

ConCiencia

Magazine

Human Health

Galapagos Biobank

Galapagos Biodiversity

Climate Change Monitoring

Scientific Monitoring Cruises

June
2022

Second Edition



GALAPAGOS SCIENCE CENTER
USFO UNC-CHAPEL HILL



@ ConCiencia Magazine
 Second edition
 Language: Spanish and English
 Print run: 350 copies
 San Cristobal - Galapagos - Ecuador - 2022

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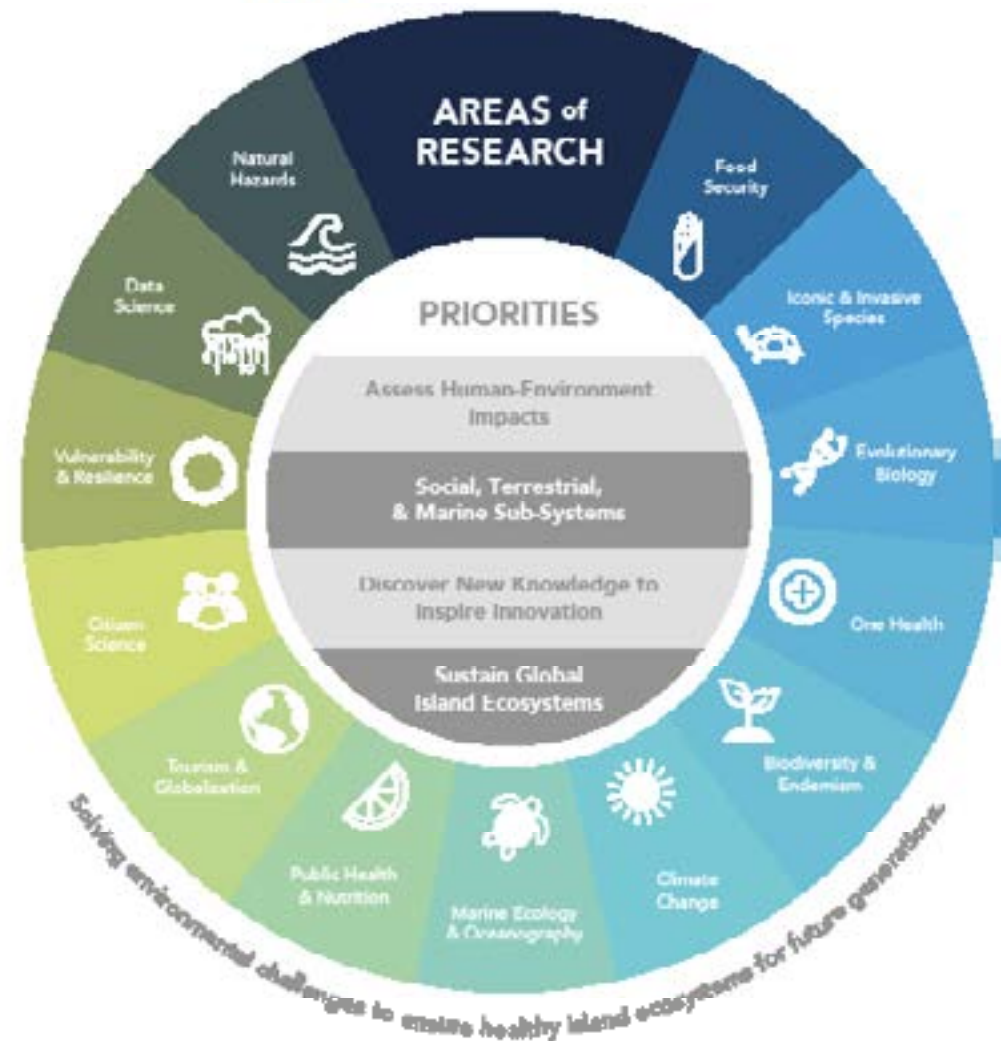
Gragvi - El poder de la impresión



The Galapagos Science Center (GSC) is an interdisciplinary research facility located on San Cristobal, Galapagos whose objective is to promote the conservation of the fragile islands' ecosystem and the development of the local population.

It focuses on the integration of the social, terrestrial, and marine sub-systems. The strategy of the GSC is based on three fundamental axes: (1) integrated scientific research, (2) education and, (3) community outreach and engagement.

Interdisciplinary Science & the Galapagos Initiative



ConCiencia Magazine: A Science Magazine of the Galapagos Science Center, a Collaborative Partnership Between the University of North Carolina at Chapel Hill and the Universidad San Francisco de Quito

Editorial Comments

Welcome, friends and colleagues, to the latest edition of the GSC Science Magazine, **ConCiencia**, a review of selected projects that represent innovative research, education, and community outreach initiatives that are conducted at the Galapagos Science Center. This edition of **ConCiencia** commemorates the 10-year anniversary of the founding of the Galapagos Science Center, a strategic partnership between the University of North Carolina at Chapel Hill (UNC) and the Universidad San Francisco de Quito (USFQ). It is my pleasure to introduce a selected group of projects and initiatives that are described in the forthcoming pages of this edition. Together, these projects offer a glimpse of the innovative work being conducted at the GSC by over 125 affiliated scientists and nearly 100 approved projects. While impossible to provide an in-depth characterization of all our projects, the project overviews are a fascinating composite of work that contributes to the generation of new knowledge that transforms science being conducted by UNC and USFQ scientists as well as scientists who are institutional members of the GSC through the International Galapagos Science Consortium.

This edition of **ConCiencia** briefly describes 13 projects, plus an overview of the establishment of the GSC by the Founding Co-Directors, Steve Walsh (UNC) and Carlos Mena (USFQ). They highlight the crowning event, the **World Summit on Island Sustainability**, designed to celebrate the 10-year anniversary of the Galapagos Science Center, introduce the laboratories within the GSC (Genetics & Microbiology, Marine Ecology, Terrestrial Ecology and Spatial Analysis & Modeling) and highlight the International Galapagos Science Consortium, designed to expand scientific capacity and vision to better address the interdisciplinary challenges facing the Galapagos Islands and other similarly challenged island ecosystems around the globe.

The selected projects detailed within the following pages highlight the important work being done, for instance, to develop a Galapagos Biobank at the GSC to handle, store, and protect genetic samples by consolidating collections of animals, plants, microorganisms, algae, and fungi that are relevant to the biodiversity of the islands and their conservation. **Water Cycling and Critical Zone Processes in the Tropics** stresses the importance of three gradients across the Galapagos Archipelago that serve as proxies for tropical systems around the globe – hydroclimatic gradient, pedohydrologic gradient, and anthropogenic gradient. **Galapagos Pinnipeds and Population Trends** examines the Galapagos sea lion and the Galapagos fur seal as important endemic species for conservation throughout the Galapagos Archipelago. The human dimension in the Galapagos is also examined through three projects that showcase **Water and Diet**

on Human Health, Water Quality and Human Health, and Human Health on San Cristobal Island. Collectively, these projects, respectively, stress the importance of (1) access to high quality food, diet quality, and health behavior, (2) analysis of microbiological and chemical contaminants in drinking and recreational water quality, and (3) enhancement of health services to the Island's population as well as to national and international tourists. **Monitoring the Aerosols and Total Ozone at Optical Depths within the Atmosphere** is important in understanding the energy balance of the Earth-Atmosphere system and assessing long-term changes in atmospheric composition that affects global climate. Global climate is further studied through **Sustainability Hinges Upon the Health of Global Climate** that links the critical importance of climate to the sustainability of fisheries, influenced by anthropogenic impacts, structure and geochemistry of the ocean, and society's ability to adapt to changing conditions. **Research and Scientific Monitoring Cruises of the GSC-GNP** describes a series of cruises throughout the Galapagos Archipelago that were conducted through the cooperation of the Galapagos National Park, UNC, and USFQ during 2014 – 2018 to generate a baseline that establishes the conservation status of several endemic species of the Galapagos and how they are impacted by climate change. **Small Things with a Big Impact** details the importance of steep physical and chemical marine gradients throughout the Galapagos Archipelago that drive microbial complexity, disrupted by El Niño/Southern Oscillation (ENSO) events that are large-scale variation of ocean and atmospheric conditions.

