sensitive to environmental conditions and can irreversibly alter a child's long-term development. Within the categories of pregnancy, birth, and the postpartum, this chapter identifies and discusses the top health risks during the first 1000 days, including maternal overweight and obesity, urinary tract infections, sexually transmitted infections, overmedication and antibiotic use during pregnancy, gestational diabetes, preeclampsia, preterm birth, low birth weight, excess of Cesarean section, infant feeding, and infant growth. The concluding remarks offer pathways for improving maternal and infant health and development within the complex context of the Galápagos.

Keywords First 1000 days · Social and environmental factors · Caesarean section · Breastfeeding · Pregnancy · Low birth weight

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13.1 Introduction

The first 1000 days of development, the period between conception and a child's second birthday, mark a time of rapid growth that is highly sensitive to environmental conditions and set the stage for long-term health and development. Nutritional, psychological, physical, and social conditions all contribute to this essential early development (Martorell 2017; Zijlmans et al. 2015). During this time, exposure to poorer conditions, such as undernutrition or infectious disease, can jeopardize infants' immediate health and survival and shape their risk for metabolic diseases, including obesity, cardiovascular disease, and diabetes (Wells 2010) and neurobehavioral disorders later in life (Zijlmans et al. 2015). With its high prevalence of maternal micronutrient malnutrition, persistent child stunting, and high levels of maternal depression (Page et al. 2013), the Galápagos Islands of Ecuador provide an important context for understanding the social and environmental factors shaping the health of mothers and infants during this critical period.

13.2 Life on the Galápagos Islands

The geographic, political, and social environments of the Galápagos Islands pose a unique suite of daily circumstances for residents. Limited access to clean water and fresh food and high rates of violence against women are major public health concerns for island residents (Grube et al. 2020; Nicholas et al. 2019; Thompson et al. 2020; Villacis and Carrillo 2013; Walsh and Mena 2013). The limited availability of specialized health services on the islands adds another hardship, particularly during and after pregnancy, when women have concerns about the safety of their delivery

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and the health of their child. As a result of these limited services, many women report traveling to the mainland for healthcare, exacerbating their emotional and economic burdens (Page et al. 2013). Further, residents operate in a tourist economy, facing much higher commodity prices on the Galápagos than on the mainland (Villacis and Carrillo 2013), which further contributes to concerns around food security (Thompson et al., Chaps. 6 and 13, this volume).

Literature on the developmental origins of health and disease aims to better understand how health disparities emerge in response to environmental conditions, and residents of the Galápagos, and particularly new and expectant mothers, face a breadth of challenges in everyday life on the islands. The peripartum period offers a particularly important opportunity to understand this process on the islands, since development during this time has intergenerational effects on health, which could perpetuate existing health disparities (Thayer and Kuzawa 2014; Wells 2010). Consequently, we have conducted several studies to examine the factors contributing to maternal and child health across the first 1000 days of life in the Galapagos Islands (Fig. 13.1), with the goal of identifying modifiable physical and social environmental exposures that may lead to poorer health outcomes during this period and across the lifespan.

Data described in this chapter come from three studies conducted between June 2016 and December 2018 on San Cristobal Island, Galápagos. While these results are only from San Cristóbal, the results may also be relevant to Santa Cruz and

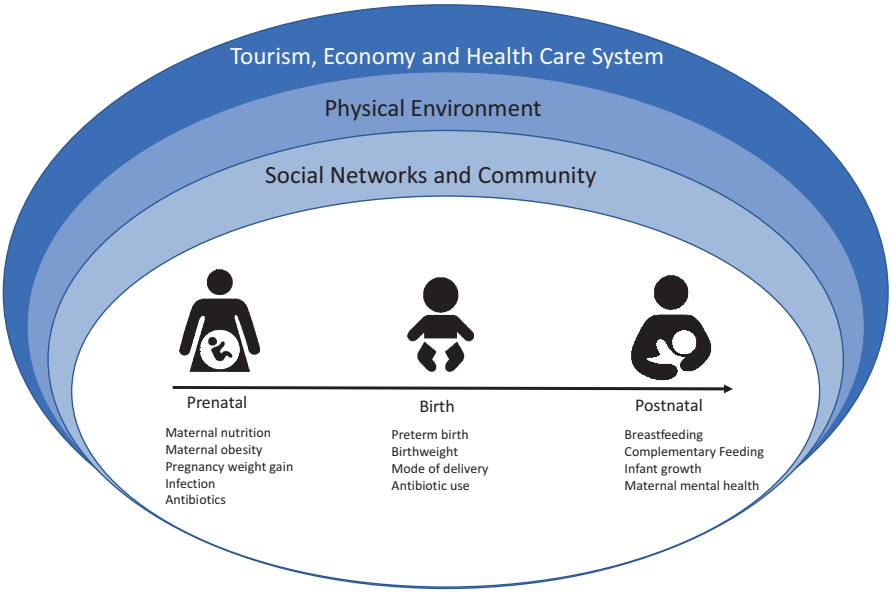

Fig. 13.1 Social and environmental factors influencing maternal and infant health across the first 1000 days in the Galápagos Islands

Isabela islands. The first study, the Birth Practices Study (BPS), was conducted from June to July 2016 and included in-home surveys assessing birth experiences and maternal and child health information from 40 mothers and 41 infants and young children, aged 1 month to 2 years. The second study, the Health Seeking Behavior (HSB) Study, was a qualitative study conducted over two summers, June–July 2016 and June–July 2017. The June–July 2017 wave of the study included in-depth interviews with ten healthcare providers on the islands addressing their perspectives on maternal and child health problems, delivery practices, and healthcare more broadly. The qualitative nature of this investigation aimed to elicit a variety of perspectives on health and healthcare on the island. The third study, the Healthy Moms, Healthy Babies (HMHB) Study, which recruited 38 women at the end of pregnancy and followed them through the first 2 months postpartum, aimed to identify the experiences and stressors of peripartum women and examine how their experiences shaped infant development. Data for this study were collected from January through December 2018 and included semi-structured interviews as well as surveys on stress, depression, and social support. As a part of this study, de-identified data on yearly maternal and infant health characteristics were provided by collaborators at the local hospital.

All three studies received approval for human subject research from the University of North Carolina Institutional Review Board. The BPS and HSB Study received local review approval from Galapagos Science Center and the Universidad San Francisco de Quito. The HMHB Study also received approval from the Institutional Review Board of Universidad San Francisco de Quito (USFQ) and approval from Ecuador's Ministry of Health.

13.2.1 Pregnancy

13.2.1.1 Nutrition and Obesity

Nutrition is a key factor shaping health for mothers and infants across the first 1000 days. Maternal nutritional status, including her diet quality, energy intake, and weight gain, has a direct impact on fetal growth and development. Pregnant women consuming poor quality diets with low intakes of iron and folic acid, for example, are at risk for having infants who are born with complications (Castillo-Lancellotti et al. 2013), preterm (Saccone and Berghella 2016; Symington et al. 2019), or at a low birth weight (Symington et al. 2019), conditions associated with higher morbidity and mortality in early life. Conversely, overweight and obesity prior to and during pregnancy puts women at risk of developing hypertension and gestational diabetes and giving birth to large for gestational age infants. These infants, in turn, are more likely to be obese as preschoolers (Mottola et al. 2010). On the Galápagos, limitations in food availability, reflected in a high prevalence of micronutrient deficiencies, and poor diet quality, associated with the high prevalence of overweight

and obesity, among reproductive aged women may contribute to poor health outcomes for women and infants. Data collected in the Galápagos, in 2012, as part of the nationally representative ENSANUT-ECU study (Freire et al. 2015), documents that 13% of reproductive aged women (15–45 years) were iron-deficient and 56% were zinc-deficient. At the same time, 74% of reproductive-aged women were overweight or obese, contributing to a dual burden of under- and overnutrition that can impact their health and the health of their pregnancies.

Hospital personnel interviewed (n = 16) during the HSB study also highlighted food insecurity and poor diet quality, overweight and obesity, and geographic isolation as central and interconnected health challenges for mothers and pregnant women living on the Galápagos. Interviewed doctors and nurses expressed concern about obesity in the general population of the Galápagos, and they estimated that even before pregnancy, half of local women are overweight. Health professionals also identified anemia as an area of concern among pregnant women on the island. Anemia during pregnancy increases the mother's susceptibility to infection and increases her risk for obstetric hemorrhage during birth (Goonewardene et al. 2012). Anemia during pregnancy also increases the risk for adverse perinatal outcomes, including preterm birth, small for gestational age, and the development of anemia in infancy (Goonewardene et al. 2012). Healthcare providers suggested that a more balanced diet of proteins, red meat, vegetables, and fruits could mitigate both obesity and anemia on the island.

In response to the challenges island residents face around the availability and cost of healthy foods, several hospital personnel noted the importance of education in changing the culture around diet. The majority of health professionals that we interviewed also suggested that the culture around food and the lack of education about nutrition manifest in both food choices and ideologies about food and health. Not only do residents not consume enough fresh fruits and vegetables even when they are available, but also cultural misconceptions about nutrition shape intergenerational health during pregnancy. Physicians repeatedly voiced concerns about the misconception among pregnant women that they should "eat for two." One physician suggested that women "take advantage" of this idea to "eat everything they want, or anything they can," justifying eating double, instead of interpreting the adage as a more mindful consideration of foods that would be healthy for both the mother's and the baby's growth and development. Research has found that the concept of "eating for two" can be detrimental to maternal and infant health, as overeating during pregnancy has been associated with excessive weight gain during pregnancy (Kraschnewski and Chuang 2014).

Health professionals, including both physicians and nurses, suggested that education on nutrition could serve as a preventative measure against overweight and obesity, particularly during pregnancy, when diet can have intergenerational consequences. To meet this need and address other early parenting concerns, in 2018 Ecuador's Ministry of Health has released an educational program, *Infancia Plena*, which has used health centers to distribute educational books on infant health and

development to pregnant women throughout Ecuador (Gobierno de la República del Ecuador 2020). This program seeks to educate parents on birth and breastfeeding, complementary feeding, infant hygiene, home safety, and general growth trends over the first year of life. Healthcare personnel are hopeful that this resource will provide simple and practical steps that will improve maternal and infant health.

13.2.1.2 Infections

During pregnancy, urinary infections are associated with increased risk of both maternal and neonatal morbidity and mortality, even when the infections are asymptomatic (Gilbert et al. 2013). In low- and middle-income countries, in particular, urinary infections during pregnancy are a prevalent and often under-emphasized risk factor for maternal morbidity and adverse birth outcomes (Gilbert et al. 2013).

On San Cristóbal, maternal infection was often reported by the women in our research studies, and it was offered as a central area of concern for pregnant women by hospital personnel. In 2014, 11% of pregnant women seen by the Ministry of Public Health on the Galápagos were treated for urinary infections. Previous research has suggested that the high incidence of urinary infections may be a consequence of bathing or showering in contaminated water (Houck et al. 2020; Walsh et al. 2010). Urinary infections are of particular concern during pregnancy, since untreated urinary infections during pregnancy have been associated with intrauterine growth restriction, low birth weight, and preterm delivery (Cohen et al. 2019). Research has found that in the long-term, offspring of women who had genitourinary infections during pregnancy had higher risk of infectious morbidity (Cohen et al. 2019), developmental delay (McDermott et al. 2000), childhood epilepsy (McDermott et al. 2010), and attention deficit hyperactivity disorder (Mann and McDermott 2011).

13.2.1.3 Antibiotics

The rising prevalence of antibiotic overprescription now poses worldwide challenges to both the environment and patient health (Ramachandran et al. 2019). Ecuador has the second highest rate of per capita antibiotic consumption in Latin America, as antibiotics have been available over-the-counter and many patients report self-medicating with antibiotics throughout their lives (Hall et al. 2017).

On San Cristóbal, the overprescription of antibiotics, both in the general population and for pregnant women, is now a central health concern. Hospital staff have reported feeling pressured to provide antibiotics to frustrated patients who demand medications for ailments that do not require them, particularly since the hospital is still building trust with the community. Physicians and nurses report witnessing the overprescription of antibiotics in response to feeling the need to satisfy patients by offering them a tangible solution to their ailments. To that end, hospital staff has

discussed the practice of prescribing antibiotics as a form of a placebo, despite the potentially harmful effects of antibiotics for patients who do not need them.

In the HMHB Study, 53% of women reported taking antibiotics at some point during their pregnancies. The reasons that women reported for taking antibiotics included urinary and sexually transmitted infections, the flu, the common cold, and morning sickness. While antibiotics are an effective treatment for urinary and sexually transmitted infections, they do not treat the other conditions mentioned. Further, any prescription of antibiotics during pregnancy should be considered carefully, since antibiotic use during pregnancy has been associated with increased risk for miscarriage (Fan et al. 2019; Muanda et al. 2017a), congenital malformations (Muanda et al. 2017b), and asthma in infants (Stensballe et al. 2013).

13.2.2 Birth

13.2.2.1 Preterm Birth and Low Birth Weight

Preterm birth and low birth weight have been associated with both short- and long-term consequences for health. Preterm birth is a risk factor for later high blood pressure, lung disease, high blood glucose, and mental health disorders (Luu et al. 2017), and low birth weight has been associated with similar outcomes later in life, including metabolic disease, diabetes, mental health disorders, and various types of cancer (Negrato and Gomes 2013).

Most women on the Galápagos give birth in a hospital (97.4%), but the infant mortality rate on the islands (4/1000) is higher than the national average (1.3/1000) (Freire et al. 2015). Physicians on San Cristóbal attribute these rates of mortality to complications from preterm deliveries. According to nationally collected data, the prevalence of preterm birth on the islands is 13.5%, compared to 10.5% nationally (Freire et al. 2015). Data from the BPS, however, suggests that these rates may be higher. Seven out of 39 women (17.9%) reported a delivery earlier than 36 weeks. While this higher figure likely derives from the small sample size and time frame of births represented, this high prevalence in a small population of women likely drives medical personnel's perceptions that preterm birth is a problem for mothers on the islands. Further, concerns about caring for both women in early labor and for preterm infants may derive from the distance of the islands to the mainland and specialized neonatal care facilities. Nurses, for example, expressed concerns about the high prevalence of preterm births on Isabela, the most isolated of the populated islands. Women who go into early labor on Isabela, which lacks a hospital, must wait for transport by air to San Cristobal or the mainland, increasing the risk to themselves and their infants.

The rate of low birth weight (<2500 g) on the islands (6.4%) is comparable to that of the national average (6.8%) (Freire et al. 2015). In the BPS, 5.6% of the infants were born low birth weight, and in the HMHB Study, only 2.6% of infants

were born low birth weight, suggesting that while preterm birth is a concern, low birth weight is not a central challenge to early development on the Galápagos.

13.2.2.2 Cesarean Section

While delivery by Cesarean section (C-section) can be imperative for the immediate health and survival of a woman and her child, unnecessary C-section has been associated with higher morbidity and mortality for both mothers and their infants (Runmei et al. 2012; Villar et al. 2006). Women who deliver by C-section are at higher risk for infection, venous thromboembolism, abnormal placentation, placenta accreta, and uterine rupture than those who deliver vaginally (Boutsikou and Malamitsi-Puchner 2011; Silver 2012). Furthermore, those born by C-section are at higher risk for hypertension (Horta et al. 2013), allergy and asthma (Cho and Norman 2013; Kristensen and Henriksen 2016), diabetes (Cardwell et al. 2008; Chavarro et al. 2020), gastrointestinal disease (Bager et al. 2012), and overweight and obesity (Blustein et al. 2013; Horta et al. 2013) in offspring later in life.

Ecuador's C-section rate has been rising far beyond the 10–15% rate recommended by the World Health Organization (World Health Organization (WHO) 2015) over the past few decades, and the C-section rate on the Galápagos is even higher than that on the mainland (Jahnke et al. 2019; Ortiz-Prado et al. 2017). In the BPS from 2016, 58% of deliveries were by C-section, and in the HMHB Study in 2018, 52% of women delivered by C-section. According to maternal report of the reason for C-section deliveries in these studies, 39% were due to previous C-sections, 13% due to prolonged labor, 13% due to fetal malpresentation, 11% due to the baby being "too big," 5% due to the mother's "narrow hips," and the remainder due to preeclampsia, a history of miscarriage, patient choice, and unidentified complications. C-sections, particularly those that occur before the onset of labor, have been linked to a number of inflammatory conditions in childhood and adolescence, including increased allergy and asthma and elevated risk of overweight and obesity (Blustein et al. 2013; Cho and Norman 2013), making the high rate of C-section on the islands a concern for long-term development.

