Acta Científica 26(1-3):121-134, 2012

IN SEARCH OF AN ADAPTIVE SOCIAL-ECOLOGICAL APPROACH TO UNDERSTANDING A TROPICAL CITY

Ariel E. Lugo[1], Carmen M. Concepción[2], Luis E. Santiago-Acevedo[2], Tischa A. Muñoz-Erickson[1], Julio C. Verdejo Ortiz[2], Raúl Santiago-Bartolomei[2], Jimena Forero-Montaña[3], Christopher J. Nytch[4], Harold Manrique[4], and Wanda Colón-Cortés[5]

[1]International Institute of Tropical Forestry, USDA Forest Service, Río Piedras, PR
[2]Graduate School of Planning, University of Puerto Rico, Río Piedras, PR
[3]Biology Department, University of Puerto Rico, Río Piedras, PR
[4]Department of Environmental Sciences, University of Puerto Rico, Río Piedras, PR
[5]*Proyecto Caribeño Justicia y Paz*, Río Piedras, PR

ABSTRACT

This essay describes our effort to develop a practical approach to the integration of the social and ecological sciences in the context of a Latin-American city such as San Juan, Puerto Rico. We describe our adaptive social-ecological approach in the historical context of the developing paradigms of the Anthropocene, new integrative social and ecological sciences, and the social and ecological conditions in San Juan. The problems faced by tropical cities are more complex than implied by isolated studies of their sociology and ecology, a situation that demands a higher level of integration of available knowledge, i.e., a transdisciplinary approach. Underscoring our effort was the added challenge of making our work understandable and useful to the citizens of San Juan, while maintaining academic rigor in our research. Our working definition of Social-Ecology is "the combination of the social and ecological both objectively and subjectively at the level of the individual and the community to assure a healthy and livable society".

INTRODUCTION

As the complexity of global environmental issues increases and our civilization becomes increasingly vulnerable to forces that humans themselves have unleashed, scientists are forced to seek novel solutions and approaches for coping with the Anthropocene, the era of human domination over the world (Crutzen 2002). From a technological perspective alone it is fascinating to observe the application of new technologies that facilitate research at all scales of space and time at which the effects of the Anthropocene on human and natural systems occur. Some of these technologies include remote sensing, geographic positioning and information systems, smart phone technology, wireless data transmission, and

powerful computers that process unprecedented quantities of data and execute global models that require months of computing time for a single run. Although illuminating to the understanding of the biophysical processes that influence ecosystems, this explosion of available technology for addressing global environmental phenomena falls short in providing an understanding of the scope of issues that we face as a civilization and much less their solutions. Similarly, the continuing failures of classic economics to anticipate boom-bust cycles and conserve vital biodiversity have been attributed to the narrow focus of the discipline and have led many to suggest alternative economic theories such as biophysical economics (Hall and Klitgaard 2012). Technology, classic economics, and biophysical sciences all fall short, because the problems of our society are as much social problems as they are problems with a biophysical foundation. We ignore either aspect at our own peril.

Luckily, it is now axiomatic that the Anthropocene requires a coupled social and ecological approach to the issues facing humanity (Pickett et al. 1997, Turner et al. 2003, Redman et al. 2004, Ostrom 2009). Moreover, there is a fast growing literature within academic circles that focuses on defining transdisciplines that seek the right combination of social and ecological approaches to address the multi-dimensional and complex problems of the world (Esbjörn Hargens and Zimmerman 2009, O'Brien 2009, Salas Zapata et al. 2011). In this essay we review and accept these new approaches as important, in fact essential, for making progress in the solution of the environmental and social problems that people face, particularly in cities. We are interested in developing a practical approach to the integration of social and ecological sciences that is adaptable to the particular social and ecological situation that we face in the Latin-American tropics.

A CHANGING PARADIGM FOR DEALING WITH PEOPLE AND THE ENVIRONMENT

The Anthropocene era not only requires us to understand the fundamental changes that occur in social and ecological systems, but it also requires a different approach to conservation. Kareiva et al. (2011) suggest that we jettison idealized notions of nature, parks, and wilderness and forge a more optimistic, human friendly vision for the relationship between people and the environment. They emphasize that the focus needs to center on protecting a nature that is dynamic and resilient, that is in our midst rather than far away, and that sustains human communities. The implication is clear; the focus of a human-nature relationship has to be personal and relevant. The same argument was made earlier by Macnaghten (2003) who observed that public support for global environmental problems has decreased and that the public interest in environmental issues is more likely to be attended when the environmental problems intersect with their personal experiences and interests. As an example, people are unlikely to become engaged in the issue of sea level rise as long as it is presented in terms of sea level increases of millimeters per year over a century. However, when an unprecedented tidal surge floods the New York City subway system and destroys countless coastal communities, personal experiences come to the forefront and people will be more likely to pay attention to this particular global phenomenon of the Anthropocene.