Beyond the science and conservation being addressed at the GSC, education and community outreach are areas of importance throughout the islands. **GSC Experiential Education Programs** highlights the cooperation between the GSC, GNP, and other public institutions to provide hands-on learning experiences for local and international students to better understand scientific inquiry, theories and practices, and professional networks for experimentation and learning. **Scholar Exchange and Science Research Experience** details the experience of a GSC scientist who has successfully engaged and navigated multiple institutions in her quest for enhanced training – Universidad San Francisco de Quito, James Cook University, and the UNC through certificates of achievement as well as undergraduate and graduate degrees. Lastly, **the Connecting with Nature Program** has impacted the experiences of the Galapagos community through innovative programs that link the GSC to the community, designed to benefit local students and families through support provided by the GSC as well as the Galapagos Conservation Trust.

In sum, **ConCiencia** effectively addresses some of the important work that is being carried out at the GSC that directly impacts science, conservation, education, and community outreach and engagement. I hope that this edition of the GSC Science Magazine demonstrates our commitment to the Galapagos Islands, its ecosystems, and to the people that live and visit this amazing place.

Dr. Stephen J. Walsh
UNC Distinguished Professor & Research Professor of Geography
Emeritus Founding Director, UNC Center for Galapagos Studies
Emeritus Founding Co-Director, UNC-USFQ Galapagos Science Center

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World Summit on
Island Sustainability
GALAPAGOS SCIENCE CENTER

Celebrating the Past & Embracing the Future

Stephen J. Walsh & Carlos F. Mena
Founding Co-Directors, Galapagos
Science Center, San Cristobal Island,
Galapagos Archipelago, Ecuador

The Galapagos Science Center and the Next Decade

Representing strategic partners in the Galapagos Islands, Professors Steve Walsh, University of North Carolina at Chapel Hill, and Carlos Mena, Universidad San Francisco de Quito, are the Founding Co-Directors of the UNC-USFQ Galapagos Science Center. Dedicated in May 2011, the 10-year anniversary of the Galapagos Science Center is being celebrated through a crowning event, the **World Summit on Island Sustainability**, held on June 26-30, 2022 on San Cristobal Island, Galapagos Archipelago of Ecuador. The World Summit features global scientists, diverse topics, and multi-disciplinary visions that seek to better

understand island ecosystems and the social-biophysical-ecological threats to their sustainability. Drawing examples from French Polynesia, the Caribbean, Hawaii, Guam, Galapagos Islands and beyond, the World Summit seeks to create a rigorous discourse about people, place, and environment on islands that addresses, for example, sustainable tourism, food security, invasive species, land cover/land use change, human health, job diversification, water quality, and human-environment interactions through oral presentations, poster presentations, panel discussions, and breakout discussions on vital topics.



The presentations will be documented through a book published by Springer-Nature, part of the Galapagos Book Series, edited by Walsh & Mena, that currently showcases 10-volumes published on diverse topics detailing the social, terrestrial, and marine sub-systems of the Galapagos Islands, with direct application to other similarly challenged island ecosystems around the globe.

Initially planned for Isabela Island, the Galapagos Science Center was built on San Cristobal Island to better engage the Galapagos National Park, the larger human population, and a building site on USFQ land that would physically

and programmatically link the UNC-USFQ Galapagos Science Center to the educational programs and facilities at the USFQ Galapagos Campus, across from Playa Mann. With over 20,000 square feet of physical space, four laboratories, and a professional staff of 12 lab technicians, coordinators, and an Assistant Director, approximately 125 scientists and over 100 approved projects rely upon the facilities at the Galapagos Science Center for research, education, and community engagement. Projects are conducted on an array of topics, approaches, and training opportunities that extend across the sciences to better inform conservation programs throughout the



archipelago and beyond. Operating from the molecular to the landscape scales, activities conducted at the Galapagos Science Center are designed to be innovative and transformative with the central goal of improving the human dimension, protecting ecosystem goods and services, and enhancing human-environmental interactions in a globally vital and important place, the Galapagos Islands of Ecuador.

Embracing scientists from around the globe to address topics important to the sustainability of the Galapagos Islands, **the International Galapagos Science Consortium** was created by Walsh & Mena to attract scholars and institutions from diverse parts of the globe that offered unique perspectives and capacities on island ecosystems, community engagement, and integrative science to support conservation and sustainability initiatives. Bringing innovative ideas, state-of-the-art equipment, interdisciplinary science teams, and engaging the community through the hiring of local students, rental of boats and trucks, and staying in local hotels and frequenting local restaurants and related establishments, the Galapagos

Consortium continues to benefit the local community as well as science and conservation more broadly throughout the archipelago. With the Galapagos Science Center continuously evolving to meet the needs of research, education, and community engagement, the Center has benefited from new funding secured from grants and contracts, institutional support, and donors to further enhance facilities, capacities, and programs in new and exciting ways.

In sum, the past has been one of significant achievement, the seizing of new opportunities, and the development of innovative programs to benefit the community, science, and conservation programs throughout the islands. While the future looks bright, we remain highly committed and motivated to expand our knowledge of the social, terrestrial, and marine sub-systems of the Galapagos Islands and their integration to better create programs that benefit the Galapagos and other island ecosystems, particularly, as we continue to expand our geographic reach and programmatic emphasis to conserve and sustain islands and their populations in new and innovative ways.

2

Galapagos

Biobank Initiative | - 80°C

By: María de Lourdes Torres, Diana Pazmiño and Jill Stewart

The Galapagos Islands are known worldwide for their high biodiversity and endemism. The protection of biological resources, including genetic resources, is a crucial task for long-term conservation. The Biobank Initiative was born out of the interest of the members of the Galapagos Science Center (GSC) Advisory Board to expand the center's capacity in matters related to the handling and storage of genetic samples. The Biobank aims to become the custodian of samples of different types, including tissue, blood, DNA, and RNA from iconic Galapagos species, mainly those that are endemic and those that are endangered or vulnerable due to anthropogenic impacts or the presence of introduced and invasive species. The goal is to consolidate collections of animals, plants, microorganisms, algae, and fungi that are relevant to the biodiversity of the islands and their conservation.



The first phase in this project's development involved allocating a physical area within the GSC and equipping this area with freezers at -80 degrees Celsius and software for registering and coding samples. For this first phase, samples were chosen from two GSC projects - one for plants and one for animals - each with different types and amounts of samples. In this phase it was crucial to learn about equipment and basic management of a biobank.

Currently, we are initiating the second phase that aims to expand the collections, including projects with a high number of samples. This will allow us to gain experience in the entry, registration, coding, and storage of samples with the use of specialized software. It is very important to ensure the traceability of samples at every stage of this process. Therefore, having functional software guarantees the correct collection and management of data from the Biobank. The long-term vision of this initiative is to make the Biobank a repository of genetic samples from all research projects carried out in Galapagos. To this end, the GSC has the support of the national regulatory authorities (INABIO, GNP, MAAE). In the future, the Biobank intends to



offer services to researchers from both USFQ/UNC and other institutions working in the Galapagos Islands.

The accurate registration and storage of collections is of the highest value as it promotes coordinated research, collaboration between different groups and institutions, as well as the safe exchange of information - all of these important steps for the conservation of biodiversity in this archipelago.

Researchers María de Lourdes Torres and Diana Pazmiño from USFQ—as well as Jill Stewart and Corbin Jones from UNC—participate mainly in this initiative which also has the support of John McGee (UNC) and Rob Zelt (UNC), experts in software management and development. The researchers have expertise in areas of marine biology, plants, microbiology, genetics, and genomics, and are convinced that preserving the genetic heritage of species that inhabit and have evolved in Galapagos' unique island ecosystem is imperative for conservation.