Many healthcare providers discussed the high rate of C-sections as a health concern in the Galápagos, but their explanations for the rate did not align with the reasons provided by maternal report in our research studies. Providers reported that the high C-section rate may be a result of limited resources, explaining that when there are not enough beds to house all the women in labor, the hospital can meet the patient demand by delivering women by C-section to save time. They also suggested that women elect to deliver by C-section for a variety of reasons. First, in the Galápagos, where women frequently travel to the mainland of Ecuador to give birth, scheduling a C-section allows them to have a specific delivery date around which they can plan travel. Second, providers suggested that women's fear of pain during vaginal birth coupled with stigma regarding the lasting effects of sexual displeasure following birth motivated women to elect C-sections. Last, doctors explained that many women who have had a C-section for their first delivery will have C-sections

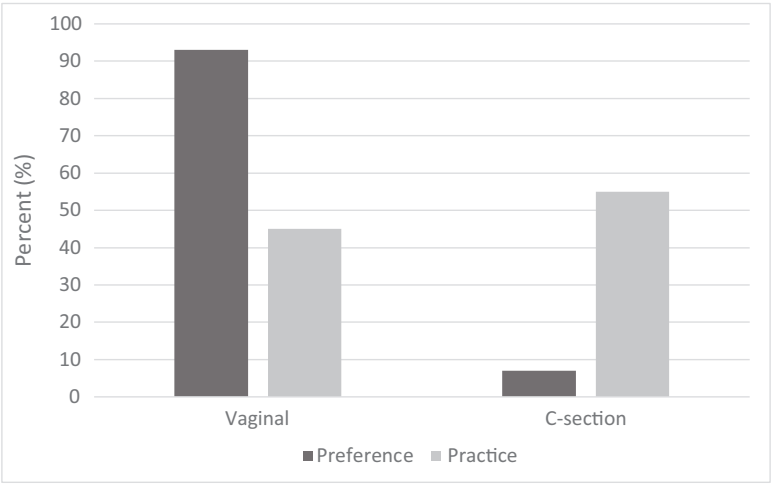

Fig. 13.2 Cesarean delivery preference and practice in the BPS and the HMHB study (combined, $n = 73$)

for all their subsequent deliveries, which is consistent with data from maternal report.

In interviews, women from our studies generally reported a strong desire to deliver vaginally. In the BPS, only 11% of women reported wanting to deliver by C-section, but ultimately 55% did have C-sections. In the HMHB Study, only one woman (3%) reported wanting to deliver by C-section. Figure 13.2 shows the percentage of women from both the BPS and the HMHB Study ($n = 73$) who preferred and ultimately had a natural or Cesarean delivery. Those who reported wanting to deliver by C-section (7%) most often cited their fear of the pain of vaginal delivery as the reason. Those who reported not wanting to deliver by C-section (93%) often reported that worrying about having to deliver by C-section was one of the most central concerns about their pregnancies. Most women in these studies who ultimately delivered by C-section but had not previously had one reported that they attempted to deliver vaginally, but eventually the birthing team suggested C-section due to a determination of prolonged labor or that the infant was too big, the woman's hips were too narrow, or the infant was positioned badly for vaginal delivery.

13.2.3 The Postpartum

13.2.3.1 Breastfeeding

Breastfeeding has numerous benefits for infant health, including the conference of passive immunity (Labbok et al. 2004), a high nutrient density (Ballard and Morrow 2013), and protection against the development of overweight and obesity later in

life (Thompson 2012). Breastfeeding is common in Ecuador with nearly universal initiation and an average duration that continues to nearly the first year of life (Freire et al. 2014; Thompson et al. 2019). Similarly, nearly all Galápagos infants receive at least some breastmilk. In the BPS, 99% of infants received breastmilk after birth, and 58.5% of infants were still being breastfed at the time of the interview, which occurred at a median of 7 months after birth (range 1–28 months). Among those still breastfeeding, over 2/3 of infants were aged 10 months or older. At the same time, the use of formula as a supplement was also common. Twenty-five of 40 (62.5%) infants received formula, with most starting within the first 3 months of life. In the HMHB Study, 27% of babies had been formula-fed at least once by 1 month postpartum and 36% of babies had been formula-fed at least once 2 months postpartum. All women reported continuing to breastfeed at 2 months postpartum. These results complement other research in Ecuador, which found that 86% of women initiate breastfeeding within 1 day of the infant's birth, but only 53% of infants are exclusively breastfed in the first month of life, and 35% are exclusively breastfed at 4–5 months of age (Freire et al. 2014).

In our studies, most women reported that breastfeeding was going well, with few or no problems. Those who did voice concerns about breastfeeding often reported difficulties producing enough milk, pain during breastfeeding, or embarrassment at the need to expose themselves to breastfeed in public. Women frequently explained that their insufficient milk production was a result of their high stress or medications they were taking (particularly from C-section). Insufficient milk production was also the primary reason that women reported incorporating formula into their feeding practices. Other reasons for formula feeding included the mother's absence for work or school, the ease and efficiency of formula feeding, and doctor's recommendation due to maternal diabetes.

13.2.3.2 Complementary Feeding and Diet Quality

Along with breastfeeding practices, the timing of introduction and the quality of complementary foods are important for infant growth and development. The WHO recommends that infants receive solid foods beginning at 6 months of age. Earlier introduction has been associated with greater risk of growth faltering, gastrointestinal infections, and, in higher-income settings, child obesity (Przyrembel 2012). Conversely, later introduction has been linked to increased risk of both growth fathering and child obesity (Stewart et al. 2013; Tahir et al. 2018). While the introduction of milks other than breastmilk is relatively common in Ecuador with 71% of infants introduced before 6 months of age, fewer than 25% of infants receive solid foods before 6 months of age (Freire et al. 2015). Similarly, in the BPS, among the 25 infants receiving solids at the time of the interview, the median age of introduction was 6 months with fewer than 10% of infants receiving solid foods at 4 months or younger and only 10% receiving solids after 6 months of age.

Fruits were the most commonly consumed solid food, as all but one infant had been introduced to fruits, and 75% of infants had eaten fruits in the past day

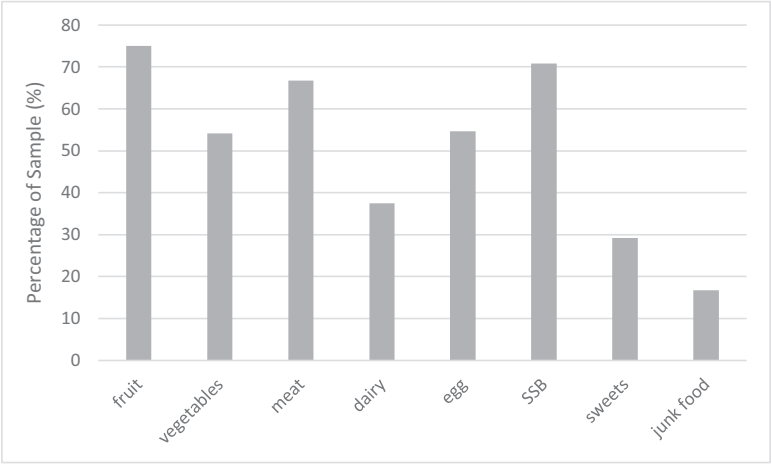

Fig. 13.3 Food consumed by infants in the past 24 h in the BPS (n = 25)

(Fig. 13.3). Commonly consumed fruits included apples, pears, mandarins, bananas/plantains, and papaya. Vegetable consumption was less common; 83% of infants had ever received vegetables and just over half (54%) of infants ate vegetables in the past 24 h. The most commonly consumed vegetables were broccoli and carrots. In terms of diet diversity, 75% of infants consumed foods from more than one "healthy" food group (fruits, vegetables, meats, eggs, and dairy) in the past 24 h. However, infants also consumed foods that would be considered empty calorie or highly processed foods. Forty-two percent of infants consumed one or more sweets or junk foods (cookies, sweets, ice creams, fried foods, or junk foods) in the past 24 h. Similarly, the consumption of sugar-sweetened beverages was high. Seventy percent of infants received juice, coladas, yogurt drinks, or soda in the past 24 h. While the sugar level of these drinks varies, juices and coladas (oatmeal drinks) are often prepared at home with added sugars, and yogurt tends to be consumed as a sweetened, flavored drink. Our work complements previous work, which also found that children in the Galápagos consume a high prevalence of processed foods (Pera et al. 2019) and that young children are overweight and obese (Page et al. 2013, 2019).

While mothers were not directly asked about why or how they chose their infants' foods, many did talk about the quality of food and water on the islands being a concern. Many mothers stated that the water is not drinkable or is "dirty." While most mothers reported providing their infants with water in the past 24 h, concerns about water quality may lead to the consumption of sodas and other bottled drinks. Similarly, mothers talked about limitations in the quality and quantity of food available on the islands. Common sentiments were that fresh food is expensive and arrives spoiled from the mainland and that the supply and/or variety of fresh foods is limited. Only one mother explicitly linked these concerns to her infant feeding decisions – that the dirty water was a concern, so her infant received breastmilk – however, these factors likely shape mothers' feeding decisions. The high prevalence

of fruit consumption, for example, may be linked to the availability of local products (bananas, mandarins, and papaya), while the lower prevalence of vegetable consumption might be due to the reliance on vegetables from the mainland (i.e., broccoli). Similarly, concerns about the quality of fresh foods may lead mothers to provide prepared beverages or packaged foods.

13.2.3.3 Infant Growth

As is common in many middle-income settings (Tzioumis et al. 2016), both undernutrition and overnutrition are problems for children in Ecuador. Nationally, 25% of children under the age of 5 are stunted, 6.4% are underweight, and 10–26% are iron deficient (Freire et al. 2015). Alongside this prevalent undernutrition, 8.5% of children under 5 are overweight or obese. In the Galápagos, the prevalence of undernutrition is lower, while the prevalence of overweight is higher. Data from ENSANUT-ECU collected in Galapagos documented that just over 10% of children under 5 were stunted, 16% had anemia, and 12.7% were overweight or obese, while the rest were in normal range (Freire et al. 2014). However, the prevalence of both undernutrition and overweight were considerably higher among children under 2 years participating in our BPS. In our study, 15% of infants and young children under 2 years were stunted, while 70% of infants would be considered overweight (>2 weight-for-length z-scores). No participating infants were considered underweight (low weight-for-age z-score) or wasted (low weight-for-height z-score); however, iron deficiency remained a common micronutrient deficiency with 57.5% of infants having hemoglobin less than 11 gm/100 mL. In the HMHB Study, none of the participants were stunted or underweight, but 8% of infants were overweight and 8% of infants were wasted at 2 months of age.

Mothers on San Cristóbal generally thought that their infants were healthy and that the social and physical environment of Galapagos promoted healthy growth in children. Mothers noted that there was little illness on the islands and that children were able to play outside, breathe good air, and eat good foods. They noted that the close social ties of community members created an environment which fostered child growth and development. At the same, mothers in the BPS described water quality and the food environment in contrasting ways. Some mothers thought there was plenty of food available, leading to good growth in children, though others commented on the lack of fresh foods and the presence of processed and junk foods. Similarly, some mothers thought the water quality had improved and that children's rashes and other illness had declined, while the majority noted poor water quality as a continued problem preventing optimal growth in children. These differing perspectives may reflect differences in mothers' expectations based on their own experiences. Mothers coming from cities on the mainland, for example, may find the air quality better in the Galapagos, but may find the water quality to be poorer. Those born on the island (34% in the BPS) may be more sensitive to changes in the food environment, with shifts from local products to processed foods, but may also find the social environment to be closer due to stronger familial and social ties.

13.2.3.4 Perinatal Mood and Anxiety Disorders

Maternal mental health is also important for infant development. While maternal postpartum depression has been the focus of much of this research, other conditions, including anxiety, may persist under the umbrella of perinatal mood and anxiety disorders (PMADs). PMADs may affect caregiver-infant relationships, and thus growth and development trajectories for infants (Hoffman et al. 2017). In particular, maternal PMADs have been associated with poorer infant cognitive development (Smith-Nielsen et al. 2016), higher risk for nonverbal communication delays (Kawai et al. 2017), and dysregulated infant sleep and feeding (Sharkey et al. 2016).

On San Cristóbal, at 1 month postpartum, 29% of women scored as depressed (using the Patient Health Questionnaire) and 26% of women scored as highly stressed (using the Perceived Stress Scale) in the HMHB Study. Both of these constitute a marked increase from scores for depression and high stress during pregnancy, which were 26% and 0%, respectively. Previous research on the islands found that 25% of women in the study scored above 15 on the CES-D depression scale, indicating a significant level of psychological distress (Page et al. 2013). Despite the high prevalence of stress and depression in new mothers, many women report not having the mental healthcare and support they require on San Cristóbal island, which only has one psychologist.

13.3 Conclusions and Recommendations

Development during the perinatal period shapes long-term health through a variety of pathways. On the Galápagos, prenatal environments, including maternal nutrition and obesity, maternal infection, and antibiotic use, all may confer risk for aberrant developmental trajectories in offspring. Concerns about the quality and affordability of food on the islands alongside insufficient education on nutrition and healthy eating have been linked with a high prevalence of maternal obesity and overweight, which, during pregnancy, puts infants at risk for obesity later in life (Mottola et al. 2010). Previous research on the Galápagos has also found a high prevalence of obesity both in mothers (Page et al. 2013; Waldrop et al. 2016) and in children (Waldrop et al. 2016). Further, the high prevalence of genitourinary infections on the Galápagos puts infants whose mothers have infections during pregnancy at greater risk of morbidity (Cohen et al. 2019), developmental delays (McDermott et al. 2000), and neurological disorders such as childhood epilepsy (Mann and McDermott 2011; McDermott et al. 2010). Previous research over the past 10 years on Galápagos has also found high rates of genitourinary infections (Houck et al. 2020; Page et al. 2013; Walsh et al. 2010), suggesting that this has been a significant and persistent health concern for residents. Last, the overprescription and overuse of antibiotics during pregnancy on the Galápagos may cause increased risk for miscarriage (Fan et al. 2019), congenital malformations (Muanda et al. 2017b), and asthma later in life (Stensballe et al. 2013).

At parturition, high rates of preterm birth and C-section are of greatest concern on the Galápagos. The prevalence of preterm birth on the Galápagos is higher than that on the mainland, and preterm birth has been associated with metabolic disease and mental health disorders later in life (Luu et al. 2017). Further, the C-section prevalence on the islands is much higher than Ecuador's national rate and the rate recommended by the WHO, and infants born by C-section are at greater risk for metabolic and gastrointestinal disease (Bager et al. 2012; Chavarro et al. 2020; Horta et al. 2013), allergy, and asthma (Kristensen and Henriksen 2016) later in life. The Galápagos Islands' high C-section rate has been examined through both demographic (Jahnke et al. 2019) and developmental lenses, and previous research on the islands demonstrates that infants and children born by C-section have significantly different gut microbiota taxa abundance (Thompson et al. 2019), suggesting that C-section may have long-term effects on development through gut bacteria.

After birth, infant feeding and infant growth can shape long-term development. While our research shows that most Galapaganean women breastfeed for the first few months of life, many women supplement with formula from a young age, and formula does not confer the same nutritional and immunological benefits as breastmilk. Interestingly, throughout Ecuador, exclusive breastfeeding during the first 6 months is associated with a lower maternal education and lower economic status (Freire et al. 2014), suggesting that perhaps work outside the home, nutrition curriculums, or social status may influence infant feeding. Further, our research found that after complementary foods are introduced, many young children consume many sugar-sweetened beverages, sweets, and other calorie-dense, highly processed foods. This is reflected in infant growth, as many participants under 2 years old were considered to be overweight. Last, maternal stress and depression may pose challenges for mothers in their own lives and in their parenting, thus shaping the development of their infants.

In order to address these challenges and improve infant health and developmental trajectories for children on the Galápagos Islands, we must consider how a coordinated intervention, changes in policy, or local practices could most efficiently address these complex and related issues. Promising next steps would work to both prevent the foundation of aberrant development trajectories within the first 1000 days of life and mitigate those that were not preventable through sustained health efforts during childhood and into adulthood. Before and during pregnancy, efforts to improve maternal diet and overweight may help to establish more healthy weight trajectories for offspring. Efforts to improve water sanitation may decrease the incidence of urinary infections, thus decreasing risks from infection as well as risks from the overuse of antibiotics during pregnancy. The sustained overuse of C-sections in the Galápagos demonstrates the need to develop better best practices protocols for C-section indication on the islands, with careful consideration of infrastructural limitations. While challenges in staffing and equipment may necessitate a higher C-section rate than that of the mainland, decreasing the C-section rate will be essential to improving foundational development for children on the islands. After birth, programs that promote the benefits of breastfeeding as well as

information on healthy complementary foods for children under the age of 2 will be necessary to improve infant diet and thus infant growth.