Personal experiences contribute to the type of deliberative, reflexive, and adaptive relationships in society that lead to novelty, social transformation, and adaptability (Macnaghten 2003, Leach 2008) and constitute a new paradigm for cultivating innovative social-ecological approaches among city dwellers. Deliberative approaches require bringing together "diverse

actors to render explicit, and discuss and negotiate, their particular views of the world" (Leach 2008, p 1792). "Reflexive governance goes further to engage with the implications of plural framing of what constitutes the social-ecological system, and the implications of Sustainability goals, recognizing that these are contingent and conditioned by divergent social values, historical experiences, interests, and institutional commitments" (Leach 2008, p 1792).

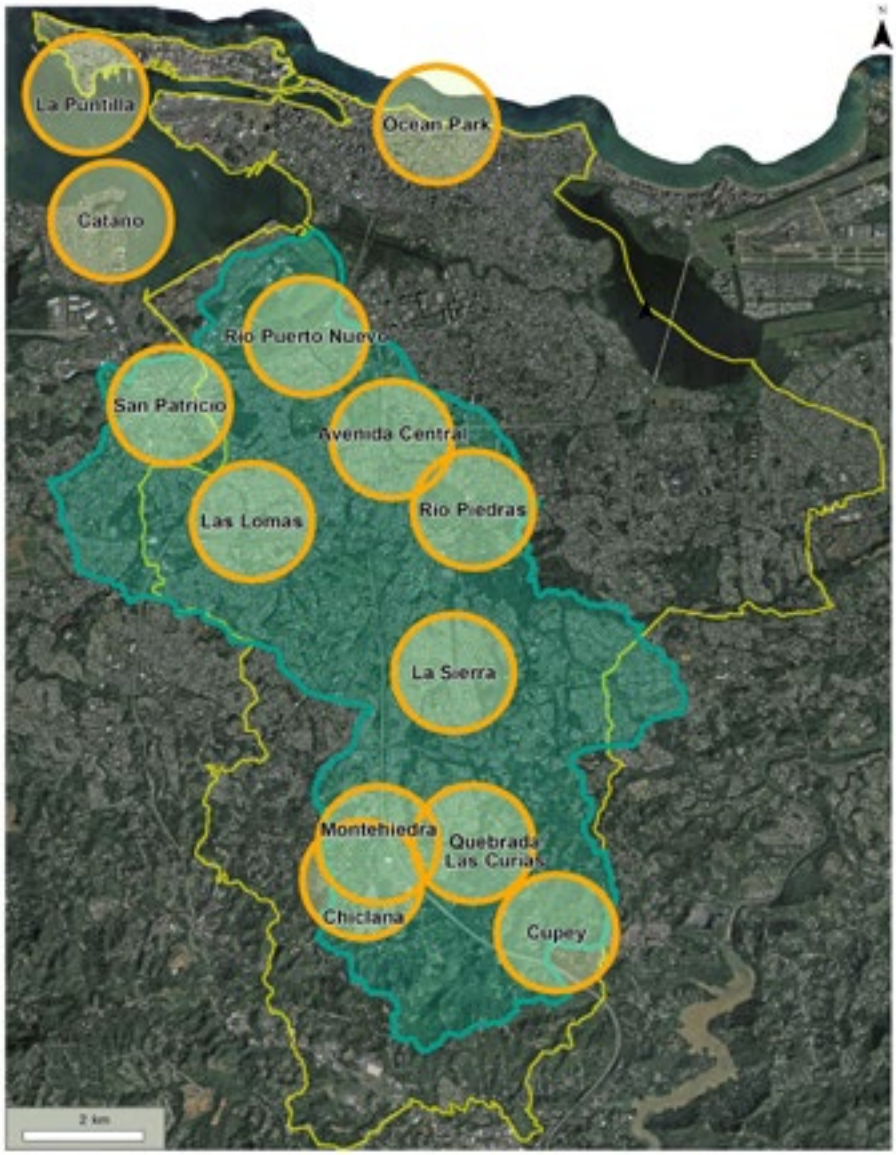
"Adaptive governance emphasizes flexibility, experimentation, and learning as strategies for anticipating and dealing with unintended consequences." (Leach 2008, p 1791). This type of governance is appropriate to situations of rapid change and high uncertainty like those of the Anthropocene. In an analysis of eight cities that take sustainability seriously, Portney (2003) found that but for one city, the most consistent characteristic that bound the cities together was that they all had an aggressive indicators program, meaning they collect information from which to learn and adapt as conditions in the city change. Notably, another common characteristic among these cities was that their sustainability efforts were initiated by non-profit, non-governmental organizations, demonstrating the importance of inclusivity in city governance and the promotion of innovation.