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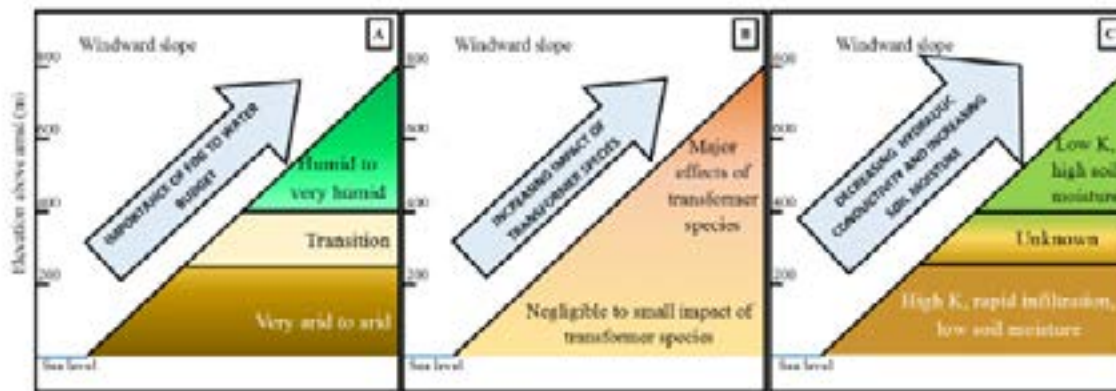
Water Cycling and Critical Zone Processes in the Tropics

The Galapagos as a Natural Laboratory

By: Diego Riveros-Iregui

In the past 50 years, global freshwater use has more than tripled. Currently, the lack of potable water resources affects about half of the population in the tropics, and the proportion of people with access to safe drinking water is lower in the tropics than in any other region of the world. Despite current water shortages facing tropical and subtropical latitudes, little research into tropical water cycling is carried out because of a limited research infrastructure coupled with lack of access to historical data. Projected population growth in the tropics, combined with climate change and the lack of conservation efforts in many tropical countries is a growing concern amongst policymakers, economists, and defense analysts alike.

Nonetheless, the Galapagos Archipelago offers an opportunity for researchers to understand tropical water cycling across a set of inter- and intra-island gradients that cover microclimatic zones representative of many zones of the tropics. Furthermore, the well-described soils and geology of Galapagos can lend further insight to hydrologic studies conducted at other tropical sites. This project focuses on three gradients across the Galapagos archipelago that could serve as ideal proxies for tropical systems around the globe (**Figure 1**). Two of those are natural gradients that affect water cycling on the islands: a hydroclimatic gradient and a pedohydrologic gradient. The hydroclimatic gradient is elevation-dependent and results in microclimates across the windward side of the islands. A stark windward-leeward contrast across each island provides for an additional opportunity to compare vertical groundwater systems in wetter and drier environments. The second natural gradient is a pedohydrologic gradient, which we define as changing soil-water interactions across islands of different age and climates. The third gradient is an inter-island, anthropogenic gradient driven by varying land use and land change. Although some islands are well-preserved and do not even allow tourist entry, over 70% of the landscape of San Cristobal and almost 50% of Santa Cruz, the two most populated islands, have been dramatically altered by land use change and invasive species.



This project identifies three particular challenges facing tropical hydrology that can be explored on the Galapagos:

1. The importance of fog inputs into tropical systems;
2. The effects of land use change on soil development and evolution; and
3. The role of pedogenesis on hydraulic and hydrochemical fluxes through the soil column.

Many environmental challenges in Galapagos are also present throughout the tropics, as growing populations and increasing tourism industries lead to water crises, or inadequate access

to or management of freshwater resources. This type of water crisis has been observed in numerous tropical systems, including agricultural zones, mountainous areas, coastal zones, and islands. These crises may be exacerbated by increasing tourism rates, which cause issues ranging from soil erosion and invasion by non-native biota to poor water quality and high demands on groundwater systems.

We suggest that the identified gradients in Galapagos, coupled with the increasing human pressures, make the archipelago an ideal proxy for not just tropical and subtropical ocean islands, but for the continental tropics, as well. The Galapagos as a natural laboratory for earth surface processes has been discussed previously, but the existing opportunities to understand the feedbacks between humans, the critical zone, and the water cycle place the Galapagos in a unique position beyond its historical importance.

Figure 1. Conceptual diagram illustrating our working hypotheses regarding elevation-controlled gradients across the Galapagos. a) With an increase in elevation, the importance of fog-water input into the water budget increases, with a large proportion of annual water input in the highlands coming from fog drip. (b) As a result of land use change, invasive (i.e., ‘transformer’) species in the Galapagos have affected the highland areas more than they have affected the lowlands. (c) The increase in the amount of water inputs to the system results in soils with a lower hydraulic conductivity and higher soil-moisture retention due to high concentrations of hydrated clays at high elevations. After Percy et al., (2016) The Galapagos Archipelago: A Natural Laboratory to Examine Sharp Hydroclimatic, Geologic and Anthropogenic Gradients. WIREs Water 3: 587-600. doi:10.1002/wat2.1145

Contributors to this research project are Diego Riveros-Iregui (UNC), Jia Hu (University of Arizona), Madelyn Percy (UNC), Sarah Schmitt (UNC), Sarah McQueen (UNC), Elizabeth Shank (UMass Medical School), Alexi Schoenborn (UNC), and Sarah Yannarell (UNC).



Galapagos Pinnipeds

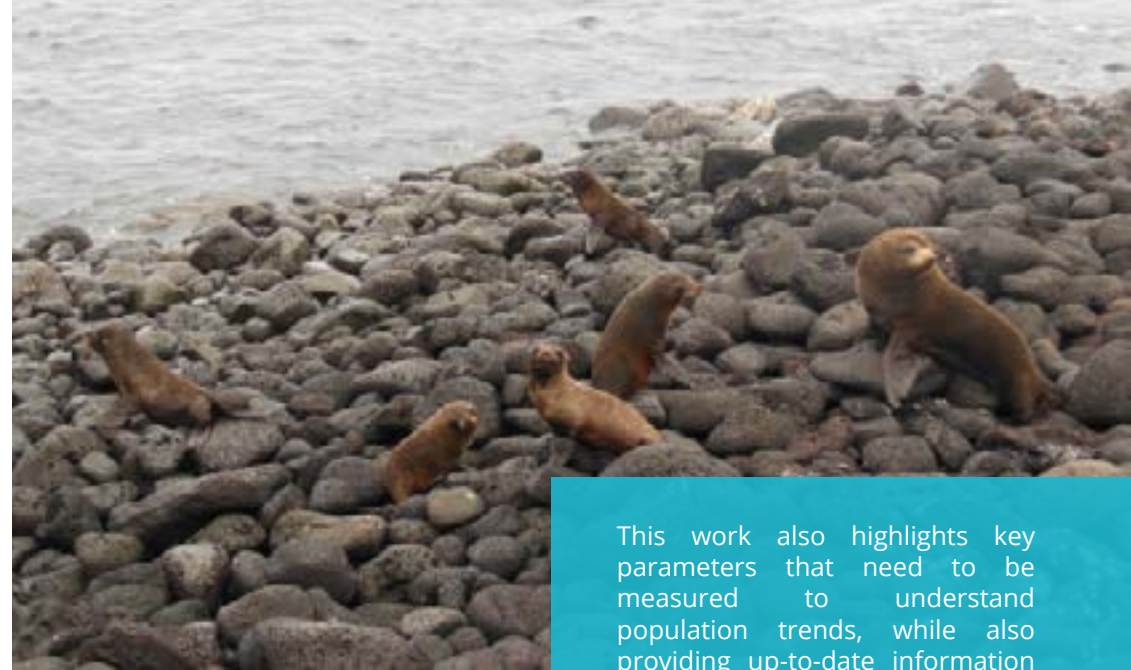
How Are Their Population Trends?

By: Diego Páez - Rosas

Currently, the Galapagos sea lion (*Zalophus wollebaeki*) and Galapagos fur seal (*Arctocephalus galapagoensis*) are among the most important endemic species for conservation in the Galapagos Archipelago. Both species are classified as “Endangered” since their populations have undergone drastic declines over the last several decades. These pinnipeds have developed a number of behavioral adaptations to living in a tropical ecosystem exemplified by high environmental variability that lead to unpredictable marine productivity. Both species have been subject to selection pressures to reduce competition conditions and reproductivity requirements compared to pinnipeds living in more predictably productive systems.



Oceanographic disturbances are another factor that has modified both reproductive and foraging behavior, thus enhancing the chances of pup survival. We estimated the abundance of both species, and their population trends using counts conducted between 2014 and 2018 in all their rookeries around the archipelago, and we analyzed the influence of environmental variability on pup production. The Galapagos sea lion population size in 2018 in all the archipelago was estimated to be between 17,000 to 24,000 individuals and has increased at an average annual rate of 1% over the last five years. The highest number of animals counted in the archipelago was in 2014 followed by a population decline of 23.8% in 2015 that was associated with the El Niño event that occurred during that year. Following this event, the population increased mainly in the northern, central and southeastern rookeries. The pup abundance of this species showed a decreasing trend with the increase in intensity of the El Niño event. The Galapagos fur seals population size in 2018 was estimated to be between 11,000 to 16,000 individuals in all the archipelago, and has increased at an annual rate of 3% from 2014 to 2018. A high number of individuals counted in 2014 was followed by a population decrease of 38% in 2015, mainly in the western rookeries. There were interannual population fluctuations and different growth trends among regions of the archipelago. Both species'



pup abundance has a strong decreasing tendency with the increase in the subthermocline temperature (ST) and the El Niño 1+2 index. Our results provide evidence that both species are highly vulnerable to periodic oceanographic-atmospheric events in the archipelago which impact prey abundance and the flow of energy in the unique Galapagos ecosystem.

This research project is led by Diego Páez-Rosas and Marjorie Riofrío-Lazo, professors and researchers at USFQ in collaboration with Galapagos National Park staff, especially with Jorge Torres Guamanquishpe, who is a fundamental part of these results.

This work also highlights key parameters that need to be measured to understand population trends, while also providing up-to-date information of their abundance to assist with the prioritizing of main rookeries. Our results show that population information of both species may have localized relevance. Therefore, adequate protection probably requires that each rookery be managed according to its specific conditions. The Galapagos Pinniped monitoring program must continue providing data to help local resource managers make effective decisions. Spatial abundance data and knowledge of population trends allow establishing effective protected areas and facilitate wildlife management. Moreover, complementary research programs investigating the feeding patterns, health status, and pup development need to be coordinated, along with demographic information to understand the population dynamics of Galapagos pinnipeds.

How Do Water and Diet Quality Influence Human Health in Galapagos?

The Healthy Families Study

By: Amanda Thompson

The Galapagos Islands have seen dramatic economic development and environmental change in response to the growth of the tourism industry and migration over the past several decades. The effects of this growth on the islands' flora and fauna have been well-documented, but the impacts on the islands' human residents have received less attention. Rapid population growth and visits from over 250,000 tourists annually - at least before the travel restrictions imposed during the COVID-19 pandemic place a strain on the already limited food and water resources of the islands. Residents tend to rely on packaged foods imported from the continent due to limited farmland and concerns about the quality and price of fresh foods and produce. While water is provided by the municipality, residents have concerns about the quality of this water and often resort to purchasing bottled water or treating their tap water before drinking. Our research team was interested in understanding whether these food and water constraints affect the physical and mental health of island residents. Specifically, we

asked whether limitations in food and water access, quality and security are associated with a "triple burden" of infectious illness, overweight and cardiometabolic disease, and distress for individuals and households.

We used multiple methods: mapping food markets to measure access to high quality foods, surveys to assess household measures such as food and water security, food purchasing, diet quality, and health behaviors, health assessments of hemoglobin status, glucose, blood pressure and body composition, and water quality testing of household and drinking water. 115 households and nearly 400 San Cristobal residents aged 2 weeks to 60 years old participated in our Healthy Families Study.

Through this research, we documented that fewer than one in five households had access to sufficient, high-quality



food and water and that over one in three households had problems with both food and water security. We found that illness and being overweight were both common, with over half of children and adults suffering from gastrointestinal or respiratory infections in the two weeks prior to the study and over 80% of adults and 70% of children having a body weight considered to be overweight or obese. Further, over one in six participants suffered from depression, anxiety, or high stress. These conditions were most common in households that suffered from limitations in both food and water compared to those with neither limitation. Overall, our results show that Galapagos

residents face significant challenges in accessing healthy, affordable diets and clean water. These challenges contribute to poorer physical health and reduced well-being for individuals and households, highlighting the need for sustained improvements in the food and water environments of the islands.



Our interdisciplinary research team includes anthropologists Amanda Thompson (UNC) and Margaret 'Peggy' Bentley (UNC), physician and pharmacologist Enrique Teran (USFQ), environmental scientists Jill Stewart (UNC) and Valeria Ochoa Herrera (Universidad del Rosario), public health researchers Jaime Ocampo (USFQ), Christopher Nicholas (UNC) and Belen Ocampo Ordoñez (USFQ), psychologist Graham Pluck (USFQ), as well as local research assistants.

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How Water Quality Influences Human Health in Galapagos?

By Jill Stewart

Water is essential to human health. At the Galapagos Science Center, we have built capacity for measuring water quality including analysis of microbiological and chemical contaminants. We developed a long-term monitoring program on San Cristobal Island to measure trends in drinking water and recreational water quality. The program was originally launched by Dr. Jill Stewart (UNC) and Dr. Valeria Ochoa Herrera (Universidad del Rosario). Results showed that the municipal water treatment plant generally produces high quality drinking water. However, contamination can occur during the distribution and storage of water.



Limited freshwater supplies on the island limit the amount of source water available for treatment and distribution, resulting in intermittent flow to households throughout the day. Households collect and store water in cisterns to ensure availability of water at the tap. The monitoring program shows that sometimes water quality can become compromised, even after water has been treated at the treatment plant. These observations are important for understanding appropriate actions to ensure safe water all the way to the point of use. The monitoring program is also providing important lessons globally, highlighting that drinking water quality depends on water quantity. These lessons are important as the world works for better coverage of centralized treatment systems and achievement of United Nations Sustainable Development Goal 6.1, focused on providing safely managed drinking water for all.



The GSC Water Research program is also helping to understand environmental determinants of water quality and disease. We are working with Dr. Amanda Thompson (UNC), Dr. Jaime Ocampo (USFQ) and others to link water quality to human exposures and health outcomes. Data from the monitoring program are being compared to precipitation and health data to evaluate the role of rainfall in the spread of waterborne disease. We collaborate on the Healthy Families Study that examines the pathways linking food and water exposures to the triple burden of disease. We are also working to understand the role of the environment in the emergence and spread of antimicrobial resistance (AMR), a critical and growing threat to global health. Our studies suggest that human activities are increasing the levels of resistance that would occur naturally, and suggest that some tourist locations may be “hotspots”

for antimicrobial resistance. The data also demonstrate that resistant bacteria can persist and spread through aquatic systems. This work supports use of a One Health framework, recognizing that the health of humans, animals, and the environment are inextricably linked. This work can help inform strategies for antibiotic use, waste management, health risk assessments, and one health surveillance. Together, the water quality research program is working to advance our understanding of human and ecosystem health in the Galapagos and in coastal systems throughout the world.

Research conducted by Jill Stewart (UNC), Valeria Ochoa Herrera (Universidad del Rosario) and Amanda Thompson (UNC).

7

Project on Human Health in San Cristobal

By: Jaime Ocampo

The joint cooperation between Universidad San Francisco de Quito and Oskar Jandl Hospital (HOJ) has been active for more than seven years. Prior to the existence of this hospital, San Cristobal Island had a center for medical assistance with only 15 beds that had been built in the 1960s. Ever since the inauguration of HOJ, the population of San Cristobal and the entire population of the Galapagos now has access to their quality service, including: 23 beds for hospitalization, an obstetrical center with a designated operating room, a psychiatry area, a neonatology area, an intermediate care unit, as well as an emergency room. Seven years ago the Galapagos extension of the university, along with USFQ Medical System, created a joint



cooperation alliance with HOJ that was divided into three areas: research, training, and medical assistance. Through these areas, many team members from various departments across USFQ, led by Jaime Ocampo and coordinated by Diana Roman, have led projects across these three areas to ultimately achieve a healthier population in the islands.

Since its inception, the objective of this project has been to be an ally for the Public Health Minister and its team in the Galapagos, in order to allow them to be able to bring quality health services to the islands' population as well as national and international tourists.



Regarding research, the objective remains to deeply understand the health needs on the island, especially with regard to diseases. For the training, these have focused on supporting the administrative and also the medical part of the hospital. Additionally, medical brigades have been conducted throughout the years of this partnership, focusing on bringing specialties the island lacks. These medical brigades were responsible for providing COVID-19 vaccinations to 90% of the island population.

This project had been principally led by Jaime Ocampo, dean of the Public Health Master at USFQ, Business School professor and CEO of USFQ Health Systems. Diana Roman, secretary to the dean of Public Health, has coordinated this project.

There has been several stakeholders along the way, including Nutrition and Medicine's professors and undergrads (including their dean, Michelle Grunauer), professors of the Public Health master, professors of the School of Business, professors and collaborators of the UNC, Texas A&M University, and Hofstra University, among others.