Together, these efforts not only may improve acute concerns for infant morbidity and mortality but also alleviate long-term and chronic health conditions later in life. Since many developmental paths are conferred intergenerationally from mother to child, investing in maternal health now has intergenerational benefits for her children and thus her children's children, establishing a healthier foundation for generations to come.

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Chapter 14
Galapagos Islands, a Captive Territory with Unique Characteristics for Sexually Transmitted Diseases and Human Immunodeficiency Virus Infection

Ana María Gómez-Jaramillo, Juan Ochoa, Isabel Hernandez, and Enrique Terán

Abstract In Ecuador, the Ministry of Public Health reported, in 2017, 49,541 cases (from 1984 to 2016) of HIV/AIDS. Sexual transmitted infections (STDs) as a gateway for HIV infection are detected as clinical syndromes due to the lack of access to confirmatory tests in most of the primary healthcare units in Ecuador. In 2011, 355,511 cases were estimated, of which 96% were women. Regarding HIV infection, the insular region contributes 0.11% of cases nationwide, and the incidence of STD is unknown. Even with these numbers, many specific factors from the Galapagos population, such as social stigma, make HIV and STD underestimated in the islands.

There is a social and biological distinctiveness in the archipelago, especially if we consider that the islands receive 245,000 tourists from all over the world every year, which also includes sexual tourism of lesbian, gay, bisexual, transgender, and intersex (LGTBI) community. The research shows that 32.8% of women and 23.5% of men had more than five sexual partners and practice of sexual contact with strangers is present in almost 40% of men. The Galapagos has a vulnerable population in

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terms of sexual health, which could contribute with the spread of the transmission of the HIV.

Keywords Sexually transmitted infections · HIV/AIDS · Health services · Tourism · Antiretroviral treatment

14.1 Introduction

Sexual transmitted diseases (STDs) are a major public health problem globally, for both wealthy and limited-resource countries (Taylor et al. 2017). From a treatment standpoint, the ideal scenario would be a patient with classical and unequivocal symptoms like vaginal or urethral discharge, genital ulcers, non-ulcerative genital lesions, and pelvic pain. For these patients, most of the time, there is no need for microbiologic confirmation, and usually empiric treatment is successful (Valsangkar et al. 2014). However, many patients with STDs are asymptomatic, and, not only do asymptomatic infections lead to a higher risk of transmission, but asymptomatic infections could lead to clinical complications such as infertility or cancer. Thus, screening based on clinical signs or targeted for patients in specific high-risk groups is an important intervention strategy (Valsangkar et al. 2014).

Implementation of screening programs in sexually active people has some intrinsic difficulties like false-positive results or even positive results in people with no apparent risks (Wi et al. 2019). Other barriers to STD screening programs include technical limitations to molecular testing for STDs which requires trained personnel and equipment and usually is expensive.

There is also a social stigma associated with STD screening programs. A great number of cases of STDs were undetected for decades because many Ecuadorians are reluctant to address sexual health issues in an open way and because of the biologic and social characteristics of these diseases (Breilh 2008).

According to the Ecuadorian Ministry of Health, STDs have increased in the last years, going from the fifth most common cause of morbidity in the county to the third most common (Ministerio de Salud Pública del Ecuador et al. 2017). The rise in the frequency of STIs was due mainly to a better understanding of these diseases and also to improvements in the reporting of notifiable diseases (Callister et al. 2010).

Ecuador has slowly emerged from a deep political, economic, and social crisis that has had a heavy impact on all sectors, with vulnerable groups being the hardest hit, especially in the earlier years. The main political and social problems that have a direct impact on the health of the population include high levels of poverty, limited access to health services, and low health insurance coverage (López-Cevallos and Chi 2010). STD epidemics have an enormous health and economic impact in the developing countries, including Ecuador (Owusu-Edusei et al. 2013).

According to the Population and Housing Census in 2015, there were 25,244 permanent residents registered in the province of Galapagos. The most populous

island is Santa Cruz with 15,701 people (62.2%); San Cristóbal, the capital of the province of Galapagos, is the second most populous island with 7199 people. Isabela Island, the biggest in geographic size, has 2344 inhabitants and is the canton with the highest population growth (INEC 2015).

The Ecuadorian public health system through the primary and general hospital health units provides tests for the detection of STDs; however, the clinical laboratory in the Galapagos Islands provides only basic tests, among them is Venereal Disease Research Laboratory (VDRL), Gram and Wright staining, and rapid fourth-generation HIV tests. Then, this level of care highlights the importance of the clinical approach of diagnosing STDs based on the signs and symptoms of these infections (MSP 2016).

14.2 Sexual Transmitted Diseases in the Galapagos Archipelago

A study published in 2015 to analyze the knowledge, attitudes, and practices about STDs on the islands of San Cristobal, Santa Cruz, and Isabela showed that 76% of respondents have an active sex life and the number of sexually active participants increased with age. The first reported sexual encounter occurred on average at 16.5 ± 2.9 years of age. Of all individuals surveyed, 13.7% of respondents report ever having paid sexual services, while 23.6% of the individuals acknowledge having sex with strangers; this value increases to 39.5% when looking at only the male respondents. This study also reports that 6.3% of participants reported having a STI in the past (Rodríguez et al. 2015).

According to the Ecuadorian Ministry of Health (MoH) in the Galapagos Archipelago during 2016, there were 115 cases of STDs, with the most frequently reported infection being genital warts, both in males and females (Table 14.1). However, in general, STDs were 2.8 times more frequent in women, and geographical distribution revealed that majority of the cases were on Santa Cruz Island (67%), followed by San Cristobal (21.7%) and Isabela Island (11.3%).

Table 14.1 Most frequently reported sexually transmitted diseases in the Galapagos Archipelago during 2016

	Men	Women	%
Genital warts	12	34	40
Trichomonas	6	21	23
STD (no specific)	3	18	18
Genital herpes	4	8	10
Chlamydia	2	3	4
Gonococcus	1	1	2
Inguinal granuloma	1	0	1
Syphilis	1	0	1

By 2017, according to the Ministry of Health (MoH) data across the whole Archipelago, the prevalence of STDs was 27% and primarily found in women (94%). Most affected age group was those between 20 and 49 years of age (88%), followed by 8% in those 15 and 19 years of age and 3% in those 50 and 64 years of age. Regarding diagnosis, most of the patients had vaginal trichomoniasis and genital warts (Table 14.2), and cases were distributed across San Cristobal (57.8%), Santa Cruz (35.6%) and Isabela (6.6%) Islands. The number of STDs reported during 2017 was 60% lower than previous years, something that cannot be to the health conditions improvement, but should rather be attributed to a lack of proper diagnosis or registry, particularly in Santa Cruz Island.

In 2018, there was a 67% increase in STD cases (Table 14.3), suggesting that some of the problems with diagnosis or registry, particularly in Santa Cruz Island, had been resolved. STDs mainly affected women (94%), and the most affected age group was individuals 20 to 49 years of age (80%). A noted increase was seen in women from 50 to 64 years old (14%) when compared to those from 15 to 19 years old (6%). In 2018, trichomoniasis was the common diagnosis (Table 14.3), and cases were distributed in Santa Cruz (76.1%) and San Cristobal (23.9%) with no cases reported from Isabela islands.

In 2019 there were 105 cases of STDs reported with a geographical distribution aligned with the population density, i.e., 59% from Santa Cruz, 21% from San Cristobal, and 20% from Isabela islands. The most affected group was between 20 and 49 years old (90%), and although most of the cases were still in women (70.5%),

Table 14.2 Most frequently reported sexually transmitted diseases in the Galapagos Archipelago during 2017

	Men	Women	%
Genital warts	7	8	33
Trichomonas	0	15	33
Syphilis	2	0	4
Genital herpes	3	6	20
Chlamydia	0	2	4
STD (no specific)	1	1	4

Table 14.3 Most frequently reported sexually transmitted diseases in the Galapagos Archipelago during 2018

	Men	Women	%
Trichomonas	1	27	42
Genital herpes	5	11	24
Genital warts	4	8	18
Syphilis	3	3	9
Chlamydia	2	0	3
Gonococcus	1	0	1
Chancroid lesions	1	0	1
STD (no specific)	1	0	1

Table 14.4 Most frequently reported sexually transmitted diseases in the Galapagos Archipelago during 2019

	Men	Women	%
Genital warts	10	26	34
Trichomonas	9	20	28
Genital herpes	4	15	18
Syphilis	7	6	12
Chlamydia	0	4	4
Inguinal granuloma	0	3	3
Chancroid lesions	1	0	1

this number was much lower than the previous year due to the growing diagnosis of genital warts in men (Table 14.4).

In addition, during our study timeframe, as a strategy to prevent complication in newborns, all pregnant women were routinely screened for STDs. A total of 314 tests for syphilis were performed, yielding 4 positive results that were confirmed with fluorescent treponemal antibody-absorption (FTA-ABS) test at the national reference laboratory in Guayaquil City on the mainland of Ecuador. These cases were immediately addressed with specific treatment. Additionally, 248 toxoplasmosis, rubella cytomegalovirus, herpes simplex, and HIV (TORCH) tests were yielding 3 cases positive for cytomegalovirus.

Unfortunately, the diagnosis of STDs in the Ecuadorian health system in general, not only in Galapagos, is primarily based on clinical symptomology due to the laboratory limitations. Because of this bias, most of the STDs reported occurred in women (96.6%), while only 1.7% of STDs were reported by males. In the mainland of Ecuador, STDs are more prevalent in the Coast region, followed by the province of Pichincha (where the capital Quito is located). Vaginitis, of any etiology (72%), was the most frequently reported STD (MSP 2016).

In 2017, with the support of the Global Fund and technical assistance of WHO/PAHO and UNAIDS, an alliance between Kimirina Corporation (an NGO focused on addressing HIV) and the Ministry of Health with its National Strategy for HIV/AIDS Control and the National Institute of Research in Public Health conducted a study of men who have sex with men (MSM) that revealed that infection with herpes virus was higher in Guayaquil (96.7%) than in Quito (88.7%). This trend was similar in syphilis cases (28.9% vs. 1.5%, respectively). Hepatitis B was only found in Quito (2.6%), while Hepatitis C was not found in either city (Acosta et al. 2017).

Moreover, in a retrospective study of STDs in mainland Ecuador from 2001 and 2008, cases of gonococcal infection were the most prevalent infections (42.6%), followed by genital warts, syphilis (22.3%), and herpes virus (17.2%) (González Andrade and Aguinaga Romero 2015).

These data from the mainland are not consistent with those found in the Galapagos Archipelago, particularly in infections of gonococcus and trichomoniasis. Interestingly, both are closely related to laboratory facilities and proper data capture and registry and reveal that STDs are a growing health problem in the islands,

particularly due to risky sexual practices like multiple sex partners, unprotected sexual contact, and other factors like tourism, travel, and cultural beliefs.

14.3 Human Immunodeficiency Virus (HIV) Infection in Ecuador Mainland

In 2007, the Ecuadorian MoH developed a strategic plan for the national response against HIV/AIDS that considered HIV/AIDS as a public health problem that needs a multisectoral response to ensure universal access, prevention, and comprehensive care, as well as equity and equal opportunities for people living with HIV/AIDS (Ministerio de Salud Pública del Ecuador 2007).

In the same year, the Ecuadorian MoH reported 49,541 cumulative cases of HIV/AIDS from 1984 to 2016, of those 37,748 cases were HIV and 11,793 cases were AIDS. Geographical distribution of the cases revealed that the vast majority were in the Coast region (74.1%), followed by the Sierra region (20.3%), the Amazon region (1.93%), and the Galapagos Archipelago (0.11%). HIV/AIDS cases are concentrated (90.2%) in the people between 15 and 49 years of age, with 71.5% of those cases found in young people (20–39 years). The incidence of HIV infection in Ecuador is 2.58 times more frequent in men than women, and by 2016 the overall incidence rate was 0.35 cases per 1000 inhabitants (11,515 new cases/yearly) (Ministerio de Salud Pública del Ecuador 2019); this is slightly below the Latin America reported rate of 0.4 [0.3–0.6] (UNAIDS 2019).

The National Strategy and Program for HIV/AIDS oversees the response to the epidemic across all sectors. Its main function is to carry out health actions derived from the Joint United Nations Programme on HIV and AIDS (UNAIDS) recommendations for the control of concentrated epidemics, a characteristic that defines the HIV epidemic in Ecuador (ONUSIDA 2018). The National HIV Strategy has focused priority attention on vulnerable groups in Ecuador, with ten priority sectors: children living with HIV and orphans of people affected by HIV; MSM and other men with bisexual behavior; transsexual people; sex workers and their clients; people in jail; police and military; children exposed to perinatal transmission; and workers exposed or with greater vulnerability to HIV infection.

In addition to public health policies, the National Program for HIV/AIDS maintains multisectoral coordination with the Care Units for **P**eople **L**iving **W**ith **H**IV/**A**IDS (PLWHA) to ensure direct attention and action to this population. There are currently 37 care units, which are located either in general or specialized hospitals distributed in 20 provinces of Ecuador (Ministerio de Salud Pública del Ecuador 2017).

According to the SIDA Global Aids Monitoring (GAM) report in 2017 that compiles several investigations done at national level, the majority of cases of HIV/AIDS are concentrated in key and vulnerable populations, i.e., MSM, sex workers, people in jail, transsexual people, and pregnant women (Ministerio de Salud Pública

del Ecuador 2017). The prevalence in each of these populations was 11% in MSM ("Fundacion Equidad" et al. 2012), 3.2% in sex workers (USFQ et al. 2007), 1.11% in persons deprived of liberty (Esparza Rendón et al. 2013), 31.9% in transsexual women (Acosta et al. 2017), and 0.16% in pregnant women (Ministerio de Salud Pública del Ecuador 2017).

Sexually transmitted diseases (STDs) are often viewed as a risk factor for HIV infection and are detected as clinical syndromes due to the lack of access to confirmatory tests in most of the primary healthcare units in Ecuador. In 2011, 355,511 cases of HIV were estimated, with 96% estimated in women (MSP 2016). In other studies, the reported prevalence of HIV/syphilis co-infection in the MSM population was 4.8%, while the prevalence of syphilis alone was 6.5%. Syphilis was also commonly associated with self-reported STD infection. These data suggest that specific behaviors among MSM are associated with increased risk of contracting an STD (including HIV/syphilis co-infections) in some regions of Ecuador (Hernandez et al. 2017).

14.4 Situation of HIV on the Galapagos Archipelago

As previously mentioned, the Galapagos Archipelago represents 0.11% of HIV cases nationwide (Ministerio de Salud Pública del Ecuador 2018). Although this percentage appears to be low, it represents 59 PLWHA and 2.34 cases per 1000 inhabitants, a very high prevalence that has not been addressed properly.

The Galapagos Archipelago has a vulnerable population in terms of sexual health that could contribute to the transmission of HIV. There are some social and biological unique factors in the archipelago, including that the islands receive 245,000 tourists yearly from all over the world, which also consists sexual tourism from the LGBT (lesbian, gay, bisexual, and transgender) community, one of the groups vulnerable for HIV infection. Multiple (more than five) sexual partners, considered a risky sexual behavior, was reported in 32.8% of women and 23.5% of men, and frequent sexual contact with strangers was reported in almost 40% of men who also reported multiple partners (Rodríguez et al. 2015).

It was not until 2016 that the Ecuadorian MoH decided to open a specific unit to care for people living with the HIV/AIDS (PLWHA) in the Galapagos Archipelago. The unit is physically located at the "Hospital Republica del Ecuador" on Santa Cruz Island. This initiative was established by assigning of a specialist in Internal Medicine as part of the MoH graduate scholarship program. This unit added value to the healthcare provided at the San Cristobal Island.

The HIV Clinic was built based on the needs of PLWHA in Galapagos for more frequent and personalized medical care, including medication dispatch and adequate follow-up. Until this clinic was open, there was no clear estimation of the status of HIV infection, and there were no mechanisms in place for the referral of new cases from primary healthcare centers to specialized care settings. The HIV Clinic was also envisioned to provide medical care based on scientific evidence for

prevention, diagnosis, treatment, and monitoring of patients with HIV/AIDS locally in the Galapagos, with the main purpose to reduce the incidence of infectious and non-infectious comorbidities and mortality, drug-related adverse effects, toxicity, and resistance to antiretroviral drugs in the Archipelago. The HIV Clinic is managed by the clinical physician and relies on the services provided by the "Hospital Republica del Ecuador" in Santa Cruz, which, being a basic hospital, has limited resources. Despite this limitation, the services available in the facility, i.e., gynecology, pediatrics and psychology, allow the HIV Clinic to cover the clinical needs of vulnerable groups.