Adaptability within a human social-ecological ecosystem occurs within both the social and ecological components of the ecosystem and more interestingly and controversially occurs as a result of the interactions between the cultural and ecological subsystems of the human ecosystem (Gual and Norgaard 2010). Gual and Norgaard (2010) reviewed empirical examples of evolution and coevolution within biotic and cultural systems and proposed a theory for the coevolution between the social and ecological systems (their Figure 1). The controversy of whether or not cultural systems affect the evolution of the biota and vice versa is outside the scope of our discussion. However, the point that we emphasize is that all components of the human ecosystem have the capacity to evolve, and do so; and in so doing adapt to the changing biophysical and cultural environment created by humans of which urban systems are the most visible and potentially dominant. Such evolutionary change is at the heart of the innovation needed to make these systems adaptable, resilient, livable, and desirable.

WHY A SOCIAL-ECOLOGICAL APPROACH?

There is always a justification in any disciplinary research effort to improve understanding and knowledge of natural or human systems through multi- and interdisciplinary scholarship, and such justification remains true of social-ecological research. Scientific research enlightens understanding, informs policy, and should benefit people. However, the benefits that humans derive from research are not always direct, and it is common for large portions of scientifically derived knowledge to remain isolated within the walls of academia and government and not yield to people all the benefits that such knowledge could deliver. A major justification for social scientists and ecologists to come together into a social-ecological modality of research is to jointly seek ways to enhance comprehension of complex social-ecological systems, to improve the access and quality of knowledge to people, and to engage a solution-seeking sector of society in order to advance the optimal development of humans. Therefore, the social-ecological approach is consonant with UNESCO's 2009 report of human development, which stated that the objective of human development is to assure that "…people develop their potential, improve their possibilities, and enjoy the necessary freedom to live the life they aspire."

Figure 1. Social-ecological sampling grid for the Río Piedras River Watershed and the city of San Juan. The yellow boundary delineates the municipality and the colored area delineates the watershed and sub-watersheds of the Río Piedras. The 13 orange circles are the half-kilometer buffer surrounding each sampling point.



IN SEARCH OF THE SOCIAL-ECOLOGICAL APPROACH

While the concept of social-ecological systems has been influenced epistemologically by perspectives from the social sciences (e.g., cultural theory in anthropology, human geography, etc.) and the physical sciences (e.g., complexity theory), only recently has it coalesced into an integrative approach with the explicit collaboration between ecological and social scientists to understand resilience in social-ecological systems (Lugo 1991, Folke 2006, Berkes et al. 2002). Yet, even with these

Table 1. Social and ecological indicators for the city of San Juan, Puerto Rico. Social data are from the U.S. Census Bureau American Community Service and apply to 2011 and from the Instituto de Estadísticas de Puerto Rico (2011) unless otherwise indicated. Environmental indicators are from the USDA Forest Service, International Institute of Tropical Forestry at Río Piedras, Puerto Rico.

Climatic Life Zone sensu Holdridge (1967)	Subtropical moist
Mean annual rainfall range (mm)	1,509-1,755
Mean annual temperature range (Centigrade)	25.7-25.9
Annual temperature range (Centigrade)	23.9-27.2
Elevation range (meters)	0 to 150
Forest cover (percent)	17
Green Area cover (percent)	50
Population	389,714
Percent male to percent female	45.9 to 54.1
Percent under 18 yr to percent over 65 yr	21.3 to 17.5
Population change (2000-2010) in percent	-6.40
Land area (square kilometers)	126.74
Population density (inhabitants per square kilometer)	3,075
Median age of the population	39.5
Educational attainment population 18 years and over	
Percent high school graduate	46.8
Percent bachelor's degree or higher	42.6
Mean family annual income (dollars)	45,381
Percent under $10,000 to percent over $100,000	24.0 to 10.4
Employment status population 16 years and over (percent)*	
Employment rate	44.6
Unemployment rate	16.8
Labor participation rate	46.3
Percent families below poverty level	40.6
Housing units	189,489
Means of transportation to work (percent)	
Car, truck or van (drove alone)	70.5
Car, truck or van (carpooled)	11.0
Public transportation (excluding taxicab)	10.4
Walked	5.8
Others (taxicab, bicycle, motorcycle)	2.3
Vehicles available per unit of occupied housing	
None	42,179
One	60,425
Two or more	42,390
Violent crimes and other felonies**	
Homicide	232
Robbery	1,560
Rape	9
Aggravated assault	345