This project plans to continue as different health needs present themselves in the islands. For example, past research showed that obesity and other metabolic



deficiencies are a serious health problem in the islands, and for that, medical brigades among other interventions will be convened. The three methodological factors have provided a holistic vision regarding the reality of health in the Galapagos and plans to keep on being part of the construction of a better health supply in the archipelago.

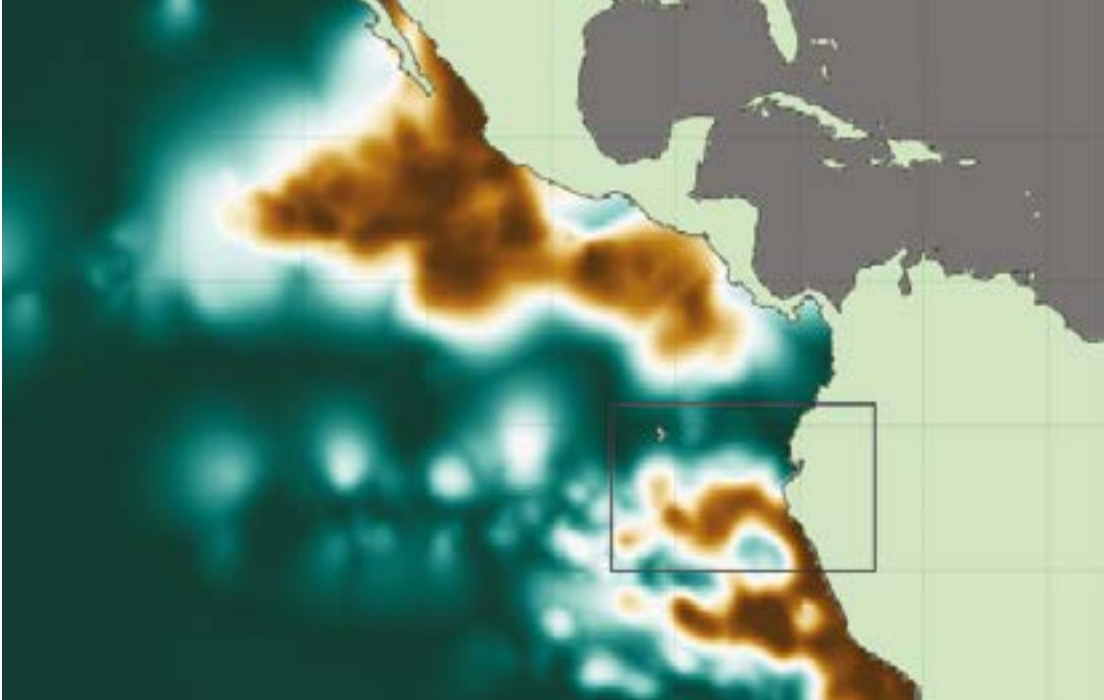


8

Sustainability Hinges Upon the Health of Global Climate

By: Andrew Babbín

The prosperity of society has always depended on local temperatures, rainfall, ocean health and productivity, and remains so today even in the face of a changing climate. Nowhere is this more apparent than in the Galapagos, where three great ocean currents – the Humboldt, the Panama, and the Cromwell – permit life to thrive across the archipelago. Yet, the Galapagos Islands are further connected to the world with the northeasterly and southeasterly trade winds converging at the equator across which the islands span. These winds transport with them signals of climate from the Pacific coast of the American continents, particularly the eastern tropical Pacific. The eastern tropical Pacific is characterized by intense upwelling leading to a highly productive surface ocean and fisheries, and by hypoxic and anoxic waters known as oxygen deficient zones in the subsurface that result from that production.



The left panel shows the extent and intensity of oxygen deficient zones in the eastern Pacific based on Kwiecinski and Babbin, 2022. While the turquoise colors represent oxygenated ocean, brown/orange colors depict the regions where oxygen concentrations are below 5 $\mu\text{mol/kg}$.

Oxygen deficient zones are intricately linked to the fertility of the global oceans and the health of the entire planet. In these regions, when oxygen becomes limiting for microbial respiration, certain microorganisms switch their metabolisms to utilizing the next best oxidant for organic carbon: nitrate. Rather than assimilating this essential nutrient to build proteins and other cellular components, these organisms convert nitrate to nitrous oxide and dinitrogen gas for energy in a pathway called denitrification. The consequences of this natural phenomenon are far-reaching: a cap on the primary productivity of the oceans and the emission of nitrous oxide, a potent greenhouse gas and agent of stratospheric ozone depletion.

Despite the critical importance for climate and the sustainability of fisheries in the region, much is still unknown about the dynamic variability of oxygen deficient zones across seasons and with El Niño/La Niña cycles and the ocean's role in the global nitrous oxide budget. Further, as the climate changes due to anthropogenic impacts, the structure and biogeochemistry of the ocean will be impacted in unresolved manners that can have dramatic importance for society's ability to adapt to a changing world. This leads to our mission at the Galapagos Science Center: to establish an ideally situated long-term monitoring station at a world-class facility to strategically measure air that has equilibrated with the ocean's surface and remotely report on the structure of the oxygen deficient zones of the eastern Pacific.



The right panel illustrates the five-day backtrajectory of air parcels located at Galapagos Science Center 10 m above the ground level during April 1-5, 2022. The backtrajectories are calculated using the NOAA HYSPLIT program.

We are building the infrastructure in the Galapagos to build precisely this monitoring program to constrain the magnitude and variability of the marine nitrous oxide budget and evaluate changes into the future. Our instrument, a cavity ring-down laser spectrometer, can measure nitrous oxide to great precision to resolve the spatiotemporal heterogeneity in its marine emissions. Moreover, utilizing computational methods of atmospheric inverse modeling, we can precisely map the emissions across the eastern Pacific continuously for decades into the future. We hope to see this Galapagos station join a global network of similar atmospheric chemistry installations as we monitor the health of the planet, reveal long-standing mysteries of the ocean-atmosphere-climate system, and

utilize the data to help inform policy decisions to maintain a sustainable and equitable environment for generations to come.

The project is led by Professor Andrew Babbin and PhD student Timur Cinay of the Massachusetts Institute of Technology in collaboration with William Vizuete of UNC and the Galapagos Science Center staff, particularly Ariel Pila, Terrestrial Ecology Laboratory Coordinator. This project is funded by the United States National Science Foundation (NSF) and MIT's Earl A. Killian III (1978) and Waidy Lee Fund.

Aerosol Optical Depth and Total Ozone Column Monitoring in the Galapagos-Andes Transect as Part of the NASA AERONET and SHADOZ Networks

By: **María del Carmen Cazorla**

In 2017, the Atmospheric Measurement Station (EMA) at USFQ joined the NASA Aerosol Robotic Network (AERONET) with two stations to monitor aerosol optical depth (AOD) and aerosol properties in the Galapagos-Andes transect. Aerosols are fine particles in the atmospheric column that have an impact (positive or negative) in the energy balance of the Earth-atmosphere system. Thus, monitoring aerosols is critical to understanding long-term changes in atmospheric composition that affect global climate. AERONET has deployed over 500 ground-based remote sensors worldwide to monitor AOD and provide means of validation to satellite observations.



Two of these instruments are deployed at USFQ.

One is located on San Cristobal island (EMA SCY), on the roof of the Galapagos Science Center, and the other one at USFQ's main campus in Quito (EMA UIO).

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The measuring instrument is a CIMEL solar photometer that follows the sun and measures the direct solar irradiance in eight spectral bands distributed in the ultraviolet, visible, and infrared regions of the spectrum.

From these measurements the column of precipitable water is also determined. In addition, the instrument scans the nocturnal sky using moonlight. Monitoring activities in the pristine Galapagos atmosphere provides background measurements in the Pacific for long term tracking of changes in atmospheric aerosols.

From these measurements, a study that characterizes air quality for the first time in the Galapagos Islands was published in 2020.

Atmospheric ozone is critical to the wellbeing of the global environment. At the surface, ozone is an air pollutant; in the free troposphere, it is a greenhouse gas, and in the stratosphere, it shields us from damaging ultraviolet radiation. Since the end of 2021, EMA USFQ joined the NASA SHADOZ (Southern Hemisphere Additional Ozonesondes) network with two stations to in situ monitor ozone over Galapagos and the Andes. The platform is a high-altitude meteorological balloon that carries the measuring instruments from the surface up to 32 km above the sea level. At this altitude, the maximum concentration of stratospheric ozone (ozone layer) is recorded.



The instruments used are an electrochemical concentration cell that measures ozone and a coupled radiosonde that measures pressure, temperature and humidity, and transmits the signal to the ground-station. Our EMA SCY station at GSC launches two ozonesondes per month. Operations are overseen by EMA UIO and synchronized once per month from both stations. At EMA UIO we have experience executing ozone soundings since 2014. Due to the high quality of collected data, we received the support of the Vienna Convention Trust Fund for 2020-2021 launches, which helped consolidate the current collaboration with the SHADOZ network.

M. Cazorla is the Principal Investigator of both projects in Ecuador. She is the director of the Institute for Atmospheric Research at USFQ as well as EMA UIO and SCY, B. Holben is the director of the AERONET global network, R. Stauffer is the director of the SHADOZ global network, E. Herrera is responsible for EMA UIO operations, M. Mejía is responsible for EMA SCY operations.

The Research and Scientific Monitoring Cruises of the GSC-GNP

A Challenge for Science and Conservation of Galapagos

By: Karina Vivanco

The scientific research cruises developed throughout the entire Galapagos archipelago are an initiative carried out thanks to the inter-institutional work of the Universidad San Francisco de Quito (USFQ), the University of North Carolina at Chapel Hill (UNC), Galapagos Science Center (GSC) and the Galapagos National Park (GNP). This research project was born out of the need to generate a baseline that establishes the conservation status of several emblematic species of Galapagos, and how they are impacted by climate change. The first trip through the Galapagos Marine Reserve took place in 2014 and until 2018, five consecutive cruises have been developed, where they collected ecological information, before, during, and after one of the strongest El Niño events that has ever been recorded.

On board the ocean vessels of the GNP, several Ecuadorian and foreign scientists carried out their research activities on 14 islands of the archipelago, where they studied the populations of sea lions, fur seals, sea birds, marine iguanas, sea turtles, scalesia, and monitored variable oceanographic data such as sea temperature and primary production levels at each of the sites studied. In turn, this initiative was used to measure the impacts produced by the contamination of plastics and microplastics, and technicians from the Agency for the Regulation and Control of Biosafety

and Quarantine for Galapagos were also invited to identify potential problems associated with the presence of invasive species.

Diego Páez - Rosas, professor and researcher at USFQ and GSC, and Scientific Coordinator of the Research Cruises stated that, "Initiatives like this, where most of the archipelago can be covered, allow us to reach pristine sites to monitor flora and fauna and have access to information that cannot be obtained in any other way." These cruises have allowed researchers to deeply investigate the archipelago, from tou-

rist areas to total protection areas.

Eduardo Espinoza, a specialist in monitoring marine ecosystems from the GNP added that, "the challenge we had to develop this project was that it was a trip that tried to cover as much of the area of the Galapagos Marine Reserve, covering oceanographic stations while also doing searches or population censuses in coastal areas." One of the main strategies to be successful was to try and conduct both these activities simultaneously: while some were taking oceanographic data, the others were taking population data.





Among the main achievements of the research cruises, the following can be highlighted:

- Carrying out interdisciplinary studies thanks to joint work between national and international public and academic institutions.
- The generation of data on the population status of several emblematic fauna species of Galapagos to inform decision makers.
- Contributions to the understanding of the resilience of species to the effects of climate change.
- The publication of 10 scientific articles with still others in the editing and revision process.

Investigating the Galapagos Marine Microbiome

By: **Adrian Marchetti**

Since the days of Charles Darwin's voyages on the HMS Beagle, scientists have long been intrigued by the richness and uniqueness of the Galapagos Island's ecosystem. The islands and the surrounding marine environment are global biodiversity hotspots and support diverse food webs that are crowned by charismatic megafauna such as iguanas, sea lions, sea turtles, penguins and sharks. However, the basis of all this life begins with the primary producers, the bulk of which are microbes (i.e. bacteria and protists). These microbes are shaped by the physical and chemical characteristics of their marine environment.

Eduardo Espinoza affirms that, "the vision is to maintain this monitoring program, although it is a bit difficult due to the aspects of financing and participation that they require." However, the idea is to invite more collaborators to participate in these cruises that are intended to be carried out year after year, mainly during the cold months (September and October).

"Unfortunately due to the COVID-19 pandemic, cruises had to be suspended but we are working to reactivate this initiative and sail again in 2022", said Diego Páez Rosas. "This is a complex initiative and we have to work hard to coordinate, raise funds, gather ideas, and put together projects, but we are going to do everything possible so that this year it is reactivated and we return to developing this initiative year after year." We are hopeful to resume the annual monitoring trips, include new species in the research, and make this project become a routine activity.

The oceanography of the Galapagos archipelago is complex because the islands lie in the convergence of several major ocean current systems. Each of these currents carries waters with distinctive properties, resulting in steep physical and chemical gradients that drive microbial complexity throughout the archipelago. Intermittently, the remarkably steady conditions of the equatorial Pacific are disrupted by El Niño/Southern Oscillations (ENSO), a large-scale variation of ocean and atmospheric conditions that occurs at 3-10+ year intervals. During the positive phase of ENSO, El Niño events, trade winds weaken and the warm waters of the western Pacific

move thousands of miles eastward to the central and eastern Pacific. These changes impact weather patterns globally and cause dramatic changes in ocean ecosystems of the tropical Pacific. The Galapagos have been profoundly impacted by past ENSO events.

Starting in 2014, UNC, USFQ, GSC, and the Galapagos National Park, began annual regional surveys of hydrography, the microbial plankton community, and a number of higher trophic level species (marine iguanas and the intertidal macroalgae they consume, sea lions and fur seals) around the archipelago. Two motivations for the cruises were the

Associate Professor Adrian Marchetti in the Department of Earth, Marine and Environmental Sciences (back row) with former graduate students Erika Neave, Nataly Guevera and Lauren Goodman (from left to right). In the background is the M/V Sierra Negra, the research vessel used to conduct the oceanographic surveys from 2015 to 2018.



Adrian Marchetti and his team had to improvise in order to establish a laboratory on board the vessel to allow them to filter phytoplankton from seawater collected during the oceanographic surveys in the Galapagos archipelago.



need for coordinated observations to support ecosystem modeling, and knowledge in 2014 that an El Niño was predicted in the coming years. Five cruises were completed, in October of 2014-2018, spanning the strong El Niño of 2015 where over a 2°C warming of surface waters across the archipelago was detected with some regions increasing by as much as 4°C. From our data collected on the cruises, we observed distinct microbial communities associated with steep gradients in environmental conditions in both space and time throughout the archipelago. Communities associated with upwelled waters in the west are most distinct from other regions of the archipelago. To date, the

research findings from these cruises have been the focus of numerous scientific publications, with more in preparation. In the longer term we seek to continue these monitoring efforts by establishing a program in the Galapagos in an effort to understand the impacts of climate change on the marine ecosystem. Such efforts will provide a more complete description of the controls on the base of the food web in this global biodiversity hotspot. Our proposed program will contribute to the scientific understanding, management and preservation of the Galapagos National Park, a UNESCO World Heritage Site.

12



By: Silvia Zavala

Thanks to partnerships with the Galapagos National Park Directorate (GNP) and other local public institutions, the Galapagos Science Center has expanded its operations to host interdisciplinary research projects. 'Flagship projects' have been strategically selected to provide hands-on learning experiences for local and international students. This unique opportunity to gain experience in practical and applied research processes is offered through our Experiential Education Program.

Who is it for?
The options are aimed at USFQ students in Galapagos as well as national and international students from other



What options are available?



Join Science Program!
An Experiential Education Program, aimed exclusively at USFQ Galapagos students, whose main objective is focused on inspiring the next generation of Galapagos scientists. It offers a unique opportunity to gain practical and theoretical experience in different research areas, and to improve possibilities for establishing professional networks.



Learning experiences
Hands on scientific research

Learning Experiences:
This option is designed to give students the opportunity to work closely with researchers and experience active scientific research in Galapagos. Through hands-on experience, students will develop a realistic view of scientific inquiry, its demands, and the excitement of discovery.

The program can be completed through a variety of options, tailored to the particular needs of each student.

a) Junior Scientist

This option is for high school graduates who are interested in science and conservation, which may prepare them for university studies in related disciplines. It is designed to offer the experience of participating and experiencing active scientific research in Galapagos.



b) Bachelor Scientist

This is an intensive option, tailored for visiting students from an international university who wish to participate at the GSC's selected Flagship Projects. Students accompany local researchers to experience scientific inquiries in areas of special interest.

c) Tailor Made Research Experience

This option has been designed to meet the different requirements of the many students applying for a research experience with the GSC. Participants will obtain a personalized program according to their interest and availability of time. This option is also aimed at professors from national or international universities who wish to offer one of their courses in the islands, whose main component is scientific research.

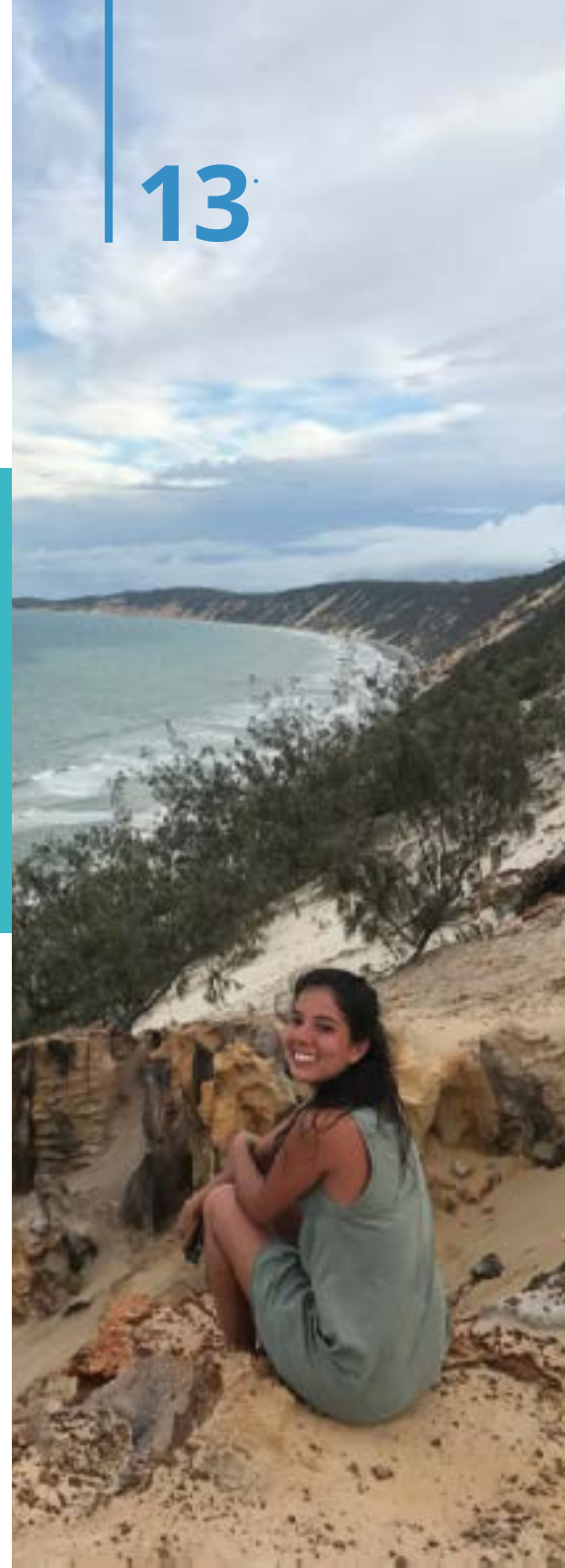
**Throughout these years
we have involved
350 national and
international students.
Their contribution to
research has been part
of numerous scientific
articles and publications.**

13

Scholar Exchange and Science Research Experience

By: Isabel Silva

In the following section we want to introduce Isabel Silva, a student who obtained her bachelor's degree in Biological Sciences at USFQ and, while doing so, also took part in an educational exchange at James Cook University in Australia. Currently, she is studying towards her Master's degree at the Department of Biology at UNC and is developing her scientific research project in the Galapagos Science Center.



When was your educational exchange and how long did it last?

I studied abroad at James Cook University, Australia. I was on the Townsville campus for the Fall 2017 Semester.



What was the main thing you learned throughout your exchange?

I learned that stepping out of your comfort zone leads to many opportunities. I also realized that experiencing a different culture helps you think outside the box and stimulates your creativity.

How has this exchange experience prepared you for your current research at the GSC?

The marine ecology subjects I took at JCU confirmed my passion for fieldwork and research. Through the experience of studying abroad, I was able to establish what I wanted to pursue as a career.

How was the entire trip planning process?

The whole application and planning process was very simple through USFQ's Office of International Programs (OPI). After getting accepted to attend JCU, OPI kept me informed with my student visa application and travel dates. On the other hand, JCU recommended the ideal classes to sign up for the semester and provided housing options.

What class or activity did you remember the most from your exchange and why?

One of the best field trips I have had in my life as a student was for my Coral Reef Ecology class. We performed fieldwork for a weekend at JCU's Orpheus Island Research Station. The main activity was monitoring the state of the coral reefs around the island using different techniques for marine research.



How was this exchange useful for your professional and personal life?

Professionally and academically, I faced many intellectual challenges throughout the semester, but it was rewarding as well. I took four subjects focused on marine ecology and management of marine ecosystems that tested (in a good way) and increased my college-related performance and capabilities.

I remember with great enthusiasm planning my trip. My parents and I were very excited when I got my visa. I am originally from Salinas, Ecuador, and my parents were the ones in charge of most of the paperwork for the application process since at that time I was studying at the GAIAS campus in Galapagos. They also helped me decide on the best route for traveling, the best options for housing, etc.



What is the focus of your MS at UNC Chapel Hill and your research at the GSC?

I am currently studying the interactive effects of temperature, nutrient availability, and herbivory on primary productivity in the shallow subtidal rocky reefs of the Galapagos.

Personally, I made friends for life and from all over the world: from the USA to Spain and from Norway to Australia. Studying abroad is one of the most enriching experiences you can have as a student!

14

Connecting with Nature has Created Impactful Results for Galapagos Community



The Connecting with Nature Program involves outreach activities with the Galapagos community implemented by the Galapagos Science Center, with support from the Galapagos Conservation Trust.



By: Leidy Apolo

Since 2019, the program has developed activities to promote interest in science and conservation, share GSC research, and encourage community participation in the protection of the islands.

The Connecting with Nature Program's objective is to engage, motivate, and empower people of all ages while creating awareness of Galapagos biodiversity and a community commitment to conservation. A few key programs within this initiative include:

DNA Galapagos Sessions

Community students learn more about new methodologies used in the field of conservation through activities developed to generate interest in science and to encourage them to protect biodiversity in their professional development.

Annual Shark Day Event

Community members participate in recreational and educational activities developed to promote the importance of protecting the indispensable species for marine ecosystems.



Shark Heroes, and Citizen Science Events

Focused on observation, bird counting, and biodiversity, these events engage the community in spreading a conservation message from their living spaces.

Reading sessions with Martí

Children from the community develop reading and critical thinking skills, generate awareness about marine species, and strengthen conservation values necessary for their protection.

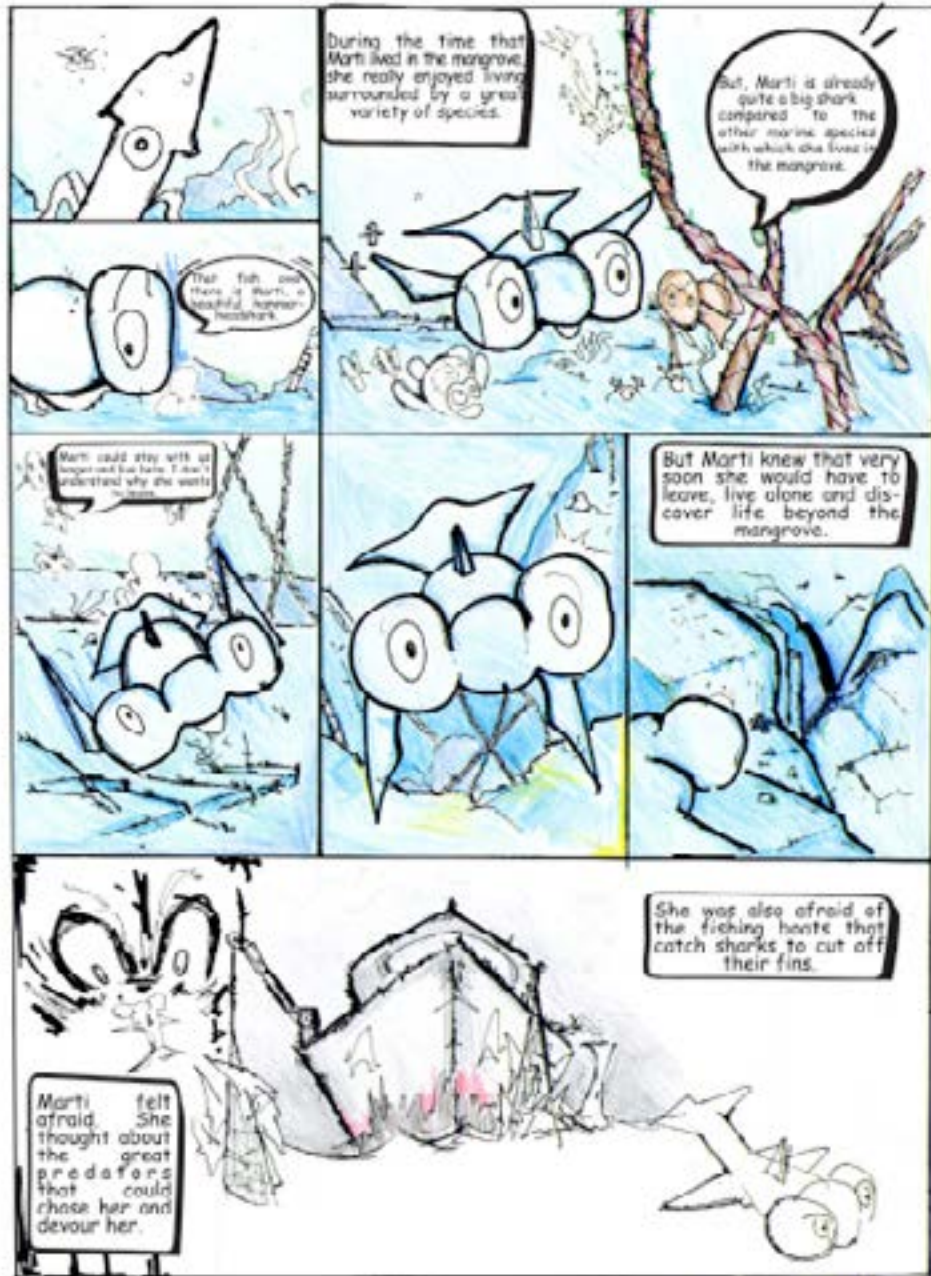


The theoretical model that helped structure the Connecting with Nature Program's activity plan is known as the "Commitment Pathway." Its premise is that conservation behaviors can be promoted gradually, intervening from childhood to adulthood.

We have successfully managed to involve community stakeholders and, throughout the different phases of the project, we have reached a total of 3927 beneficiaries as of January 2022. Of those beneficiaries, we have positively impacted 1137 children, 33 local and provincial teachers, 2683 community members, 28 students, and 46 professors of the USFQ Galapagos extension.

Despite the limitations imposed by the pandemic, the Connecting with Nature Program remained present to generate interest in science in the community and to strengthen conservation values. We are confident that the islands of San Cristobal, Santa Cruz, Isabela, and a small part of mainland Ecuador have positively embraced the program's activities. We aim to reach Floreana Island, expand activities in mainland Ecuador, and move on to other countries in the tropical Eastern Pacific Marine Corridor. We will continue to move the community towards positive changes for the benefit of the Galapagos.

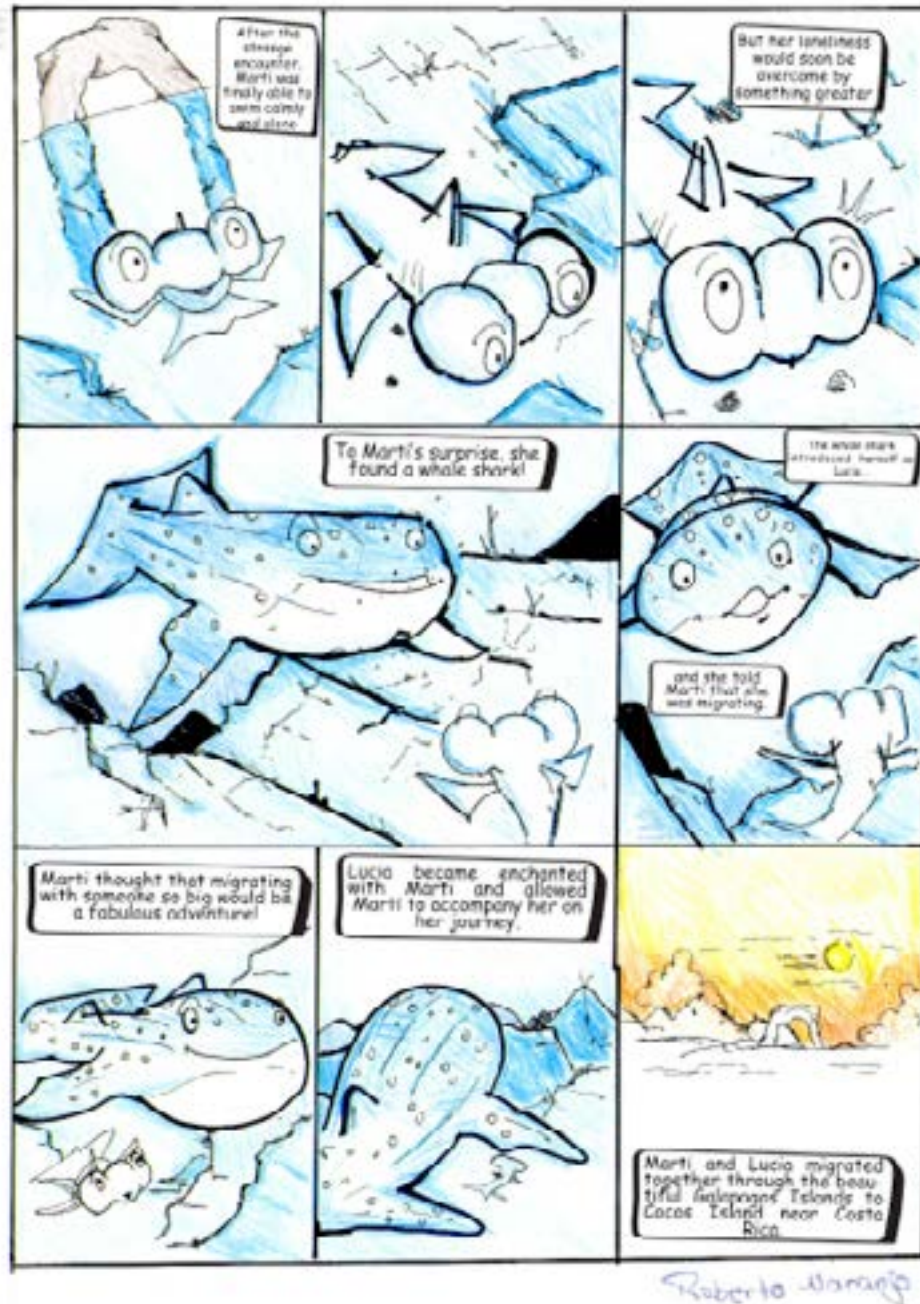
We thank those who make these activities possible!



Roberto Usmanj



Roberto Usmanj



Roberto Naranjo Arévalo is 20 years old and is currently in his 5th semester at the School of Arts and Digital Animation at the Universidad Católica de Guayaquil. The idea for the comic arose from a school project as part of the Galapagos Science Center's community outreach program titled "Reading Sessions with Martí."

"The idea of the comic started as a school project that I gladly did, because it was a way to get out of my comfort zone and do something that wasn't just for me. In the future I would like to dedicate myself to illustration and design, making concept art for video games and movies, as well as dedicating time to personal projects."



IN CELEBRATION OF THE 10TH ANNIVERSARY OF GSC'S GALAPAGOS INITIATIVE



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