There are several barriers to appropriate care of patients in the Galapagos Islands. Among the barriers for an optimal activity of the HIV Clinic on Santa Cruz Island is the necessity to ship samples to facilities on the mainland, most frequently in Guayaquil, to evaluate the viral load and CD4 cell count. These samples require an adequate cold chain to retain specimen integrity. It is also necessary to create critical mechanisms for the referral of patients from healthcare facilities in the archipelago to mainland Ecuador for those cases that required attention in specialized centers.

It is important to note that PLWHA in Floreana and Isabela islands must be referred to the HIV clinic in Santa Cruz for daily medical treatment, while PLWHA in San Cristobal usually are managed locally. Just for reference, the journey among islands takes approximately 2–3 h, depending on sea conditions; and in the first half of the year, from January to June, sea conditions are more stable than in the second half, from July to December, when the waves are stronger (Dirección del Parque Nacional Galápagos 2020). For this reason, the work of the HIV unit has expanded to include the collection of clinical and demographic data of all the islands, which show the real status of HIV infection in the Galapagos and allow for calculation of disease burden on each of the inhabited islands.

In 2019 at the HIV Clinics in Santa Cruz, there were registered a total of 58 PLWHA, of those, 25 had HIV (43.1%) and the other 33 were patients with AIDS (56.9%). The majority were men (67.3%), and ethnicity and employment data are shown in Table 14.5.

One of the most frequently reported risk factors for HIV and AIDS is unprotected sex. Sexual behavior reported by the vast majority of HIV subjects in the Galapagos Islands had sex only with males (64%, n = 16) rather than with only females (36%, n = 9), while most subjects with AIDS reported sex with only women (46.9%, n = 15), followed by sex with only men (40.6%, n = 13) or both genders (12.5%, n = 4). The cohort included only one case of genital ulcers in HIV (4.2%) and AIDS (3.0%) patients. According to the US Centers for Disease Control and Prevention (CDC), 58.8% of the AIDS cases were in the category A2 (Asymptomatic HIV infection without a history of symptoms or AIDS-defining conditions and 200–400CD4+ T-cell/μL) to C2 (HIV infection with AIDS-defining opportunistic infections and 200–400 CD4+ T-cell/μL), while 79.2% of the HIV subjects were in category A1 (Asymptomatic HIV infection without a history of symptoms or AIDS-defining conditions and >500 CD4+ T-cell/μL; Table 14.6).

Opportunistic infections were the first clinical manifestations that alerted clinicians to the occurrence of the AIDS and occurred on average 7 to 10 years after

Table 14.5 Sociodemographic characteristics of PLWHA in the Galapagos Archipelago

		Cases			
		HIV		AIDS	
		Number	%	Number	%
Ethnicity	Mestizo	23	92.0	29	87.9
	Indigenous	0	0.0	2	6.1
	Black	2	8.0	2	6.1
Employment	Farmer	3	12.0	3	9.1
	Work at home	3	12.0	5	15.2
	Tourism	1	4.0	4	12.1
	Gastronomy	3	12.0	3	9.1
	Business	2	8.0	2	6.1
	Public employee	1	4.0	1	3.0
	Private employee	6	24	3	9.1
	Student	1	4.0	2	6.1
	Others	1	4.0	4	12.1
	Unemployed	4	16.0	6	18.2

Table 14.6 CDC categories of PLWHA in the Galapagos Archipelago

	HIV		AIDS	
	Number	%	Number	%
A1	19	79.2	7	20.6
A2	1	4.2	6	17.6
A3	1	4.2	2	5.9
B1	0	0.0	1	2.9
B2	0	0.0	2	5.9
B3	0	0.0	3	8.8
C1	1	4.2	6	17.6
C2	2	8.3	7	20.6

infection with HIV (Alcabes et al. 1993; Bacchetti and Moss 1989). Until effective antiretroviral therapy (ART) was developed, patients generally survived only 1–2 years after the initial manifestation of AIDS (Bacchetti et al. 1988). HIV-related opportunistic infections have been defined as infections that are more frequent or more severe because of HIV-mediated immunosuppression (Kaplan et al. 1995).

Most of the subjects with HIV (86.4%, $n = 19$) and around half of the patients with AIDS (46.7%, $n = 14$) were free of opportunistic infections. In those patients with AIDS who were diagnosed with an opportunistic infection, the most frequently diagnosed were oropharyngeal candidiasis and tuberculosis (16.7% each, Table 14.7).

The PLWHA of the Galapagos Archipelago receive monthly free-of-charge antiretroviral treatment (ARVT) at the HIV Clinics either in Santa Cruz or San Cristobal hospitals. Drugs are provided by the MoH, and 93.1% of patients receive treatment

Table 14.7 Opportunistic infections of PLWHA in the Galapagos Archipelago

	HIV		AIDS	
	Number	%	Number	%
Candidiasis	0	0.0	5	16.7
Tuberculosis (pulmonary and extrapulmonary)	1	4.5	5	16.7
Pneumocystis jirovecii pneumonia	2	9.1	1	3.3
CNS* toxoplasmosis	0	0.0	2	6.7
Histoplasmosis	0	0.0	2	6.7
Others	0	0.0	1	3.3

[a]*CNS* central nervous system

Table 14.8 Reasons for antiretroviral therapy failure in PLWHA in the Galapagos Archipelago

	HIV		AIDS	
	Number	%	Number	%
Lack of adherence	1	20.0	0	0.0
Due to social factors	2	40.0	0	0.0
Due to drug consumption	1	20.0	2	100.0
Major depression	1	20.0	0	0.0

continuously, while the remaining 6.9% are lost to follow-up cases due to treatment abandonment.

Regarding treatment, 84.4% of PLWHA are prescribed tenofovir/emtricitabine/efavirenz-based treatment plan, considered the first-line therapy recommended by the Ecuadorian Clinical Practice Guidelines until 2018. In 2019, the guidelines were updated to align with the WHO recommendations, and dolutegravir was included in the treatment plan, but this drug is not yet available for use in this population (Ministerio de Salud Pública del Ecuador 2019).

It is important to mention that in Ecuador, at least in the public health system, resistance to antiretrovirals is not tested. Clinicians determine whether to use one ART or another in an empirical manner, usually based on viral load values and the clinical status of each patient. In the PLWHA in the Galapagos Islands, 4.2% of HIV-positive patients and 20% of AIDS patients have presented virologic failure and have had a switch ART regimen.

ART failure in the Galapagos is mainly due to lack of adherence to ARVT, attributed to social factors (Table 14.8). Currently, 79% of HIV-positive patients and 85% of AIDS patients have viral loads that are undetectable; the remaining percentages correspond to the cases of ART failure previously mentioned.

Before 2016, PLWHA in Galapagos received sporadic medical attention, depending on their ability to travel to mainland Ecuador. Since the HIV Clinic was created in 2016, PLWHA are not required to travel to mainland Ecuador for control and follow-up, which has resulted in a positive impact on viral load values (Fig. 14.1, panel A) as well as the values of CD4 cell counts (Fig. 14.1, panel B).

Other relevant clinical data obtained at the HIV Clinics in Galapagos revealed that 36% of HIV patients and 24% of AIDS patients had at least one comorbidity

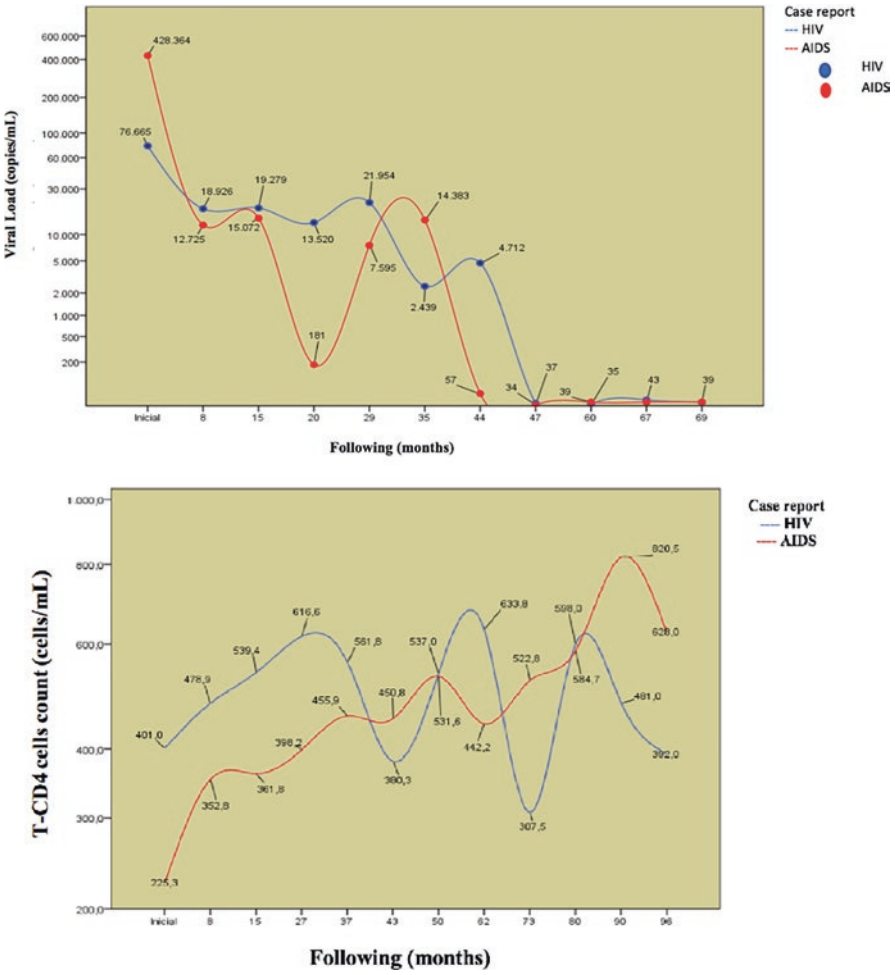

Fig. 14.1 Viral load and CD4 cell count of PLWHA in the Galapagos Islands during follow-up at the HIV Clinic since 2016

associated with their infection. Hypertension was most frequent among patients with HIV (12%), while alcoholism was most prevalent in those with AIDS (Table 14.9).

In comparison to the mainland Ecuador, PLWHA in the Galapagos Archipelago who report mainly homosexual intercourse exhibit similar demographic characteristics. Of the PLWHA in the Galapagos Archipelago, there are more cases of AIDS than HIV, but of course, that might be due to the previously mentioned difficulties to get attention that were characteristics in the past, which allowed the disease to progress from HIV to AIDS. It is likely that the increased ability to obtain medical attention for HIV/AIDS-related complications also contributed to the low number of non-infectious comorbidities in the Galapagos Archipelago when compared to

Table 14.9 Comorbidities of PLWHA in the Galapagos Islands

	Cases			
	HIV		AIDS	
	Number	%	Number	%
Alcoholism	0	0.0	4	11.8
Drugs abuse	2	8.0	1	2.9
Visual disability	1	4.0	2	5.9
Cognitive disability	2	8.0	0	0.0
Diabetes mellitus	2	8.0	1	2.9
Hypertension	3	12.0	0	0.0

PLWHA on the continent (Hernández et al. 2019), although the absence of depression is particularly intriguing, as it has been directly related to the ART (Checa et al. 2020). It is important to mention that the diagnosis of HIV itself, in the insular region, is happening late, something that is in alignment with the fact that most of the new cases are members of the same family and contacts of PLWHA on AIDS phase.

There is still a lack of information about the real risk for HIV transmission amongst residents of the Galapagos Archipelago, because some islands have published reports that tourists have higher levels of sexual activity/intercourse (Colón Burgos et al. 2019; Padilla et al. 2010) and lower use of risk reduction behaviors such as condoms (Bellis et al. 2000). Nevertheless, there is no doubt that creation of an HIV Clinic located on the island of Santa Cruz has significantly impacted the awareness of unique needs of PLWHA, increased the follow-up and treatment adherence, and improved disease outcomes. However, more population and qualitative studies are needed to determine other factors related to the quality of life of these patients and the behavior of the infection in this population.

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Chapter 15
"*You Have to Eat What There Is*": Barriers to Effective Self-Management of Type 2 Diabetes in San Cristóbal, Galápagos

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Abstract Epidemiological shifts due to changes in global food production and dietary habits have led to an increased burden of chronic diseases, including type 2 diabetes, a condition that requires lifelong self-management. Factors at the individual, relational, and structural levels affect self-management. We conducted a formative, qualitative study to obtain a contextualized understanding of the lived experience of type 2 diabetes in San Cristóbal, in particular barriers to self-management and the role of the health system. We conducted semi-structured interviews with adults with type 2 diabetes ($n = 20$) and healthcare providers ($n = 9$). We identified four categories of healthcare engagement: (1) patients who were not actively receiving diabetes care ($n = 1$); (2) patients receiving care exclusively in Galapagos ($n = 11$); (3) patients receiving care exclusively on the mainland of Ecuador ($n = 4$); and (4) patients receiving care in both the mainland and Galapagos ($n = 4$). Using this framing to analyze patient narratives, we found three main barriers to diabetes self-management: (1) access to healthy, affordable foods; (2) medication worry and scarcity; and (3) access to quality care on the island. Patients

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described an interplay between their individual-level perceptions, knowledge and resources, and geographic isolation and limited access to specialized, quality care at the structural level. Patients' ability to adhere to self-management recommendations requires improved patient-provider communication and structural reform of food distribution systems and healthcare services.

Keywords Type 2 diabetes · Qualitative research · Food access · Medication availability · Health services

15.1 Introduction

Epidemiological shifts, in part due to changes in global food production and dietary habits, have led to an increased burden of non-communicable, chronic diseases, including type 2 diabetes (Arredondo 2014; Frenk and Gómez-Dantés 2018; Wingert et al. 2015). Type 2 diabetes requires lifelong self-management, including maintaining a healthy diet and regular exercise, attending to routine healthcare, and adhering to medication (Wingert et al. 2015; World Health Organization 2016). Factors at individual, relational, and structural levels influence self-management (American Diabetes Association 2018). Individual-level behavior, such as healthy eating and exercise, can improve diabetes-related outcomes (American Diabetes Association 2017; Colberg et al. 2010), but psychosocial factors such as lack of knowledge, depression, fear, and poor coping skills can lead to complications (Ahola and Groop 2013). At the relational level, social support from family and friends can facilitate self-management (Fisher et al. 2015; Koetsenruijter et al. 2016), while lack of support has been associated with poor health outcomes. Structural barriers, such as poverty and limited access to care and medication, can also limit effective self-management (Hänninen et al. 2001; Nam et al. 2011).

Following global trends, obesity, hypertension, and type 2 diabetes are now leading causes of death and premature mortality in Ecuador (Pan American Health Organization 2017). Adult diabetes prevalence in Ecuador is estimated to be 7.3% (World Health Organization 2016), yet recent estimates among older adults are as high as 12.9% for women and 19.7% for men (Orces and Lorenzo 2018). In a screening study in Santa Cruz, 11% of adults were identified as having undiagnosed type 2 diabetes (Tufton and Chowdhury 2015). Another study on the island of Isabela reported 8% prevalence of hyperglycemia among participants under 50 years old and 24% for those above 50 (Alexander et al. 2017). These two studies suggest there may be a disproportionate burden in Galapagos compared to the mainland.

The capitol seat of the Galapagos province, San Cristóbal, has approximately 7200 residents, geographically spread across a rural highlands region known as "El Progreso" and an urban center, the capitol city of Galapagos, "Puerto Baquerizo Moreno" (Galapagos Conservancy, Inc. 2020; Instituto Nacional de Estadadística y Censos 2010, 2015). San Cristóbal is the eastern-most island of Galapagos, and

tourism is the main source of income for residents as the island has one of the two airports with flights from the mainland and is the starting point for many tourism cruise ships.

Ecuador has a three-tiered public healthcare system. Within this system, anyone can join the Instituto Ecuatoriano de Seguridad Social (IESS) system by purchasing insurance for a cost of 17% of their taxable income, a cost some employers may cover or share with their employee (IESS 2019a; Lucio et al. 2011). Rural farmers and artisanal fishermen may also receive health insurance for themselves and their families through rural IESS associations. These rural associations require participation of at least 25 families to affiliate, but then provide publicly funded, cost-shared health insurance specifically for farmers and artisanal fisherman which costs 0.35% of their taxed income (IESS 2019b). IESS also offers low cost insurance plans for non-working women and children through separate programs. Those working in the military or police are automatically enrolled in their respective insurance systems. Beyond IESS, those who are not formally employed have the option to participate in the public system run by the Ministry of Health (MoH) or seek care at private hospitals and clinics. Despite having a universal healthcare system, in 2014 there were almost three times as many private healthcare facilities than public facilities in Ecuador (Yunga 2014).

Healthcare in Ecuador is decentralized and managed at the provincial level. In Galapagos, there is an MoH hospital, an IESS hospital, and two rural clinics in San Cristóbal and an MoH hospital on the most populated island of Santa Cruz. Collectively these facilities serve all 25,000 residents of Galapagos and an estimated 150,000 tourists visiting the islands annually (Instituto Nacional de Estadadística y Censos 2010). Positioned within this unique geographical location and healthcare system, we aimed to obtain a contextualized understanding of the lived experience of type 2 diabetes in San Cristóbal. To this end, we addressed two research questions: (1) what are the main barriers to diabetes self-management in San Cristóbal? and (2) what is the role of the health system in diabetes self-management?

15.2 Methods

***Study design and sample*:** We conducted a formative study including semi-structured in-depth interviews with adults ($n = 20$) diagnosed with type 2 diabetes. We purposively sampled both men and women given past research highlighting the gendered experience of type 2 diabetes management (Wallace et al. 2019). We included both rural and urban participants from both MOH and IESS facilities to gain a more contextualized understanding of healthcare. We also interviewed healthcare providers ($n = 9$) including physicians, nutritionists, nurses, community health promoters, and health directors from a variety of facilities in both rural and urban areas to gain a range of experiences.

Field research team: Our research team consisted of three field researchers and a primary investigator. The field research team included one female Ecuadorian university student resident of Galapagos (PLM); one male, native Spanish-speaking researcher from UNC (HG); and one female bilingual graduate student also from UNC (HD).

***Recruitment*:** We began patient recruitment using a list of all patients with type 2 diabetes in San Cristobal. To reach potential participants, we accompanied public health workers on routine home visits to invite patients to participate in the study. At the IESS hospital, the hospital administrator contacted patients directly and invited them to participate in the study. We also purposively sampled participants who received diabetes care exclusively through the private sector outside of Galápagos, including both mainland Ecuador and the United States, through snowball referrals.

Data collection: We obtained oral informed consent and conducted all interviews in a private space. Participants were offered a locally acceptable incentive (10 dollars) to compensate their time. Interviews were completed in Spanish, by one of three interviewers, using a semi-structured interview guide. Interview guides were reviewed with the Ecuadorian research assistant prior to data collection and edited iteratively throughout data collection based on the team's observations. The patient interview guide included guiding questions and probes asking patients to detail their experiences with diabetes diagnosis and long-term management and care. The patient guide also asked about barriers and facilitators of self-management. Provider guides focused on experiences providing care and were adapted to the providers' specific role.

Analysis*:* Analysis began during field work, starting with writing detailed field notes immediately after every interview. We audio recorded all interviews and produced verbatim transcripts in Spanish. We analyzed all data in Spanish, beginning with patient interviews by reading each individual transcript and creating analytic summaries of key themes and reflections from field notes. Guided by the interview guide and the themes identified in the analytic summaries, we created a codebook which was applied systematically to all transcripts using ATLAS.ti8. After coding, we used patient quotations to create thematic narrative timelines detailing lived experience from diagnosis to long-term care for each patient to contextualize the key themes identified in coding. Finally, we integrated quotations from providers to reflect their perspectives on these themes and others introduced by providers.

15.3 Results

We first describe characteristics of the patient and provider samples. We then present the three main barriers to diabetes self-management including (1) access to healthy, affordable foods, (2) medication worry and scarcity, and (3) access to quality care on the island. As reflected in Table 15.1, 7 participants lived in the rural area

Table 15.1 Demographic information about patient participants (pseudonyms used to preserve anonymity)

Pseudonym	Age	Years living with T2D	Care location	Region of residence
Sebastian	60	20	No care	Urban
Maria	86	30	Galapagos	Urban
Salome	65	13	Galapagos	Urban
Isabella	74	24	Galapagos	Urban
Angel	72	3	Galapagos	Urban
Sofia	53	16	Mainland	Urban
David	43	1	Galapagos (rural)	Rural
Diego	40	5	Galapagos	Urban
Valeria	68	19	Mixed	Urban
Luis	70	1	Mixed	Urban
Jose	75	7	Galapagos (rural)	Rural
Clemencia	53	5	Galapagos (rural)	Rural
Emiliana	71	20	Mainland	Rural
Mariana	34	5	Mainland	Urban/rural border
Samuel	81	8	Mixed	Rural
Matias	35	3	Galapagos	Urban
Joel	66	7	Galapagos	Rural
Gabriela	78	20	Mixed	Rural
Alejandro	38	4	Mainland	Urban
Pablo	25	4	Galapagos	Urban

Mainland refers to care exclusively in the mainland. Galapagos refers to use exclusively of any of the care services on San Cristóbal. Mixed refers to individuals who use Galapagos services for day-to-day care or to pick up medicine, but go to the mainland a few times per year for more advanced tests. One individual reported not participating in the healthcare system at all

of El Progreso, and 13 lived in the urban center of Puerto Baquerizo Moreno. Of those living in El Progreso, three were female and four were male. Four participants were couples where both partners had type 2 diabetes. Among the 13 participants living in Puerto, 7 were male and 6 were female. Participants' ages ranged from 25 to 86; most were over 60 years old. Time living with type 2 diabetes ranged from 1 year to 30 years. All participants had lived in San Cristóbal for more than 15 years. We identified four categories of healthcare engagement in participants' narratives: (1) those who were not actively receiving any diabetes care at the time of the interview ($n = 1$); (2) those who receive care exclusively in Galapagos (IESS Hospital, MoH Hospital, or rural clinic) ($n = 11$); (3) those who receive care exclusively in the mainland ($n = 4$); and (4) those who received some combination of Galápagos and mainland care ($n = 4$).

Healthcare providers included physicians, nurses, community health workers, and nutritionists. Eight had at least 1 year of experience in their role, and seven were from Galapagos. Due to the small number of healthcare providers in Galapagos, in order to maintain anonymity, we have not included more demographic information.

15.4 Patient Demographic Information Including Both Care Location and Region of Residence

15.4.1 Accessing Fruits and Vegetables

Patients' discussions of long-term management of type 2 diabetes focused on systemic barriers tied to the isolated and resource-constrained nature of the island. Access to fruits and vegetables was one of the most salient barriers to diabetes self-management. Since most produce on Galapagos is imported from the mainland, participants complained that products arrived "spoiled" or often did not arrive at all. Valeria said, "there was a time when there were no vegetables at all [on the island]." Participants felt that limited access to fresh produce limited their ability to manage a healthy diet, as explained by Sofia:

> Here we can't keep a diet like on the mainland where you can find everything. Here, we are limited. And a lot of times a Diabetic person cannot keep a diet because there are no vegetables sometimes. You have to eat what there is.

In addition to access, participants also discussed lack of variety and high cost of fruits and vegetables as barriers. Mariana said:

> Eating healthy is expensive. If I want to eat or want my children to eat fruit, it costs more. It's easier to buy candy more cheaply, or there's a lot more (candy) than fruit.

Patients emphasized the high cost of produce in Galapagos compared to mainland Ecuador. Sebastian stated, "I should eat salads preferably every day but if you want to use broccoli to make a salad…for one head of broccoli…it costs $2.50 or sometimes up to $3.00, which in the mainland, you could get for one dollar." Healthcare providers similarly cited the cost of fruits and vegetables as a barrier. One stated:

> Here the cost of healthy foods is a little higher…and many families are large in number, so what is a head of household going to prefer, if they have three, four children…carbohydrates which are much cheaper or a healthy meal that is varied? Obviously, they are going to prefer carbohydrates.

This provider recognized that patients were faced with the decision to eat healthy or save money, which in turn limited consumption of fruits and vegetables.

Notably, locally grown fruits and vegetables from the farms in the rural highlands were not identified as accessible to participants. One patient suggested that products from the highlands were priced as high as produce imported from the mainland, which he believed made them unaffordable to local residents. Similarly, a provider mentioned that the lack of preservatives and chemicals used on produce in the highlands caused them to rot quickly, which affected distribution and access. Additionally, Sebastian explained that a greenhouse was built in the highlands to produce fresh products, but all the products were sold to the cruise ships for a higher price, suggesting local produce was prioritized for the tourism industry over Galapagos residents' health. There was shared sentiment among patients that the government prioritized tourism over the needs of the local population, as Emiliana

stated, "the authorities (here)…they don't take interest in humans… people… they take care of animals, they take care of those things more than the people." The prioritization of selling high-quality fresh foods to cruise ships for tourism was also mentioned during general discussions with fishermen and farmers in Galapagos.

15.4.2 Lack of Medication

A second barrier to effective management of diabetes was lack of medication and worry related to lack of medication. All but one patient reported taking some medication for type 2 diabetes, which they received at no cost each month through the public system on the island or purchased at a private pharmacy either on the island or the mainland. Despite this, a few patients, like Clemencia, still expressed worry about lacking medication:

> If there's no medicine we're screwed. More than anything, they should have medicine. It's the most fundamental thing that they have to have here. One time I had to just take pills (instead of insulin and pills) because there weren't any for like… a month

Clemencia's experience lacking insulin left her worried and unable to properly manage her condition. Even patients who had not experienced extended medicine shortages identified medication as their biggest worry due to the implications for their health as well as the added cost of procuring alternatives.

While some providers recognized that at times the public healthcare system did not have diabetes medications, they did not highlight medication precarity as a major barrier to self-management given the guaranteed access to all patients within the public system. One provider stated, "even though sometimes we lack medication and resources, we at least try to do everything possible so that they (patients) feel good." Providers emphasized the importance of lifestyle change with diet and physical activity for self-management over medication, but in contrast few patients discussed the importance of physical activity and rather focused on using medications and diet to manage their diabetes.

15.4.3 Access to Care

As described earlier, we identified four categories of healthcare use patients in our sample: (1) individuals who received no diabetes care ($n = 1$); (2) individuals who received all routine diabetes care on the island ($n = 11$); (3) individuals who received all routine and specialty care on the mainland ($n = 4$); and (4) individuals who received routine diabetes care on the island but visited the mainland for specialty care ($n = 4$). Seventeen participants mentioned having some experience visiting the mainland for diabetes care at some point in their lives, whether to confirm diagnosis or for a specialty test. The two main drivers of seeking care outside of Galapagos

were lack of trust in the public healthcare system and lack of specialty care on the island. Participants described a shared discourse of the health system being corrupt, underfunded, and negligent. For example, Valeria stated:

> In the hospital a lot of things have happened, (people) have died… so many things that have happened… kids that have died and I don't know why… negligence or what happens (in the hospital)… because the hospital there is a big hospital I think it should not be like that, but…and here in the IESS hospital it's the same, they give us medicine and attend to us but this also is lacking.

Based on her perception that services were "lacking," Valeria sought out specialty care on the mainland. Sebastian, the one participant who was not actively receiving diabetes care, said he had experienced "physician malpractice." He sought care at the hospital after stepping on a rusty nail, but there were no tetanus shots available. After a few days, he finally received the shot, had the wound bandaged, and was sent home. A few weeks later, Sebastian was unable to walk and returned to the hospital where, after an attempted minor surgery, he developed gangrene in his foot. He was referred to the mainland, but his transfer was delayed due to lack of air transport. He was eventually flown to the mainland, where his lower leg was amputated. Because of this traumatic experience, Sebastian reported not engaging in the healthcare system in Galapagos, outside of emergency needs.

Physicians were aware of patient mistrust towards the healthcare system. One physician stated:

> We are burdened with the perceptions of the services that were provided before (in the hospital), it's not the best, it wasn't the best; There weren't specialists, they made many errors. But in what hospital do they not commit errors? Now, our population is stuck with this…with this idea, so they come here (to the hospital) and for us it is really difficult, because here (in this hospital) we treat cases that would be appropriate for a higher tier (of care), so the population maybe, they don't realize this… or the good things that have happened (in the present) don't make up for the past.

This narrative reflects how some providers felt that the public hospital was under scrutiny by the community due to diffusion of information about extreme cases spreading within the small island community.

Despite mistrust of the Galapagos healthcare system, all patients who received care in San Cristóbal spoke highly of their relationship with their physician and the quality of care they received. For example, when asked about her relationship with her physicians on the island, Mariana stated:

> Yes (my relationship is) good, and even though I don't always go they are aware of me or sometimes even they see me in the street and say to me 'how are you, do you feel good? Why haven't you been to get your pills?' Yes (the care is) very good.

Both patients and providers mentioned "personalized" care in Galapagos, with providers giving patients their cell phone numbers to call or text with questions or in case of emergency. One physician created a WhatsApp messaging group with patients to send information, and another created a Facebook page to share information with patients. Physicians from the MoH hospital and clinic also participated in a Neighborhood Doctors program, which sent physicians, nurses, and community

health promoters to the homes of patients that were unable to visit the clinic, in both the highland and in the urban areas. But despite feeling they had personalized healthcare, patients still lacked trust in the overall healthcare system.

In addition to the lack of trust, lack of specialty care was another barrier to type 2 diabetes management. Of the eight participants who reported visiting the mainland for diabetes care (either exclusively or in addition to getting care in San Cristobal) at the time of interview, more than half stated the reason was the lack of specialists on the island. Most visited a private specialist outside of the public healthcare system, but a few received referrals for specialized care in the public system. Some patients said they had previously received care from an endocrinologist in San Cristóbal, but this provider no longer lived in San Cristóbal at the time of this study.

Providers also discussed that specialists relevant to diabetes care, including podiatrists, opticians, and endocrinologists, were only available on the mainland. From the provider perspective, while seeing a specialist could be necessary, receiving these services on mainland Ecuador could also disrupt the flow of regular care:

> So apart from this, they (patients) go to the mainland and they come back and it was worth it, but you lose the connection, because they leave (the Galapagos) every three months or once every year…but you can go to the mainland where there's an excellent endocrinologist, an excellent diabetes specialist, but as long as there is no follow-up on site, you lose the point, because diabetes has to be controlled…with exams every three months.

Multiple physicians mentioned the lack of communication with patients between appointments on the mainland and routine care visits in San Cristóbal as a challenge for providing effective care:

> so a patient just comes and says to you 'they prescribed me this'. 'yes and what else did they tell you?'…what else did they find? But you don't know, you don't know all of the other part, like if they need rehabilitation, if they need psychotherapy, if they need a consult with nutrition, with the psychiatrist, whoever.

On a systems level, this lack of communication also occurred between doctors in San Cristóbal, as one physician stated there is no common digital health system to facilitate information exchange between the different hospitals and clinics on the island.

Providers also discussed the cost of trips to the mainland was a barrier for their patient's ability to receive specialized care. For example, one physician, when asked why they do not immediately send patients to the mainland, stated, "because they (patients) don't have the money to leave." Patients reported trips to the mainland for care ranging from $500 to 2000 dollars, which is equivalent to up to double the average Galapagos monthly salary. Pablo described the financial burden of visits to the mainland:

> I see that the people that have (money) can spend it, but the majority don't have money, don't have it for this (a trip to the mainland), so they push through. They take the pills from here, and don't leave for treatment.

Pablo's narrative highlights how, despite having universal healthcare, people with more resources had better access to specialized diabetes-related care.

It is also important to note that there were quality concerns regarding care received in the mainland. When referencing care in the mainland, patients utilizing the public system spoke of long wait times and expressed generally negative experiences of care. Luis, who used public care through IESS on the mainland and in San Cristobal stated, "they (other patients) prefer to go to Guayaquil… but in Guayaquil it is worse! I'll tell you- if I ask for an appointment now (in June) they will give me one for December." Some providers echoed these negative patient experiences. One stated that when referring patients to the mainland through IESS, many patients returned unhappy with their care, having spent lots of money, taken days off work, and received less personalized care than they were accustomed to in Galápagos. Participants who received specialty care in the private sector in the mainland were often more satisfied; however, these services were inaccessible to most patients due to high travel and care costs.

15.5 Discussion

In our qualitative assessment of type 2 diabetes experiences in San Cristóbal, we found that patients face multiple barriers to self-management. Limited access to fresh fruits and vegetables and quality healthcare affected patients' self-management and well-being and providers' ability to care for patients. These barriers reflect an interplay between perceptions, knowledge, and resources at the individual level and geographic isolation and healthcare access and quality at the structural level, which can deter an individual's ability to manage diabetes (American Diabetes Association 2018; Dao et al. 2019).

Access to healthy food was one of the most salient barriers to diabetes self-management identified by participants. Across both rural and urban settings in Latin America, the cost of healthy foods has been identified as a significant barrier (Fort et al. 2013). Among patients at low-income clinics in Mexico City, healthy eating was perceived to be expensive (Whittemore et al. 2019), and rural patients in the Dominican Republic struggled to balance dietary recommendations with overall food security (Gonzalez Rodriguez et al. 2018). Many participants in San Cristóbal similarly discussed the cost of fruits and vegetables as a barrier, yet the perception of expense was often compared to the mainland of Ecuador, where such foods were perceived to be more affordable. Despite the fact that individuals living in Galápagos receive a governmental supplement to account for the increased cost of goods on the island, participants in this study still feel they are unable to afford healthy foods. Beyond cost, participants also mentioned the limited availability of fruits and vegetables due to their reliance on importation from the mainland and highlighted inequalities in food distribution driven by prioritization of the tourist industry. This lack of access to fresh produce can add chronic stress to the lives of those living with type 2 diabetes (Gonzalez Rodriguez et al. 2018), which can inhibit self-management, leading to poorer diabetes-related health outcomes (Ahola and Groop 2013). Future research is needed to examine perceived versus actual access to fresh

fruits and vegetables and to identify opportunities to improve access to locally produced food in San Cristóbal.

Lack of trust in the healthcare system was another salient barrier identified by participants. This lack of trust was driven, in part, by the perception that governmental entities are more concerned with preserving wildlife and tourism over the human population needs. The mistrust drove concerns about medication, both in terms of access and quality. While some patients had experienced medication shortages, others described concerns about the quality of medications provided by the public healthcare system and felt stress related to the possibility of medication shortages. Concerns about medication shortages have been described as a source of stress among adults living with type 2 diabetes in medically under-served settings in Latin America, including in Ecuador, despite having universal healthcare (Gonzalez Rodriguez et al. 2018; Eckhardt et al. 2019). Given the central role of medication in type 2 diabetes self-management, stable access to quality medication is essential for both physical and emotional well-being (Nam et al. 2011; Ong et al. 2018). Notably, healthcare providers did not emphasize medication shortages as a barrier as much as patients and perhaps could provide more assurance to patients in their clinical encounters, which has been shown to reduce patient worry and improve health outcomes (Leibowitz et al. 2018; Pincus et al. 2013).

Another consequence of the lack of trust was that patients sought care outside of the public system and traveled to mainland Ecuador and elsewhere to get care. We identified four distinct diabetes care patterns with nearly half of the sample receiving at least some of their care outside of Galápagos. While officially structured as a universal system, patients living with diabetes in Galápagos reflected inequitable access to services, as is the case across Latin America (Frenk and Gómez-Dantés 2018). While both the MoH and IESS healthcare systems are underfunded, the fact that IESS is a mostly contribution-based system while the MoH is fully publically funded creates a perception of tiered public healthcare in Ecuador (Atun et al. 2015; Cotlear et al. 2015; Frenk and Gómez-Dantés 2018). Beyond the public systems, an additional tier of private care further divides those who have the resources to leave San Cristóbal and generally pay for private healthcare and those who do not. Such inequities and substantial patient expenditures have also been identified in the realm of emergency care in the Ecuadorian system (Eckhardt et al. 2019). While the massive national healthcare reform program in Ecuador in 2008 led to improved facilities, lingering mistrust continues to serve as a barrier.

Participants' real and perceived needs for specialty care also drove them to mainland Ecuador, and beyond, and providers noted that this negatively impacted their continuity of care in San Cristóbal due to information gaps and limited communication. Continuity of care and coordinated communication are essential for effective diabetes management (Hänninen et al. 2001; Lustman et al. 2016; Ross 2013). Having a strong relationship with providers characterized by trust and social support has also been shown to increase patients' ability to self-manage (Ahola and Groop 2013; Fisher et al. 2015; Koetsenruijter et al. 2016). Despite expressing overall lack of trust into the system, most of our participants who received care in Galápagos praised the quality of care and support they received from their

individual providers, which enhanced their ability to manage their diabetes. Continuing to strengthen local care connections and improving communication across sectors could contribute to improved diabetes self-management and outcomes.

This study had several limitations. Not all participants were directly asked where they received the majority of their care, and some information had to be inferred from the context of the interview. Some patients were interviewed while a provider or healthcare worker was nearby which may have affected participants' ability to speak freely about their experience within the healthcare system and health regimen compliance.

15.6 Conclusions

A context of limited access to essential components of diabetes self-management together with lack of trust in the healthcare system has the potential to negatively impact self-management behaviors and increase type 2 diabetes-related stress. Inequity in access could ultimately lead to health disparities in type 2 diabetes outcomes, despite having universal healthcare in Ecuador. Our findings suggest the need for improved patient-provider communication together with structural reform of food distribution systems and healthcare services to improve patients' ability to adhere to self-management recommendations. There is a need to improve understanding of medical mistrust in the Galápagos context in order to address both perceived and actual gaps in the current system. Future research should also probe further on patterns of physical activity and its role in diabetes self-management.

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Chapter 16
Health-Seeking Behavior and Perceptions of Care: A Qualitative Study Investigating the Underutilization of Public Health Care on the Galápagos Islands

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Abstract Since Ecuador's vast restructuring of its health-care system in 2008, Ecuador has invested in new and improved public health-care infrastructure. As a result, the government was able to construct new hospital on San Cristóbal Island, the provincial capital of the Galápagos Islands, with hopes that it would significantly reduce residents' need to travel to the mainland for care. Nonetheless, despite the hospital's enhanced technologies and free care, it has been underutilized since its opening, hindering the provision of care to island residents and perpetuating the burden on residents to seek costly care on the mainland. Interviews and one focus group were conducted to examine the perceptions of care and the factors deterring residents from utilizing hospital services. Andersen's behavioral model was used as a conceptual model and informed the decision to interview a variety of participants,

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including community members, hospital personnel, and local stakeholders. Audio recordings from the interviews and the focus group were transcribed and iteratively coded for themes using qualitative analysis software. Residents' perceptions that the hospital lacks specialists and is inefficient have deterred residents from seeking care there. Participants also voiced concerns with provider trust and overall health-care quality. These estimations have motivated residents to travel to the mainland for care, posing both financial and health burdens on individuals. Improvements to the hospital, including instituting a rotation of specialists, improving telemedicine, and establishing a simulation lab, as well as community outreach programs to engage residents and solicit feedback would improve health-care utilization. Further, residents' positive experiences at the new hospital could improve its reputation on the small island where word of community experience and approval spreads quickly.

Keywords Health-care utilization · Health-seeking behavior · Public health · Ecuador · Andersen's behavioral model

16.1 Introduction

Over the past few decades, Ecuador has vastly restructured its health-care system, transitioning from primarily private to increasingly public care (De Paepe et al. 2012; Rasch and Bywater 2014). Since 2000, the Ministry of Public Health has increased spending on care, and, in 2008, Ecuador passed legislation making health care a right and guaranteeing free care to citizens (Aldulaimi and Mora 2017; De Paepe et al. 2012). Nevertheless, Ecuador's medical system remains fragmented into a combination of public and private facilities, which are made up of both nonprofit and for-profit institutions (López-Cevallos and Chi 2010b). Public health care accounts for the majority of health facilities in Ecuador (PAHO 2008), and in many rural settings, public care is the only option (López-Cevallos and Chi 2010a). Further, since 2008, Ecuador has invited over 1000 Cuban doctors to work within the country (Anderson 2015). Recent studies have found that even since the major shifts in health-care provision, Ecuadorians have reported being disappointed in public health care (De Paepe et al. 2012; Rasch and Bywater 2014), which may influence its utilization and ability to improve health among Ecuadorians (Adane et al. 2017).

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The Galápagos Islands, the archipelago province of Ecuador, are best known for their endemic flora and fauna, but less is known about their human inhabitants. The creation of the Galápagos National Park in 1959 and the designation of the Galápagos as a World Heritage Site in 1978 incited population growth as tourism and migration spurred economic and urban development (Walsh and Mena 2016). Despite efforts to control tourism and restrict immigration, the population of 30,000 continues to grow, putting pressure on the resources available for residents (Walsh and Mena 2016). Agricultural restrictions limit food production and increase dependence on imported food from the mainland (Page et al. 2013; Pera et al. 2019), and freshwater scarcity restricts potable water availability (Walsh et al. 2010). Existing research suggests that residents suffer from a dual burden of infectious and non-communicable diseases likely stemming from contaminated water (Gerhard et al. 2017) and diets consisting of largely highly processed and energy-dense foods (Page et al. 2013). Further, compared to those on mainland Ecuador, residents of the Galápagos experience worse child growth and micronutrient status and a prevalence of overweight and obesity that is the highest of Ecuador's provinces (Freire et al. 2015). Last, the infant mortality rate of the islands (2.1%) is higher than the national average (1.4%) (Freire et al. 2015).

In 2014, with new funding, the Ministry of Health built a new hospital in Puerto Baquerizo Moreno, the capital city of the province located on San Cristóbal Island. This free and public hospital, Hospital Oskar Jandl, replaced a smaller, older hospital on the island and is now the only hospital on San Cristóbal. The new building contains both the hospital itself and the Centro de Salud, which is independent and provides other resources to the community. The only other health-care center on the island is a small public health clinic in the highlands of El Progreso which provides basic care, and the only other hospital on the Galápagos is another public hospital located on the island of Santa Cruz. Despite the Hospital Oskar Jandl's improved facilities and technologies, in 2016, health-care providers at the hospital and hospital administrators identified underutilization of health-care services for both primary care and hospital services as a major concern.

Here were present the results of a qualitative research study that was designed by a team of interdisciplinary researchers in collaboration with the administration at Hospital Oskar Jandl in order to understand the reasons for limited community utilization of the hospital. We use Andersen's behavioral model as a conceptual framework to consider how the relationships among individuals, the community, and health-care providers shape health-seeking behavior (Andersen 1995). This model places the determinants of health care making into three categories: (1) predisposing factors, which include an individual's demographics, social structure, and personal beliefs about the benefits of health services; (2) enabling factors, which include personal and community resources that encourage the utilization of health services; and (3) need factors, which correspond to the actual and perceived need for health services. Previous research that has applied this model found that comprehensive assessments of constraints and opportunities in promoting health-care utilization and health-seeking behavior must combine household, community, and health facility information pertaining to predisposing, enabling, and need factors in

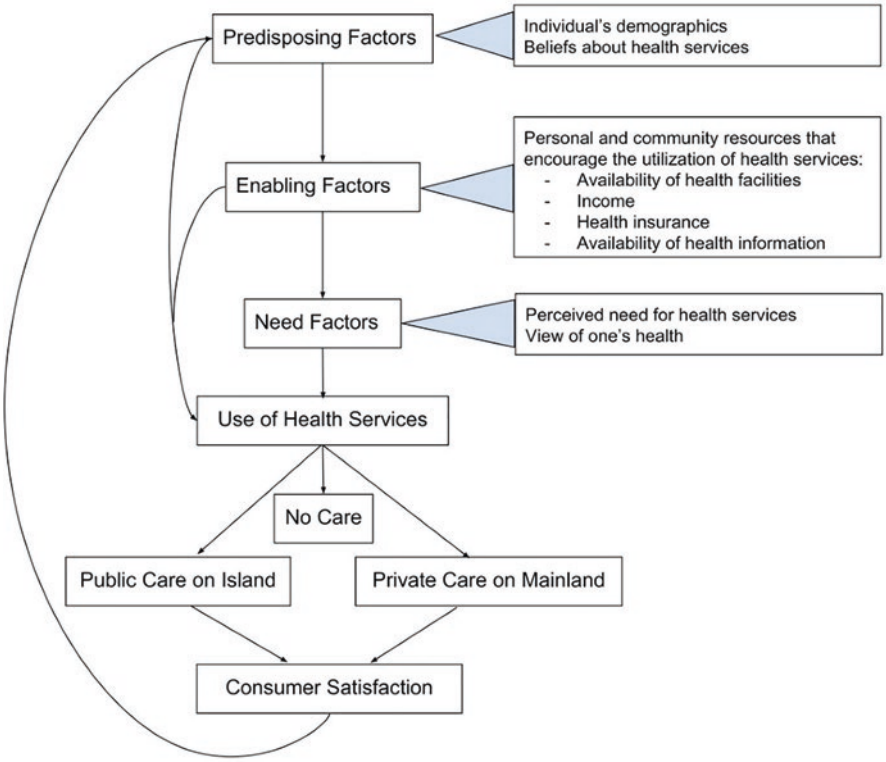

Fig. 16.1 Andersen's model on the health care in the Galápagos

order to maximize health (Adane et al. 2017). Our conceptual model (Fig. 16.1) is based on Andersen's (1995) emerging behavioral model, in which health-care experience and patient satisfaction influence one's perception of health services.

16.2 Methods

16.2.1 Ethical Considerations

The study was approved by the Institutional Review Board at the University of North Carolina at Chapel Hill, and permission was received from collaborators, including the director of Hospital Oskar Jandl and colleagues at *Universidad San Francisco de Quito* (USFQ) in Ecuador. All participants provided written informed consent to participate in the study.

16.2.2 Setting and Population

The study site was the island of San Cristóbal, Galápagos, which had a population of approximately 9300 people (Instituto Nacional de Estatísticas y Censos (INEC) 2011). Our data were collected from the capital city, Puerto Baquerizo Moreno, where the majority of island residents live, and from the surrounding rural and highland areas of El Progreso.

16.2.3 Study Design and Participants

Driven by Andersen's model, which analyzes how relationships among individuals, the community, and health-care providers shape behavior, data were obtained from a total of 81 participants, including community members, community leaders, and hospital staff. Table 16.1 summarizes the breakdown of participants. Sixteen nurses, physicians, and administrative staff were interviewed at Hospital Oskar Jandl. Of the 16 participants, 8 were registered nurses, 6 were physicians, and 2 were administrative staff. Five key informants from the community, including leaders in health, government, and education, were selected using purposeful sampling (Bernard 2011).

Members of the community were divided into two groups. The first group, 40 women with children under the age of 2 years (hereafter: "mothers"), was selected through convenience and network sampling (Bernard 2011). Mothers were selected because, as they are often primary caregivers, they have the most knowledge about their children's health and the most contact with the health-care system. Having mothers as participants was essential to understanding how the hospital treats infant and child health. The second group of community members (hereafter: "community members") was composed of 20 participants of all ages and genders and was selected using convenience sampling. Community members were selected to glimpse other health problems on the island that mothers may not be exposed to.

Table 16.1 Participants by role

Participant type	Description
Hospital staff (16)	Registered nurses (8) Physicians (6) Administrators (2)
Key informants (5)	Community leaders in health, government, and education
Mothers (40)	A variety of socioeconomic statuses, ethnicities, education levels, and neighborhoods, including Puerto Baquerizo Moreno and the highlands
Community members (20)	A variety of socioeconomic statuses, ethnicities, education levels, and neighborhoods, including Puerto Baquerizo Moreno and the highlands

Participants were selected to reflect a variety of socioeconomic statuses, ethnicities, education levels, and neighborhoods, including Puerto Baquerizo Moreno and the highlands. Ethnically, participants were predominantly *mestizo*, though some participants identified as black, white, or indigenous Ecuadorian.

A qualitative study design was selected for its ability to exemplify and give value to a variety of perspectives, including those that go against predominant cultural or political leanings. Due to the small, non-representative sample that often results in qualitative work, quantification of our results in this study may not accurately represent the community.

16.2.4 Data Collection

Our team conducted semi-structured interviews and a focus group in order to garner information on perceptions of health concerns, the quality of health services, and health-seeking behavior on the island.

Hospital staff, key informants, and mothers were interviewed using semi-structured interviews that lasted from 10 to 40 min. The semi-structured interview format leaves questions open-ended, so participants can provide their own insights into health problems and solutions as well as share their feelings, attitudes, and opinions without the bounds of a structured interview (Bernard 2011). All interview guides focused on themes of health, existing care on the island, and health-seeking behavior. All interviews were conducted in Spanish and audio-recorded. Hospital personnel and key informants were interviewed at their places of work and were asked about their perceptions of the health problems on the island and about how they think community members view the new hospital. Mothers were interviewed in their homes or at their places of work, according to their preference, and were asked about key health problems, child growth, their perceptions and experiences of the new hospital, and their strategies for seeking care.

The focus group was composed of 20 community members. We used a focus group for this population because the interaction of the group, such as agreement and disagreement among participants, produces data that is not accessible in a one-on-one interview (Tolley et al. 2016). Participants all lived on San Cristóbal Island, and all utilized the same health-care infrastructure. The focus group was held at a local university and lasted for 1 h. The group was prompted with questions about health-seeking behaviors, experiences at the new hospital, and perceptions of care.

16.2.5 Data Analysis

All interviews and focus groups were transcribed verbatim using a standardized transcription protocol (“QualitativeBeyond the qualitative interview: data preparation and transcription” 2003), translated, and read and re-read to code for themes.

All interviews were transcribed and translated by two bilingual speakers. Portions of audio-recordings that were difficult to hear or understand were discussed together by the translators and a third bilingual speaker to come to an agreement about their meaning.

Qualitative data analysis was conducted using a qualitative data analysis software package, Dedoose Version 8.0.35 (SocioCultural Research Consultants, Los Angeles, CA, LLC), for managing and coding of the data. Coding was done by first developing a framework for coding of a priori initial codes and then adding codes as themes were identified. Last, matrices were developed to reduce the data and visualize important themes (Miles and Huberman 1994).

16.3 Results

16.3.1 Key Health Concerns

Analysis first explored Andersen's need factors, the actual and perceived need for health services, by identifying the key health concerns voiced by participants. The commonly mentioned concerns among all groups were gastrointestinal disease and diarrhea due to unclean water as well as metabolic conditions, such as diabetes, obesity, and hypertension, stemming from poor-quality diets. Other health concerns that were mentioned repeatedly included overconsumption of alcohol, drug use, respiratory infections, and scarcity of medicine.

16.3.2 Strengths of Health Services

Next, we analyzed interviews for Andersen's predisposing factors to health seeking, including both the perceived strengths of Hospital Oskar Jandl and participants' concerns about its health services.

In interviews, participants were asked to describe the positive characteristics of Hospital Oskar Jandl. Overwhelmingly, participants discussed the hospital's beauty and state-of-the-art medical equipment, which many lauded as improvements over the previous hospital. Participants also mentioned that overall, the hospital provides good care and that care during pregnancy and childbirth is excellent. Participants explained:

> The new hospital is much better [than the old hospital] because it has good infrastructure and it has more workers than it had before. (female, mother)

> I love it. There is a big difference in care between the old hospital and the new hospital. My daughter was born at the old hospital, and her birth was attended by a rural doctor, and there were no specialists. The new hospital has more doctors, and there are specialists like a neonatologist, obstetrician, and gynecologist. (female, mother)

Overall, mothers were particularly impressed with the prenatal and labor and delivery care that they had received at Hospital Oskar Jandl. Key informants lauded the hospital's increased number of doctors, especially specialists, and the new equipment, though many felt that more specialists were still needed, as described below.

16.3.3 Deterrents to Utilization of Health Services

Key informants, mothers, and community members were then asked to discuss their concerns about Hospital Oskar Jandl. Hospital personnel were asked to describe the concerns that they felt community members had about the hospital.

Participants from each group expressed the primary concern that the hospital does not have enough specialists. Many participants felt that there is seemingly never the specialist that they need when they go to the hospital. Often, participants described that for care requiring a specialist, they fly 2 h to the mainland to visit a specialist in Quito or Guayaquil. Others explained that since they do not have regular access to a specialist on San Cristóbal, their health issues are exacerbated as they wait to get both an appointment on the mainland and the money to travel. Further, many participants felt that while the hospital has excellent new equipment, hospital personnel do not always know how to use it. These factors combined prompted participants to suggest that the hospital is really meant only for basic medical care, but that it is not equipped for serious illness or injury. For example, participants described:

> The hospital is nice, and beautiful, but always lacking. It needs gynecologists, ophthalmologists, neurologists, and child psychologists. (female, mother)

> Problems become chronic because if there is a specialist, at times you go and the specialist is not there. And if someone has money, he goes to the continent. If not, the appointment keeps getting postponed, and then that illness becomes more chronic. (female, key informant)

While mothers and community members generally did not provide an explanation for the lack of specialists, key informants and hospital personnel were well-aware of this institutional shortcoming and the reasons for it, and they explained:

> I understand that, because the population is small, they don't put a permanent specialist here. But, at least they should have a calendar of visits from specialists, like medical brigades, so that individuals can coordinate and be able to have a check-up with those who come here. (female, key informant)

> To be an island with a small population makes bringing specialists from different specialties, for example, cardiology or endocrinology, difficult. If one takes the point of view of productivity, it's probably going to be low. Right? The specialists aren't going to be as productive here. (male, key informant)

Further, community members and mothers felt that wait times at the hospital are too long and that there is slow service despite the hospital's underutilization. Many participants were frustrated by the fact that they had to wait for care when doctors and nurses appear to be available. Participants attributed the long wait times to both an understaffing of nurses and doctors or to the possibility of poor service of the existing staff. Participants explained:

> It takes a very long time to receive service in the Emergency Room. They leave you sitting there and you could die of pain. (female, mother)

> They should make the service faster. More attention. You go in, and they are all just chatting. (female, mother)

While hospital personnel and key informants were not asked directly about slow service and long wait times for patients, they did not bring it up as a primary concern for the hospital. Hospital personnel did, however, express concern that there could be long wait times for patients in need of transport to the mainland in cases of emergency. These wait times were generally due to only periodic access to flights to and from the mainland. This concern was not mentioned by other groups.

Last, community members repeatedly suggested that discordance in various physicians' treatment plans concerned them and deterred them from seeking care at the hospital. Several key informants suggested that this concern may also stem from a distrust of foreign (specifically Cuban) doctors in general. One woman explained her own experience with this issue:

> They have Ecuadorian, Venezuelan, and Cuban doctors. They all say different things. One says it's this way, and another says, no, it's this way. There are three ways of caring for a baby. (female, mother)

Other concerns about the hospital that were mentioned by community members and mothers included the perception that the doctors were young and inexperienced, the hospital's unpreparedness to treat serious illness or injury, institutional inefficiency and bureaucracy, the frequent prescription of outdated medications or lack of medications, and inefficiency and lack of diagnostic labs for frequent illness including gastrointestinal disease.

Hospital personnel also suggested that hospital underutilization may stem not from the community's experiences with the hospital itself, but instead from an unfair estimation of the hospital based on the previous hospital's poor reputation. Similarly, hospital personnel felt that the underutilization of the hospital may have more to do with its reputation than with its service, and others suggested that citizens' opinions were informed by their politics. Hospital administrators and physicians spoke of hearing the hospital referred to as a "white elephant," a term suggesting uselessness and excessive expense. Nonetheless, overall, hospital personnel were hopeful that they could build trust with the community through the hospital's staff, services, and infrastructure as well as through its reputation as more residents have good experiences.

16.4 Discussion

This study uses Andersen's model to analyze the relationships among individuals, the community, and health-care providers to better understand health-seeking behavior on San Cristóbal Island. Results show that predisposing factors, particularly beliefs about health services; enabling factors, particularly financial constraints; and need factors, particularly the perceived severity of disease, together shape where individuals seek care.

16.4.1 Predisposing Factors

Our results show that while the hospital has many strengths, including excellent medical equipment and an increased number of specialists, the central concerns about Hospital Oskar Jandl are poor service and negative clinical experiences. Participants often cited long wait times, lack of sufficient staff, and general inefficiency of the hospital as deterrents for utilization. Participants discussed feeling ignored by doctors and nurses who appear to be available as evidence of poor care. Further, skepticism about the quality of service at Hospital Oskar Jandl was a central theme in interviews and focus groups. Participants repeatedly cited the limited number of specialists as one of the biggest deterrents of the hospital. This sentiment was echoed by participants' suggestions that many of the hospital staff do not know how to use the equipment in the hospital. In addition, participants were frustrated by the abundance of young and foreign doctors, whose treatment plans were often in conflict.

Other studies have found that despite Ecuador's Ministry of Health's increased spending on care since 2008, public institutions have had difficulty keeping up with the increased patient demand (De Paepe et al. 2012), and community members have perceived public care to be low quality (Rasch and Bywater 2014). In our study, though Hospital Oskar Jandl has been underutilized, understaffing and lack of specialists have led community members to suggest that the hospital cannot meet patient demand. Our results are consistent with several other studies that found that, particularly in remote communities, public health facilities are understaffed, are in poor condition, and lack necessary equipment (Aldulaimi and Mora 2017; Castiglione et al. 2018; Rasch and Bywater 2014). Further, studies have found that on islands in particular, dissatisfaction with care is frequently met with travel to more comprehensive hospitals on the mainland (Gould and Moon 2000).

Previous research on health-care utilization has demonstrated the importance of the clinical experience for decision-making around care seeking. In particular, individuals' perceptions of the center's dignity, satisfaction with services, perceptions of medical equipment, and confidence in staff to use equipment are central to one's perception of clinical experience (Hayes Constant et al. 2014). Many studies have found that utilization of health facilities depends on an individual's perception of

the quality of service at the institution (Adane et al. 2017), and perceived poor-quality care at hospitals has been a significant barrier in accessing health services (Qureshi et al. 2016). Last, participants in our study were dissatisfied with the service of foreign, particularly Cuban, doctors, whose treatment plans were in conflict with those of other physicians. When the participants were interviewed, the vast majority of specialists working at the hospital were Cuban (approximately 12), while all of the nurses were from the Ecuadorian mainland. These results are consistent with studies that have reported strained patient-provider interactions based on cultural differences (Scholl et al. 2011) and strained provider-provider interactions between a country's native and its Cuban-immigrant physicians (Villanueva 2013).

16.4.2 Enabling Factors

In our sample, financial constraints did not limit health seeking at Hospital Oskar Jandl, which is a free, public hospital. In fact, those who were most financially constrained utilized the public hospital the most, and wealthier participants frequented private doctors on mainland Ecuador. While participants admitted that seeking private care on the mainland was expensive, many felt that paying for higher-quality care was the best option in times of serious illness or injury. In Ecuador, the private sector has been able to enlist highly skilled medical staff from public institutions through higher salaries, and with the promise of more efficient health care, it has been able to maintain paying patients despite the free care offered by the public sector (De Paepe et al. 2012). These results add to existing literature showing that in countries with free health care, wealthier residents overcome their dissatisfaction with public care by instead paying for private care (Castiglione et al. 2018).

Similarly, though many studies find that availability of information on health services is a factor in health seeking, we did not find this to be relevant in our study. Every participant we interviewed was aware of Hospital Oskar Jandl and its services, likely due to the island's small size and population as well as government campaigns to publicize the hospital.

16.4.3 Need Factors

The most commonly mentioned health concerns were diarrhea and metabolic diseases, for which participants did report utilizing Hospital Oskar Jandl. For conditions that participants considered more severe, like serious injury or surgery, most participants reported that they would seek private care on the mainland if they could afford to. Other studies have found that private care providers play a critical role in treating more severe conditions (Beogo et al. 2014) and that the accessibility of private services has been detrimental to the utilization of public services (Singh

et al. 2017). Our study found that despite the inconvenience and expense of private care, its perceived higher quality was enough to draw residents of the Galápagos to the mainland.

16.4.4 Strengths and Limitations

This study is the first to address the underutilization of health care on the Galápagos Islands, where many citizens pay to travel to the mainland rather than use the newly constructed public hospital. In order to analyze health-care utilization from different angles, we interviewed community members, mothers, government employees, and health-care personnel. In a broader context, this study assesses the use of new health-care infrastructure in the Galápagos in contrast to previous studies that analyze the use of long-standing public and private care centers (Borja and Chavez 1991; De Paepe et al. 2012). Our study was limited to the island of San Cristóbal, and results may not be generalizable to the entire Galapagos population. Further, we did not use formal evaluation criteria for the trustworthiness of the data, and there is always the risk of social desirability of responses. Nonetheless, we are confident that the narrative data we collected were truthful. We have a strong relationship with the community and with the hospital, and we made certain that we could establish rapport with all participants during interviews. Respondents provided both positive and negative comments about the hospital, and data saturation was reached, so we do not suspect bias.

16.5 Conclusions

The Ecuadorian government has made great strides in improving access to health care over the past two decades. Increased funding has allowed the construction of new and updated health-care facilities, and the number of health-care visits per year in Ecuador increased from 16 million in 2006 to 38 million in 2012 (Aldulaimi and Mora 2017). Over the same period, Ecuador has seen vast improvements in health outcomes, including infant mortality, low birth weight, and overall mortality (Aldulaimi and Mora 2017), and its WHO assessment of health-care efficiency jumped from 111th in 2000 to 13th in 2014 (World Health Organization (WHO) 2016). Nonetheless, administrators at Hospital Oskar Jandl, a new public hospital on San Cristóbal Island, reported underutilization of care.

In the present study, which examines the reasons behind underutilization of care at Hospital Oskar Jandl, participants praised the hospital's new, state-of-the-art equipment, the increased number of doctors and specialists, and the high-quality labor and delivery care. Nonetheless, our findings show that skepticism about the quality of care at the new public hospital on San Cristóbal has limited its use.

Increased utilization of the facility can be achieved through a few avenues. First, improvements to the hospital can increase utilization if the changes are made known to the community. Second, consistent with our conceptual framework, positive experiences at the new hospital can change perceptions of the hospital and thus increase utilization even without instituting changes to the facility. Third, we recommend improvements that would address the hospital's lack of specialists and inability to handle more serious cases. Since its opening, Hospital Oskar Jandl has used telemedicine with the medical school at *Universidad San Francisco de Quito* to assist virtually with complicated cases and surgeries. An increase in telemedicine may improve the community's faith in the hospital to handle more serious cases. Further, we recommend (as did a key informant) that the hospital institute a monthly rotation of specialists. This way, island residents could make appointments for specialized care without travel to the mainland. In addition, we recommend the establishment of a simulation lab so that hospital personnel can train for cases of severe illness or trauma.

As the hospital makes changes, it is important that it improve its reputation, and thus utilization, through community outreach programs. We recommend that the hospital engage the community through the establishment of a Community Advisory Board that would elicit suggestions for the hospital in order to have constant feedback about concerns or strategies for improvement. Opportunities for community members to give suggestions to the hospital anonymously may also improve its reputation. Last, we suggest that the hospital invite community members to explore the hospital and introduce them to existing specialists, so that individuals can have a better understanding of available care and rely less on community commentary. These recommendations are not only important for improving the utilization of Hospital Oskar Jandl, but also, similar approaches may improve health-care utilization and ultimately health in other isolated contexts as well.

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Chapter 17
Facilitating Evidence-Based Nursing and Humane Healthcare Through Professional Development

Julee Waldrop, Alasia Ledford, Betty Martinez, Johanna R. Jahnke, and Gwen Sherwood

Abstract This chapter begins with the healthcare-related community assessment in 2016 that led to the *convenio* between UNC, USFQ and the Ministry of Public Health. Health concerns documented in prior studies and the community assessment were the basis of the charge to the SON to provide education and training for nurses and other healthcare professionals at Hospital Oskar Jandl. A review of the literature on published health education programs from high- to lower-resource countries although limited is informative for current and future efforts. The approach to providing this professional development over the last 3 years will be described including topics, attendance, and formal and informal evaluation as well as anecdotal evidence of ongoing practice change to improve health. Current needs and observations including culture of the hospital and local community as it impacts trust and use of health services will be discussed. In particular efforts to engage all healthcare staff at the hospital in learning about humane care principles (moral responsibility and respect for autonomy) as a way to increase engagement and satisfaction from patients and family members with care provided by the hospital will be considered. Conclusions and possible ideas to increase impact and sustain this partnership into the future will be reviewed.

Keywords Continuing professional development · Nursing education · Healthcare · Bank's typology · Sustainable partnerships

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17.1 Introduction

Until recently, most research from the Galápagos Islands has focused on themes of conservation with little consideration for the health of the humans living and working on the islands. Within the past decade, as initial research on human health has emerged, stakeholders have recognized the need for better quality healthcare for residents. In 2017 the local health sector collaborated with educational institutions on mainland Ecuador and the United States (US) to both develop resources for research and improve the provision of healthcare. The chapter presents an overview of healthcare in the Galapagos, its resources and challenges, and strategic planning for professional development to promote healthcare quality, access, and acceptability.

17.2 Overview: Healthcare in the Galapagos

Initial assessments of health and healthcare on the islands formed the foundation for initiating an ongoing collaboration focused on improving healthcare, access and acceptability to its residents, and its overall quality (Jahnke et al., Chaps. 13 and 16, this volume). Food and water insecurity (Thompson et al. 2020; Gerhard et al. 2017; Page et al. 2013; Pera et al. 2019; Walsh et al. 2010), obesity and metabolic diseases (Freire et al. 2018; Pera et al. 2019; Tufton and Chowdhury 2015; Waldrop et al. 2016), maternal and infant health (Page et al. 2013; Thompson et al. 2019; Waldrop et al. 2016), and general underutilization of health resources are reported as areas of concern for residents.

A 2012 comprehensive report about life on the Galapagos revealed the same concerns the residents continued to report in 2017 (Golon 2012). Healthcare quality and access were concerns for 70% of residents who participated in assessing overall considerations for living in the Galapagos. Participants in this study also shared their lack of trust in island healthcare facilities, citing lack of specialists, critical equipment, and adequately trained professionals, and the majority believed that better care was available on the mainland in spite of the high cost of travel.

17.3 Healthcare Provision

Healthcare is provided to residents of the San Cristobal, Galápagos, through a public hospital, public clinics, and private clinics. Hospital Oskar Jandl (HOJ) on San Cristóbal, the seat of government for the Galapagos, was built in 2014 with 22 beds (Ministerio de Salud Pública 2015). Residents remain skeptical of the new facility, although the use of the hospital and clinics has been increasing slowly. Mistrust of the hospital persists despite the new construction, crucial new equipment, and qualified staff, and thus, patient census remains lower than desired. Physician specialists

employed by the hospital also see patients at clinics within the hospital (Jahnke et al., Chaps. 13 and 16, this volume). The number of patients in the hospital each day varies widely. For example, in the summer of 2019, during a visit to the hospital, there was only one patient, yet the next day census swelled as numerous people were hospitalized for a food poisoning outbreak. Such fluctuations make staffing challenging. Although government policies that guide staff recruitment prioritize residents of the Galápagos, the physician and nursing staff at HOJ are almost exclusively from mainland Ecuador or other Spanish-speaking countries including Cuba and Puerto Rico. Non-resident staffing limits terms of service, contributing to high turnover. In addition to HOJ, San Cristobal Island has two public health centers. The clinic attached to the hospital includes outpatient services such as preventative services like vaccinations, primary care, behavior health, and dental, while the public health clinic in Progreso, a small community in the highlands, provides preventative and primary care only.

Despite the government's efforts to improve healthcare quality and access on the island, the residents remain apprehensive about the quality of hospital services (Jahnke et al., Chaps. 13 and 16, this volume). Staff recognize the need to develop trust with the population to build confidence in the healthcare they provide. Despite the modern advantages of the hospital as well as more specialists, gaps remain to satisfy needs and expectations to avoid a trip to the mainland. Hospital staff believe that the reputation of the hospital is improving as more and more patients have good experiences and share their experiences with others. Nonetheless, the long history of looking to the continent for solutions is challenging to replace, particularly as many residents have established relationships with physicians and other caregivers in Guayaquil, the closest city on the mainland. Many community members continue to express dissatisfaction with healthcare quality and access. Many residents continue to travel to the mainland for care, in spite of high costs, separation from family and loved ones, and the consequences of delays in treatment (Jahnke et al., Chaps. 13 and 16, this volume).

17.4 Professional Development to Improve Healthcare Quality

To address the need to improve healthcare provision, in 2017, Hospital Oskar Jandl (HOJ), the Ministry of Health, and the University of San Francisco de Quito (USFQ), a private university in Quito, developed an official agreement to form a partnership to address healthcare in the Galapagos. The agreement was founded on the principle that health is a right guaranteed by the state and that the Ministry and the USFQ will work together to strengthen the hospital's ability to respond to the health needs of the people in the Galápagos. Three main strategies formed the agreement: (1) develop a program for telemedicine and consultation with specialists in Ecuador; (2) provide education and training of existing physicians, nurses, and

technicians of the hospital; and (3) foster educational and investigative programs between the university and hospital that focus on health issues that are the most common on the islands and have a significant impact on the community. Within 2 months of the agreement, the UNC School of Nursing (SON) entered the partnership to help address the second strategy with the long-term goal of identifying and supporting the development of education and training programs that will improve the health of the community (Blaney et al. 2019). Access to education for continued professional development has long been recognized as a key strategy for recruiting healthcare professionals to remote geographical areas (Blaney et al. 2019; Sherwood 1995).

Principles defined in the Nursing Code of Ethics and concepts of evidence-based practice guided the development of a partnership with USFQ and the UNC SON to support healthcare access and quality. The primary aim was to provide continuing professional development, both on-site and ultimately with web-based programs, to the nursing staff and other interested healthcare professionals to improve the quality of care provided at the hospital. In accordance with the spirit of the agreement that health is a human right, the Nurses Code of Ethics (2015) provides a framework for addressing the challenges that the nurses, the hospital, and the community on the Galápagos are confronting regarding healthcare quality and acceptability. Provisions 1 and 2 of the Code are particularly relevant for professional development and education in this context of deep mistrust between providers and residents. Provision 1 stands on the principle of respect for human dignity and the right to self-determination or autonomy in decisions related to health and illness. Provision 2 protects the patient's interest, while at the same time, it states the importance of collaboration between provider and patient, broadly defined to include family or population (e.g., community). Trust between the healthcare provider and the patient is an integral and necessary component of ethical care.

Establishing evidence-based practice is a requirement for professional practice. Nurses need access to continuous learning to develop a model of providing care as it is informed by three principal components for healthcare decision-making: the use of the best research, the clinicians' expertise, and the patients' values (Sackett et al. 2000). Evidence-based practice considers patients' values, beliefs, and practices in making decisions about their care. Evidence-based healthcare can improve patient trust as patients see the results, which contributes to satisfaction and participation in their care.

In early discussions for developing a plan for continuing professional development, an assessment of nurses' needs revealed a desire to provide quality, evidence-based care in an interprofessional manner (i.e., a team approach to patient care by the physician, nurse, and other health professionals as indicated). Topic requests were matched with the expertise of bilingual students at UNC SON, and professional development began in 2017 at HOJ. In the first 2 years of the partnership, nursing graduate students provided education on quality and safety in nursing care,

Table 17.1 Professional development for nurses

Year	Professional development topics	Attendance[a]
2017	Quality and safety education for nurses	32
	Breastfeeding challenges	60
2018	Wound care	24
	Cardiac rescue	27
2019	Postpartum care	10
	Humane treatment – respect of the patient	66

[a]Attendees included primarily nurses, but physicians, other hospital staff, or interested persons such as public health personnel, ambulance attendants, and therapists are included in totals

breastfeeding challenges, cardiopulmonary rescue, and wound care to nurses, physicians, and other ancillary healthcare providers (Blaney et al. 2019). Table 17.1 provides a summary of the topics and healthcare professional attendance.

In 2019, graduate nursing students designed and implemented a professional development series for the HOJ nursing staff. Topics included evidence-based postpartum care guidelines, breastfeeding, and caring for late pre-term infants. Another presentation was provided for nursing and physician staff on the humane person-centered treatment of patients. After the educational portion of this presentation, participants were given scenarios simulating an interaction between a patient and hospital staff. Volunteers from the audience were provided a description of a patient presenting to the hospital with non-emergent symptoms or a non-emergent condition, for example, a full-term pregnant woman who is in active labor with her first child and whose water has broken. Her contractions are frequent and strong. Participants in the simulation chose a role to play, either as the patient, nurse, physician, or family member, and had to act out the scenario thinking about how they would approach the patient, communicate with the patient, listen to the patient, and involve the patient and/or family in shared decision-making. The audience members were asked to reflect on what went well and what could be improved in the interactions between hospital staff and patients. Following the success of the program, the director of the hospital asked the graduate nursing students to repeat the presentation to the entire hospital staff. During the second presentation, scenarios were adjusted to include the role of ancillary staff, such as environmental services. This scenario encouraged the entire hospital staff to recognize they have a role and responsibility in meeting the needs of patients. Informal feedback from attendees indicated this was a topic of great interest to all staff and one they found especially relevant to their existing relationship with the community.

17.5 Opportunities for Continuing Professional Development

The students also had the opportunity to observe nurses and their interactions with physicians, patients, and others in the healthcare setting, therefore gaining insight into the duties and responsibilities of nurses in the hospital and the unique needs and challenges they faced. Additionally, they had the opportunity to shadow a physician and community health worker from a public health clinic on a visit to a school and police department to deliver vaccinations.

These observations, experiences, and conversations revealed the limited opportunities for professional development and leadership afforded to nursing staff. Nurses desire to practice to the full breadth of education and competence. They also expressed the desire to develop advanced skills, so they feel confident and prepared to handle complex health needs, which would foster trust among residents. However, the hospital context presumes that nurses practice as generalists in the truest sense, having basic knowledge in many areas, without ever developing in-depth expertise in a particular specialty. Opportunities for developing leadership capacity are equally limited. As is often the case, physicians and nurses function in a hierarchical, authoritarian structure at Hospital Oskar Jandl, which limits collaborative interprofessional team care. However, many of the nurses are weaving a thread of change into their work environment, describing their desire and need for leadership development and a more collaborative approach toward patient-centered care that positions everyone on the same team working toward better health for the patient.

Conversations also highlighted the continued need to develop trust between hospital staff and the community. Nurses revealed their sincere desire to make a difference on the island and their surprise when Galapagueños (Galapaganeans) did not receive them with open arms but instead inquired about where they were from, how long they would be there, and why they had come to take their jobs and money. The nurses also described their own stress and uncertainty related to feeling unwelcomed and knowing that because of their status as afuereñas (outsiders), they could be asked legally to leave at any time if someone from the community with the same qualifications applied for a nursing position at the hospital, as outlined in the Special Law of the Galápagos from 1998 (Hoyman and McCall 2012). This law's intent is to protect the Islands from the rapid migration associated with tourism on the islands by providing preferential hiring, if qualified, to those who are residents of the Galapagos. While the Special Law was meant to prioritize jobs for Galapaganeans, the government's generous subsidies have provided a financial incentive to work on the islands, drawing many Ecuadorians from the mainland to seek employment on the Galápagos even if temporary. In the years since, tensions have been growing between Galapaganeans and Ecuadorian mainlanders, who may be changing the culture of the island and are ostensibly taking the jobs of Galapaganeans, at least until a qualified Galapaganean wants them. Of course, it is not lost on Galapaganeans that many of these jobs require higher education and skilled training, which are out of reach for most islanders due to the islands' limited infrastructure and lack of higher education. Apart from concerns about jobs, many Galapaganeans view the

presence of outsiders, and thus the hospital and its staff, as another means of political control imposed upon them from the continent. Much of their anger, though directed at the nurses, is rooted in perceived past political injustices and current lack of control over many political and conservation-related efforts on the islands (Hoyman and McCall 2012; Kerr et al. 2004).

17.6 Discussion

The tension between Galapaganeans and Ecuadorian mainlanders seems to be at the heart of the dissatisfaction of both patient and provider on the Galápagos. While others have focused on the patients' distrust with the hospital (Jahnke et al., Chaps. 13 and 16, this volume), this work suggests that hospital personnel, and nurses, in particular, are dissatisfied with their ability to provide care to the disenfranchised and dubious community. Others have used a theory of insiders and outsiders to examine such circumstances sociologically. From this perspective, the insider identifies with the "order of things," whether that is a formal set of laws or an informal "way things are done" (Hage 2006). The insider perceives that this collective order of things is their own, and they can speak of the "we" as their collective identity and way of doing things. The outsider is someone from "elsewhere" and feels "out of place" and does not identify with or experience the law or way of doing things as his or her way (Hage 2006). This dichotomy is perhaps too simplistic to describe the complex interactions among Galapaganeans and Ecuadorian mainlanders. Banks (1998) describes four different types of educational researchers within the cultural context, which can also be useful in conceptualizing the forces at play when attempting to influence institutions such as healthcare in the Galápagos. Because there are no indigenous people in the Galápagos, we have modified Banks' terms slightly for our purposes.

We use a modified version of Banks' four types of people to include (1) insider; (2) outsider; (3) external-insider; and (4) external-outsider. The insider is the Galapaganean who has citizenship and is considered a "legitimate" member of the community and endorses the values and culture of the community. An insider was either born on the Galápagos or moved there at a young age. The external-insider has been socialized within the community and assimilated to various degrees. These people are often those who married an insider (Galapaganean) or are extended family members. The outsider is someone who is viewed as having "sold out" to the external outsiders, for example, a Galapaganean politician who supports the mainland (Ecuador) policies for the islands or represents the work and views of outsiders (such as educators and researchers) to the community. The external-outsider has been socialized in a community different from the Galapaganean and may have varying degrees of understanding of the values and beliefs of the community. In the Galápagos, this group can be broken down further into those who are socialized in mainland Ecuador and everyone else. Both groups are at risk for misunderstanding

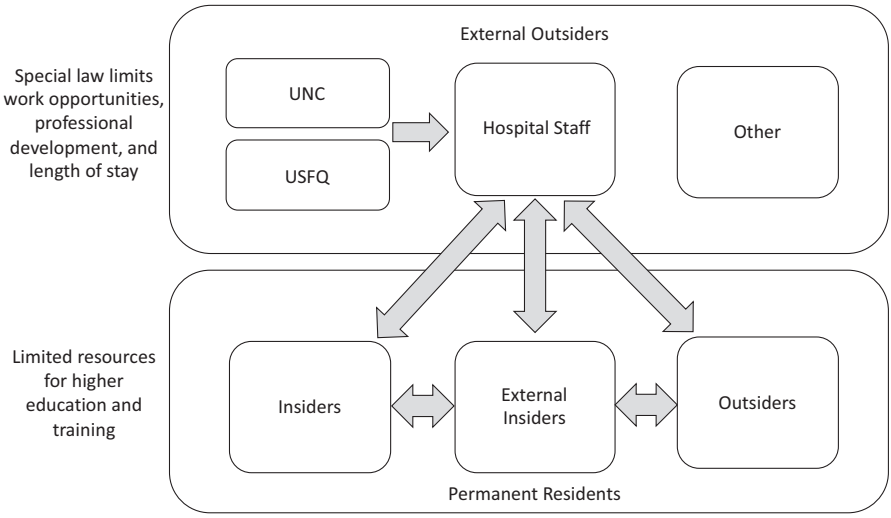

Fig. 17.1 Four types of people within the cultural context

and being misunderstood when interacting with and engaging on the islands. Figure 17.1 shows the nested levels of this community.

It is important to consider this construct when attempting to affect change in the healthcare system or in the delivery of healthcare. Understanding the nuances of residence and non-residence, which is insider and outsider, helps explain some of the undercurrent in balancing the tensions between healthcare providers and patients. Figure 17.2 provides a conceptual model for how educational partnerships and the hospital fit into the broader community of the Galápagos using this type of framework.

17.7 Conclusions and Implications for Sustainable Partnerships

High-resource countries share in the responsibility to collaborate with resource-challenged areas. Committed healthcare providers strive to implement best care practices; yet, if they are continually frustrated by barriers, it makes it difficult to provide quality care. Partnerships such as this example with USFQ and UNC SON are one strategy to address the Code of Ethics for Nurses by sharing educational resources.

In co-creating professional development in remote areas with limited resources, educators have a dual responsibility. First is a direct obligation to the nurses to meet their professional development needs related to improving patient care and outcomes, and second is an indirect responsibility to the community that the nurses and

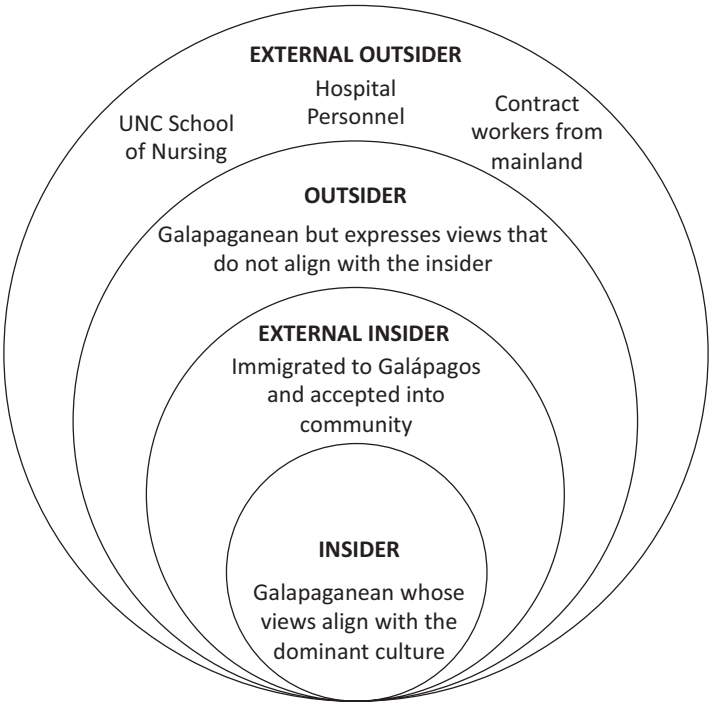

Fig. 17.2 Conceptual model of educational partnerships, the hospital and the community

other healthcare providers serve. After 3 years of interacting within this unique system and culture, the framework of evidence-based practice, shared decision-making, and humane care principles is laying the foundation to improve engagement between external outsiders (e.g., the healthcare providers) with insiders. An additional consideration for healthcare providers is self-reflection on their position as external outsiders and a true spirit of inquiry to learn about the health values and beliefs of the community they serve. Because of the temporary, relatively short-term stays assigned to most employees of HOJ, there needs to be a transfer of knowledge that has been gained between departing and newly arriving healthcare team members.

The first step of engagement between the community and the HOJ, as represented by those who work there, was the SON students teaching about the ethical principles of care. It is up to those who participated to continue to develop effective relationships and positive interactions with patients and the broader community. Regular assessments of learning needs, developing leaders, and celebrations of successes will help to promote the continuation of this strategic partnership.

The framework of the insider-outsider can be the lens for those who want to support healthcare in other similar contexts – remote or underserved areas, both internal and external to their own country. This lens, ethical principles of care, and evidence-based practice can support improvements in the provision of healthcare in any context.

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