Table 1. Social and ecological indicators for the city of San Juan, Puerto Rico. Social data are from the U.S. Census Bureau American Community Service and apply to 2011 and from the Instituto de Estadísticas de Puerto Rico (2011) unless otherwise indicated. Environmental indicators are from the USDA Forest Service, International Institute of Tropical Forestry at Río Piedras, Puerto Rico (continuación).

Burglary	1,604
Theft/Larceny	5,954
Auto theft	1,421
All violent crimes and other felonies	11,125

*Although U.S. Census data do not correspond to figures provided by the Puerto Rico Department of Labor, the data suggest a trend in labor force indicators. According to the Puerto Rico Department of Labor, preliminary unemployment rate for San Juan was 11.7 percent for 2011.
**Puerto Rico Police Department, San Juan Region.

developments, the social-ecological approach to the study of cities is relatively new for both the social and ecological sciences. For example, the 5th edition of the dictionary of sociology (Abercrombie et al. 2006) does not mention the term or the approach. Similarly, recent books on urban ecology (Breuste et al. 1998, Nimelä 2011) recognize the importance of sociology to understanding urban systems but are silent on fully integrated social-ecological approaches. Finally, Pickett et al. (1997) presented a formal articulation of the approach to study a city as a social-ecological system by ecologists and social scientists.

The notion of ecosystem services is an obvious way of illustrating the connections between the ecological systems that supply the services and the social systems, which benefit from their successful delivery (Nimelä 2011). Redman et al. (2004) emphasized that the relationship between social and ecological systems should be focused on their interactions to shed light on the social dimensions of ecological change and the ecological dimensions of social change. Building on the work of G.E. Machlis and others, Pickett et al. (1997, 2011) diagramed the many interactions between social and ecological systems and advocated an ecosystem approach to the study of these interactions. Specifically, they discussed the advantages of using a watershed approach for delineating subsystems, tracking mass and energy fluxes of social ecological systems, and as an integrating tool, to tie together information from different sources (Pickett et al. 1997, 2011). They also suggested, as we will do, that a city is a human ecosystem with social and natural components (a social-ecological system).

Our mixed group of social and natural scientists dedicated two years to the development of this transdisciplinary effort, which we describe below. Our approach involved a diverse series of activities that immersed our group, which had not worked together before, in a variety of intellectual exercises of discovery and self-improvement that expanded everyone's horizons and thrust us into a higher level of understanding of how a city works and how we might approach its study.

We agreed that a social-ecological approach is characterized by:

- The inclusivity of as many sectors of the city as want to be included.
- The dependency on all available knowledge, regardless of discipline of origin.

- The synthesis of such knowledge.
- Its focus on human wellbeing and the sustainability of the institutions and ecological systems that support both humans and their institutions.
- An integrated explanation of the processes and social-ecological interrelations that take place in the city.
- Recognition of the importance of the knowledge, perceptions, awareness, and experiences of urbanites with their surrounding environments (local knowledge) to the production of knowledge and decision-making processes in the city.
- Taking into consideration the way decisions are made both individually and institutionally.

If we are correct on our depiction of the characterization of a social-ecological approach for understanding how cities function, we can immediately list the challenges that must be overcome by a group of budding social-ecologists as they transition their work from a disciplinary to a social-ecological approach. The most immediate challenge is to overcome the traditional disciplinary barriers that isolate information and limit the scope of analysis. This is facilitated if we agree on a common vocabulary that would assure that we use the same meaning for commonly used, but differentially defined concepts in our respective fields. We also need a new and open attitude towards collaboration and sharing of data and insights. This should lead to sharing both problem identification and solutions to issues. Such shared and open collaboration requires respect for all participants and their particular disciplines and points of view as well as the development of trust among all participants. The strength of collaborations is soon tested during the decision-making process of developing methodologies, analysis and interpretation of data, and citizen involvement in the scientific method. Group participants must assure that the group always has access to the best information available, an outcome that is facilitated by the breadth of disciplines and knowledge groups present in the team. Knowledgeability, or the coordination of such diversity of information sources, becomes a major issue with which to contend for social-ecological teams. The success of the group in dealing with acquired knowledge is critical to its effectiveness and allows the group to develop and depend on networks of information exchange to advance understating. As these information networks develop and prove effective by containing data collected reliably and with appropriate quality controls, social-ecological approaches require that the group look forward to the possibilities of alternate configurations and states of social-ecological systems within the city.

SAN JUAN, PUERTO RICO

San Juan is a tropical city with a Hispanic heritage that dates back over 500 years. The city is densely populated (Table 1), and is the center of economic and urban cultural activity for Puerto Rico. San Juan is subject to the effects of urban sprawl, overdevelopment, organized crime, top down government, and environmental problems such as heat islands, rising sea level, urban flooding, and polluted surface waters. The social fabric is fragmented by the way the residential districts are laid over the landscape with the resulting in social stratification and low levels of environmental justice. San Juan is also the center of government (municipal, insular, and federal) and hosts many non-governmental organizations and institutions of research and higher learning, including the University of Puerto Rico, the island's leading university. This means that there is sufficient knowledge and means within the city to address social and ecological problems and orient city development towards inclusivity, sustainability, resilience, and livability.

San Juan is a city in a beautiful setting. On the north it fringes the vast Atlantic Ocean, and to the south and east enjoys the vista of the Central Cordillera and the Luquillo Mountains. Over fifty percent of the land cover of San Juan has green cover, which provides the city with a beautiful tapestry of tropical vegetation that together with its interconnected mangrove-lined lagoons give the appearance that the gray infrastructure of the city is embedded within a lush green infrastructure. While this ecological setting is an asset to city functioning, for example the steady trade winds moderate climate and disperse air pollutants, the social indicators are not as favorable for the city (Table 1). The outlook of many of its citizens reflects despair and a sense of impotence in the face of socioeconomic conditions beyond their control. The list of citizen woes is typical of that of many other metropolitan areas, particularly in the tropics: concern for personal and public safety due to rampant criminal activity; concern for public health due to exposure to overflowing sewage lines, dengue epidemics, and Saharan dust; traffic congestion; poor government services; deteriorating and poorly maintained gray infrastructure; official intolerance and limited outlets for public expression and meaningful dialogue with government agencies; a sense of a corrupt and biased governance with resulting social injustice; and dysfunctional government agencies.

Like most world citizens, those of San Juan worry about their quality of life and rather than sustainability seek a livable city. Livability is a concept that is more relevant and attainable to individual city dwellers than the idea of sustainability, which by its nature appears more distant in terms of its payoff for people. The livability of the city, like sustainability, is a concept rooted in the development trajectory of the city, and as such is subject to analysis and improvement (Portney 2003, 2009). Therefore, any progress made in the solution of city woes should not only affect its long-term sustainability, but also its short-term livability and maintenance. The question that we address first is: What is the role of the social and natural sciences in informing such improvements?

TRADITIONAL ECOLOGICAL AND SOCIAL SCIENCES IN THE CITY AND THEIR COMBINATION

The study of the ecological systems of San Juan has surprised ecologists who had a low expectation of the levels of biodiversity that they would encounter in the city environment (Lugo 2010). For example, in the heavily polluted Río Piedras River, a river that originates and has its entire watershed within city limits, ecologists found over 30 aquatic taxa including native species deemed extremely rare in the island (Lugo et al. 2011, Ramírez et al. 2012). How can such a diverse fauna survive in heavily modified and polluted waters? Similarly, native and endemic tree species occur within the city along with introduced tree species, forming novel forest types unprecedented on the island. Bands of introduced granivore birds, including macaws, parrots, and parakeets fly everyday over the city making their presence felt with their loud calls and large numbers and in the process awing urbanites who are unused to such displays of avian abundance. These examples of natural history observation and ecological research within the city illustrate what ecology does best in urban environments: it informs about the nature and extent of green infrastructure within the city, and provides guidelines by which to base actions for conserving the ecological values of the city. When a disturbance such as a hurricane strikes the city, ecological research can measure the effects on city vegetation and help mitigate effects and restore the resilience of urban forests (Duryea et al. 2007). Moreover, ecological studies of the relationship between terrestrial and aquatic systems in the city inform

about the importance of soils and vegetation for improving the quality of urban surface waters. Ecological knowledge also contributes to educating the public about the type and properties of ecological systems within city limits and developing ecological literacy (Orr 1992, Capra 1995). While these ecological activities constitute a significant contribution of the natural sciences to overall city functioning and management, they frequently fall short in effectiveness because ecologists traditionally work alone and communicate the findings of their research to a very limited audience usually missing most sectors of the city.

Social scientists approach the city with a great breadth of disciplinary diversity. They typically consider the environmental, economic, and social conditions within the city in order to make sense of social structures in political, economic, and cultural contexts. The emphasis is on the social causes of both environmental and social urban problems using urban economic models, for instance as well as focusing on the implications of urban sprawl to human health, community, and well being. Considering an example from Puerto Rico, a group of social and environmental scientists teamed up to promote "smart growth" concepts to island development (Juncos Gautier et al. 2009). Understanding the use of power and how decisions are made in such critical processes as the organization and use of urban space are also emphasized by social sciences studies in San Juan. In another example from southeastern Australia, Luck et al. (2009) related vegetation change over 15 to 20 years of socio-economic change in urban neighborhoods. Social scientists share with ecological scientists the reality that their studies, while important and relevant to the understanding and livability of the city, are not generally known to the public and contribute little to the decision-making processes of the city, so well described by the studies themselves.

Most important to our analysis, the problems faced by the city reflect a situation much more complex than implied by isolated studies of the ecology or sociology of the city. Since the city is neither an ecological nor a social system, but a social-ecological system, it behooves those that want to study and understand the city to approach the studies from a social-ecological perspective, rather than from the perspective of individual disciplines. In attempting to do so, one immediately comes to the realization of the complexity inherent in a social-ecological system such as a city, a complexity that transcends the complexity of its component social and ecological systems by themselves. The following examples illustrate how social studies conducted as part of the San Juan ULTRA umbrella revealed unexpected and surprising findings that would not have surfaced if only the ecological or social component were considered in isolation.

Ramos et al. (this volume) found that during the past fifty-years, green area availability decreased in two lower income neighborhoods, while remaining nearly constant in a higher income neighborhood both within the Río Piedras River Watershed. Traditional research at a watershed scale and a more extensive time period does not reveal understanding about the relationship between household income and neighborhood green area availability.

Another study (Santiago et al., this volume) found that much of the population in the Río Piedras Watershed has poor access to parks or other green public areas. Lack of accessibility is compounded by the incidence of criminal activities within the green service areas. As a result, residents may be deterred from using a park during certain hours, and their use for recreation activities is rather limited. By looking at green areas from the residents' perspective, the study underscores the deficiency of this resource despite the nearly 50 percent green cover in the city.

A third study (Santiago Bartolomei et al., this volume) found that the current institutional and legal framework for flood management is ill suited to foster risk awareness and local adaptation strategies for flood-prone communities in the Río Piedras Watershed. Forty eight percent of surveyed residents from flood-prone communities in the watershed did not feel at risk from flooding even though they lived in a FEMA designated Special Designated Hazard Area. Institutional adaptive capacity is further weakened by a lack of attention to the watershed as a planning unit by the central management agencies in the city's governance network (Muñoz-Erickson 2012), thus creating an institutional void in the management of flood risk through land use planning. Once again, a social-ecological analysis is necessary to gain a broader understanding of the sources of vulnerability to flooding.

OUR APPROACH TO STUDYING SAN JUAN

San Juan does not appear to be on a path towards a reduction of its vulnerability to events that result from unresolved social and ecological issues, a situation that degrades life quality and anticipates an uncertain future for many sectors of the population. Therefore, a group of us from the social and natural sciences decided to integrate our collective disciplinary understanding of the city into models and approaches reflective of the academic standards being developed for the new integrative science of social-ecology. Our focus, while academically rigorous, was intentionally designed to be practical and understandable to the people of San Juan, regardless of their academic preparation. This essay introduces a special issue of Ecology and Society where we provide an initial report on how we have worked to conquer the barriers that prevent social and natural scientists from working together and the barriers that prevent academic research results from being communicated to the residents of San Juan. Therefore our research had a dual goal. First, we wanted to improve our understanding of San Juan as a social-ecological system; second, we wanted to share our progress with the residents and organizations in San Juan, so that knowledge could be injected into the information network of the city through public empowerment.

We summarize in Table 2 the key actions that we undertook to develop our social-ecological approach to the study of San Juan. We first made an island-wide call for collaboration in the research, and assembled the research group from those who responded and persevered. From the outset we insisted in maintaining a 1 to 1 ratio of social and natural sciences participants and we worked very hard at developing personal relationships among all participants to assure that the group felt comfortable with each other. We also implemented an extensive participatory approach that included surveys, face-to-face interviews, meetings, and informal interactions to assess the needs and knowledge priorities of different social groups in the city and thus frame research questions that are relevant and timely to issues facing the city Among the intellectual exercises that we conducted were: developing a heuristic model of the city agreeable to all, developing a glossary of terminology with definitions from the social and physical sciences and Webster's dictionary, and involving the general public and government agencies in all our meetings.

A team of natural and social scientists designed resident surveys and selected sampling sites (Fig. 1). We made sure that field sites and questionnaires satisfied required criteria for both social and natural sciences and that a majority of results could be interpreted within a social-ecological context. Data and manuscripts are shared freely within the group. We adopted a watershed approach for extensive studies of

Table 2. Steps and key actions that we undertook to develop our social-ecological approach to the study of San Juan.

1. Setting the social-ecological context
Review of the scientific, policy, media, and gray literature to identify key social and ecological issues that the city faces.
Island-wide calls for review of preliminary context and participation in setting an interdisciplinary agenda.
2. Framing the social-ecological research agenda
Survey of stakeholder knowledge and research needs.
Field trips of stakeholders and scientists along the watershed to deliberate and identify key social-ecological issues.
3. Crossing disciplinary boundaries
Interdisciplinary workshops to frame agenda and develop integrated research plan.
Developed a common vocabulary through a glossary of disciplinary and cross-disciplinary terms.
Set up research teams with a 1 to 1 ratio of social and natural scientists.
4. Building an epistemic community
Developed a heuristic social-ecological model of the city to stimulate deliberation and cross understanding of the different perspectives of the city between natural and social sciences.
Held community forums to communicate and evaluate the research plan with the non-scientific community.
Social and natural scientists deliberated sampling criteria and developed a mutually agreeable sampling network where all of our social-ecological data would be collected (13 sites across the watershed were selected).
5. Collaborative knowledge production
Natural and social scientists collaborated in the development of a household survey to characterize resident's perceptions, use, and management of green areas and yards.
Cross-trained students from the social and natural sciences to work together in the implementation of the household survey.
Every year we held three All-Scientists Meeting to facilitate cross-collaboration among research groups, and an Annual Meeting to synthesize results and share with stakeholders and the general public.
6. Synthesis, Application and Reflexivity
Used social network analysis map to reflect on our role and contribution to the city's knowledge-action network.
Held Synthetic Meeting to link research highlights to our SES system conceptual framework and evaluate the vulnerability and adaptive capacities of the city with respect to the desired futures and expectations.
Developed an education and public outreach program - Registering my Watershed: Knowing and Celebrating the Rio Piedras - that included water sampling activities with schools, restoration events with local community groups, oral history documentation, and an environmental fair.
7. Adaptation and re-organization
Held face-to-face meetings with stakeholders and other community members to evaluate ULTRA's science products and performance and provide input on new necessities.
Re-focusing our research to the role of novel ecological and social systems related to green areas and their contribution to building adaptive capacity of the city.

the city and scaled down to community and household levels for questions addressing smaller scales and more intensive sampling. We cross-trained graduate students and made sure that fieldwork, including administering questionnaires to households, was carried out jointly between physical and social scientists. We conducted workshops especially designed to inform community leaders and the public about our research and we queried the public on changes in research priorities while also informing them of research progress and results. To become a source of information and facilitate its transfer within and outside academia, we established a highly interactive web page where we post the results of all our activities and the public can post geographic-specific information about any point within the study watershed (visit www.http://sanjuanultra.org/). Team members participate in many public and academic fora, reaching thousands of individuals and creating an institutional presence to the study group.

Once we established the sampling grid over the city and assured that all research involved both social and ecological components, the methods used for specialized studies followed the rigor of the corresponding specialties. Not only does the context and interpretation of the research results become social-ecological, but also scientists have undergone a transformation that requires them to think of future scientific inquiries as inter-disciplinary, or perhaps trans-disciplinary endeavors.

A challenge to the natural sciences is recognizing the subjectivity of science, particularly when natural scientists are trained to believe the myth of the objectivity in the physical sciences (Salas Zapata et al. 2011). Accepting subjectivity and recognizing that the researcher is part of the system it studies represent a major adaptive change in the mindset of the natural scientists in our research group. Recognition of the role of subjectivity in research is often accompanied by the acceptance and use of methods complementary to the scientific method.

A constructivist approach recognizes various forms of knowledge acquisition and validation outside of the traditional scientific method. Methods range from purely quantitative to purely qualitative, with most empirical applications falling somewhere in the middle. One measure of integration within our research group is the acceptance and use of methods not traditionally used in respective fields of study. A group of social and natural scientists became familiar with various research methods that frequently pushed them outside their comfort zones.

Another challenge for us was agreeing on a simple definition of social-ecology, one that we can share and explain to the public. The key is to include critical aspects of the new science while using non-technical terminology. We defined social-ecology simply as the combination of the social and ecological both objectively and subjectively at the level of the individual and the community to assure a healthy and livable society. Our search for a practical and adaptive approach to social-ecology in the tropics is far from over, but we have a solid beginning and expect to continue improving in the coming years.

ACKNOWLEDGMENTS

This manuscript originated as part of a keynote address by three of us to the Enrique Marti Coll Urban Congress in San Juan, Puerto Rico in 2011, and was then expanded as part of a graduate seminar in the School of Planning of the University of Puerto Rico. Work was supported by the National Science Foundation under grant number 0948507 and was done in collaboration with the University of Puerto Rico. Olga Ramos, USDA Forest Service, developed Figure 1.

LITERATURE CITED

Abercrombie, N., S. Hill, and B. S. Turner. 2006. The penguin dictionary of sociology. 5th edition. Penguin Books, London, UK.

Berkes, F., J. Colding and C. Folke. 2002. Navigating social-ecological systems: building resilience for complexity and change. Cambridge University Press, UK.

Breuste, J., H. Feldmann, and O. Uhlmann, editors. 1998. Urban ecology. Springer, Berlin Heidelberg, Germany.

Capra, F. 1995. *The web of life*. Harper Collins.

Crutzen, P. J. 2002. Geology of mankind. *Nature* 415:23.

Duryea, M. L., E. Kampf, R. C. Littell, and C. D. Rodríguez Pedraza. 2007. Hurricanes and the urban forest: II. effects on tropical and subtropical tree species. Arboriculture & Urban Forestry 33:98-112.

Esbjörn Hargens, S. and M. E. Zimmerman. 2009. An overview of integral ecology. Pages 1-14 Resource Paper No. 2. Integral Institute, Louisville, Colorado, USA.

Folke, C. 2006. Resilience: the emergence of a perspective for social-ecological systems analyses. Global Environmental Change 16:253-267.

Gual, M. A. and R. B. Norgaard. 2010. Bridging ecological and social systems coevolution: a review and proposal. Ecological Economics 69:707-717.

Hall, C. A. S. and K. A. Klitgaard. 2012. Energy and the wealth of nations: understanding the biophysical economy. Springer, New York, USA.

Holdridge, L. R. 1967. Life zone ecology. Tropical Science Center, San José, Costa Rica.

Instituto de Estadísticas de Puerto Rico. 2011. Instituto de Estadísticas de Puerto Rico, San Juan, PR. [online] URL: http://estadisticas.gobierno.pr/

Juncos Gautier, M. A., J. Hernández, S. I. Vázquez, J. Carbonell, and N. Barreto, editors. 2009. Hacia el desarrollo inteligente: 10 principios y 100 estrategias para Puerto Rico. Centro de Estudios para el Desarrollo Sustentable, Universidad Metropolitana, Bayamón, PR.

Kareiva, P., R. Lalasz, and M. Marvier. 2011. Conservation in the Anthropocene. Breakthrough Journal 2:26-36.

Leach, M. 2008. Pathways to sustainability in the forest? misunderstood dynamics and the negotiation of knowledge, power, and policy. Environment and Planning A 40:1783-1795.

Luck, G. W., L. T. Smallbone, and R. O'Brien. 2009. Socio-economics and vegetation change in urban ecosystems: patterns in space and time. Ecosystems 12:604-620.

Lugo, A. E. 1991. Cities in the sustainable development of tropical landscapes. Nature and Resources 27:27-35.

Lugo, A. E. 2010. Let's not forget the biodiversity of the cities. Biotropica 42:576-577.

Lugo, A. E., O. M. Ramos González, and C. Rodriguez Pedraza. 2011. The Río Piedras watershed and its surrounding environment. USDA Forest Service FS-980, Washington, D.C., USA.

Macnaghten, P. 2003. Embodying the environment in everyday life practices. The Sociological Review :63-84.

Muñoz-Erickson, T. A. 2012. How cities think: knowledge-action systems for urban sustainability. Dissertation, Arizona State University. Tempe, Arizona, USA.

Nimelä, J., editor. 2011. Urban ecology: patterns, processes, and applications. Oxford University Press, Oxford, UK.

O'Brien, K. 2009. