

Social and Ecological Interactions in the Galapagos Islands

Thomas Kvan  
Justyna Karakiewicz *Editors*

# Urban Galapagos

Transition to Sustainability  
in Complex Adaptive Systems

 Springer

# **Social and Ecological Interactions in the Galapagos Islands**

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Editors

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# Series Preface

In May 2011, the University of North Carolina (UNC) at Chapel Hill, USA, and the Universidad San Francisco de Quito (USFQ), Ecuador, jointly dedicated the Galapagos Science Center, an education, research, and community outreach facility on San Cristobal Island in the Galapagos Archipelago of Ecuador. The building dedication in 2011 was the culmination of an emerging partnership between UNC and USFQ that began several years earlier through a 2006 invitation to Carlos Mena and Steve Walsh to assist the Galapagos National Park and The Nature Conservancy in a remote sensing assessment of land cover/land use change throughout the archipelago. Leveraging related work in the Ecuadorian Amazon, Carlos Mena (USFQ Professor of Life and Environmental Sciences) and Steve Walsh (UNC Lyle V. Jones Distinguished Professor of Geography), Co-Directors of the Galapagos Science Center, traveled throughout the islands using preprocessed satellite imagery and spectral and geospatial equipment to validate preliminary analyses of the Galapagos with a focus on invasive plant species. Since that project, Mena and Walsh have continued to regularly engage the Galapagos Islands, coordinating research conducted at the Galapagos Science Center by faculty, staff, and students from both campuses as well as by collaborating scientists from institutions around the globe who together seek to understand the social, terrestrial, and marine subsystems in the Galapagos Islands and their linked and integrative effects. Now with nearly 50 permitted park projects operating at the Galapagos Science Center and a diversity of scientific topics being studied using a host of theories and practices, innovative work continues in an assessment of compelling and vital ways. The state-of-the-art facilities at the Galapagos Science Center include nearly 20,000 ft<sup>2</sup> of space that supports four laboratories (i.e., Microbiology and Genetics, Terrestrial Ecology, Marine Ecology, and Geospatial Modeling and Analysis), operated by a permanent administrative and technical staff, to support science, conservation, and sustainability in the Galapagos Islands. In addition, students enroll in classes taught by UNC and USFQ faculty as well as conduct research to complete their undergraduate honors theses, graduate theses, and doctoral dissertations. And several scientists at the Galapagos Science Center engage the community on topics including water and

pathogens, nutrition and public health, tourism and community development, marine ecology and oceanography, and invasive species.

From these beginnings and with the general intention of developing a Galapagos Book Series to document our findings, highlight special needs, and describe novel approaches to unravel the social-ecological challenges to the conservation and sustainability of the Galapagos Islands, the Springer Book Series was launched through its inaugural book, *Science and Conservation in the Galapagos Islands: Frameworks & Perspectives*, edited by Steve Walsh and Carlos Mena and published by Springer in 2013. The series has continued to expand, with books, for instance, on evolution, the Galapagos Marine Reserve, and Darwin and Darwinism, energy mix on islands, and understanding invasive species in the Galapagos Islands. Now with considerable pleasure we welcome, *Urban Galapagos: Transition to Sustainability in Complex Adaptive Systems*, edited by Tom Kvan and Justyna Karakiewicz, University of Melbourne, Australia.

The general goals of the Galapagos Book Series are to examine topics that are important in the Galapagos Islands but also vital to island ecosystems around the globe. Increasingly, viewing islands as a coupled human-natural system offers a more holistic perspective for framing the many challenges to island conservation and sustainability, but the perspective also acknowledges the important context of history, human population, migration of plants, animals and people, economic development, social and ecological disturbances, and the evolution and adaptation of species (including humans) on islands to changing circumstances. This book offers new and compelling insights and further adds to the Galapagos Book Series in important ways.

Chapel Hill, NC, USA  
Quito, Ecuador

Stephen J. Walsh  
Carlos F. Mena

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# Chapter 1

## Complexity and Consequence in Coupled Natural Urban Systems



Thomas Kvan and Justyna Karakiewicz

We start by stating the obvious: human activities have profound impacts on the environment. While there are more apparent and singularly evident mechanisms by which we harm the natural environment, such as through pollutants and waste, the impact of human settlements is more extensive yet less examined outcome. It has been widely noted that our human population is moving increasingly into urban or collocated settlements, concentrating our footprints into ever larger towns and cities. Such collocation brings economic and cultural benefits but concentrates environmental impacts. There is increasing work that recognizes that urban and natural ecosystems must be considered as continuities and that zoning regulations that prescribe areas for settlement do not delineate boundaries of these systems.

The Galapagos Islands are an appropriate living laboratory in which to consider both the consequences of a growing urban population and the interlinked systems. The resident population of the islands is growing as are the number of visitors who wish to see the distinctive ecology first-hand. The permanent and transient human population of the islands is growing, posing obvious and real challenges to the primary source of the opportunity, the natural environment. The chapters of this book therefore examine matters that have consequences for sustainable cities by taking a case study of a particular and distinctive example.

Only 5 out of 18 major Galapagos Islands are inhabited with permanent human settlements. Until the Galapagos National Park (GNP) was established in 1959, both settled and natural areas were managed in the same way. The GNP was assigned 97% of the total land area, and the two areas were subject to distinct management through zoning. The boundaries between National Park (natural) and inhabited

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areas are carefully maintained to control the detrimental impact of human settlements on natural ecosystems.

While the primary focus of research in the islands has been on the natural systems, this Springer series has been established to examine human-environment interaction both for consequential outcomes but also to inform better management of these. Other volumes have examined social and economic aspects of human activity; this volume turns attention to the forms and means of habitation. Any human presence must be supported by urban settlements as the presence is contained to limited footprints. Supporting life in these settlements requires consumables and transportation, generates waste and introduces species as well as pollutants.

Short of banning all access to the islands, it must be acknowledged that both areas are essential to the future of the islands. The National Park cannot operate without staff as managers and guides; thus both natural and urban areas are essential components. The delineation is, however, artificial. Species, flora and fauna, cross the boundaries. The border is thus not a distinct line between two systems; our understanding of the islands will benefit from a closer consideration of the two as linked and codependent systems that are both areas of protection and areas of production (Valdiva et al. 2014).

The Galapagos Islands are a living laboratory for considering the impact of human settlements, and this includes postulating the alternatives for future actions. This volume engages the framing of complex adaptive systems theory to consider the interactions of human settlements in the mutually dependent situation in the islands. In doing so, it moves beyond common practice in urban design and planning that relies on zoning and simple model descriptions. We have become increasingly aware of the limitations and the inadequacy of using “concepts tied to logical positivism such as rationalism, reductionism and comprehensive long-range planning to address the problems and challenges of the urban environment” (McAdams 2008). We now perceive that our previous tools in considering social change, an assumption that every observable effect has an attributable cause or that complicated phenomena can be understood through by breaking the complex problem into smaller coherent pieces to analyze separately or that sufficient analysis of the past events can provide the capability to predict future events, are irrelevant and misleading (Jones and Hughes 2003).

While complex systems theory has been present in many disciplines for the past 40 years, such as economics, management, biology, and social science, the majority of urban planning and design has followed a problem-solving paradigm. This approach often leads to an intensification of the problem or the creation of consequent problems through inappropriate interventions. To quote Forrester (1969), *we misunderstand symptoms for causes*. He notes that complex systems are counterintuitive since causes cannot be found in prior events but rather in “the structure and policies of the system.” Therefore, even when we speak about complex adaptive systems (CAS) in the urban context, we remain trapped in simple systems thinking, identifying linear causality. It has been noted that this condition is present in the Galapagos:

The Management Plan of the Galapagos National Park (GNP 2005) recognizes that an enormous effort has been invested in the last three decades to attack the effects and not the real causes of the problems... To be able to effectively change the current path of Galapagos we must look at the archipelago from different perspective, one that will permit the identification of real causes of the crisis. (Tapia et al. 2009)

What is absent in the discussion to date is a framework in which to align our understanding of the urban and natural systems and a framework in which to identify ways forward to a sustainable future for the community resident on the islands. Key to the transition is the displacement of fishing as the primary economic driver in the island economy by a rapidly growing tourist economy. Most tourists visit for boat-based tours in which little of the income reaches the island population, thus the growth has little effect locally.

This is changing, however, to capture locally more of the benefits of tourism. Local skills and services need to be created to ensure the growth is not only in the boat traffic but also contributes a land-based tourism in which residents can participate. The challenge is therefore identifying how this might be developed without adding to the problems created by a reliance on products and produce shipped from the mainland, as is described in chapters of this volume, and to identify a transition strategy by which a more resilient future can be realized. A component in this transition will be reconsideration of the urban forms to manage the growth in population without a commensurate expansion of the urban footprint nor the negative consequences of consumption.

In this volume, we have brought together researchers working with CAS theory in both natural and human systems. The work here is the outcome of a workshop held in October 2016 at the Galapagos Science Center in Puerto Baquerizo Moreno on San Cristobel island in the Galapagos that came about from discussions between Justyna Karakiewicz, Carlos Mena, and Stephen Walsh in which they recognized that their work, respectively, in urban and natural research drew upon a common underpinning, CAS theory. This offered a framework in which to consider the implications and opportunities of population growth on the islands.

The following chapters are organized to lead the discussion from the background to human settlement to move into the theoretical tools to understand the context. Current conditions are then examined to illuminate the challenges and to understand what has occurred both top-down through regulation and bottom-up through emergent activities. These insights are then applied to postulate how further change might occur, using the CAS concept that interventions can lead to productive change.

The volume starts by providing the background to understanding the urban challenges of the islands and progresses to set out the theory to understand these opportunities. In Chap. 2, Jaime López and Diego Quiroga describes the physical condition and situation of the islands focussing on the history of their urban settlements and the general parameters of the natural and urban ecosystems. They note that the urban areas are the loci of most human activity on the islands and also where most invasive species and contamination occur. Regulations have not been effective in containing human activity and the inefficient use of resources, particularly land

surface, makes the problem worse than it might be. Noting that urban settlements are necessary but negative influences, the authors call for a deeper understanding of these areas and their role in the environment.

In Chap. 3, Michael Batty, Luís M. A. Bettencourt and Michael Kirley then introduce CAS theory and its application in urban settlements. Rather than conceiving of such settlements as static, the authors use CAS to consider the dynamic nature of urbanism. From this, they develop from a general modeling framework to characterize coupled urban natural systems, extending the characterization presented in coupled human and natural system (CHANS) models. The coupled urban natural systems framework provides insight to guide urban development that delivers more resilient outcomes which, in turn, can inform sustainability planning in the Galapagos.

The path to a sustainable future requires change and that change will take place in a global context. Fjalar de Haan, Diego Quiroga, Stephen Walsh, and Luis Bettencourt turn our attention in Chap. 4 to the transformative change that must occur to move a society from the current unsustainable trajectory and explore how urban centers can be drivers for positive change. The authors consider the change of scale at which these drivers act to enable socio-economic transition. The changes that have occurred in the island can be understood as part of larger systems of change and also that the transitions that occur in a place may be consequences of needs elsewhere. As they note, “the place in transition is not necessarily where the transition ‘comes from’.” Addressing the question whether growth in the urban population might be a driver for positive change, they frame this in complexity theory to consider self-organizing and co-evolutionary change to postulate how such change might occur and argue that the next transition should be essentially *galapagueña*, that is, a distinctive and locally defined transition.

The following chapters apply these approaches to current conditions and provide a foundation for exploring change. Chapter 5 by Stephen J. Walsh, Kim Engie, Philip H. Page, and Brian G. Frizzelle considers the changes that have occurred in the Galapagos as ecotourism has grown in value, and the declaration of natural parks has limited the economic activity of the fishing population. The authors employ the framework of a coupled natural-human systems to develop an agent-based model of fishing and tourism and explore five scenarios of change on the islands. They note that social, administrative, and organizational systems have failed to keep pace in the change, revealing points of failure that have exacerbated problems in the balance of human and natural systems. The chapter concludes with reflections on implications more generally for agent-based models and complexity theory in human-environmental interactions.

The next chapter looks more closely at the regulatory systems. Diego Quiroga provides a more detailed history of human settlements on the Galapagos Islands in Chap. 6, in particular at the development of regulatory controls. He documents the changes in population and activity over time, with the consequent risks to the environment that underpins the economy. In this history, he reveals how top-down and emergent processes have worked together to transform the islands and their environment, documenting in this the complex adaptive system that has operated there and the opportunities for intervention within the system.

The major economic driver in the island systems is tourism and any consideration of future opportunities for transitions to sustainability must address this economy. Paola A. Espin, Carlos F. Mena, and Francesco Pizzitutti present a systems dynamics model for tourism in Chap. 7 to articulate in particular the dimensions of sustainability for the islands. The model illuminates the mechanisms by which the tourist industry influences the islands and their economy and provides particular insights to the questions of scale and feedback in the system. The social and economic implications of tourism strategies are explained as are the environmental dangers of an ever-growing tourism economy to sustain unconstrained population growth, a path that can lead to collapse.

The last two chapters bring design approaches to bear in understanding how the preceding material can be interpreted to inform urban change. In Chap. 8, Justyna Karakiewicz takes these insights into a design-led thought experiment to consider how urban development can be the agent of positive change. She uses Holling's cycle of adaptive change and panarchy to develop a model of the natural, urban, and knowledge cycles and then applies these to inform specific strategies for urban interventions. The chapter considers specifically the opportunities in the challenges inherent in the handling of waste, the management of invasive species and the provision of potable water and illustrates interventions using material from design studios held in San Cristobel between 2014 and 2017. These challenges are addressed by changes to urban form and economic activities and postulate a *galapagueña* resilient urban future.

A design approach can be used to enable a broader engagement in decision-making to effect these transitions in urban form. Mark Burry, Camilo Cruz, and Geoff Kimm generalize the design approach in Chap. 9, outlining how computational methods in design might be used more generally to support end-user engagement and communication into design action. The model postulates a decision-making approach in the generation of architectural form by considering the specificity of human settlement needs in the Galapagos Islands and the conditions of the complex adaptive systems as described in earlier chapters. A proof of concept system is presented using a reactive scripting environment.

Together the chapters in this volume provide a theoretical insight to a sustainable island future, consider examples of change that are occurring and postulate how interventions in urban settlements might be realized through design.

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**Part I**  
**The Galapagos as a Living Laboratory**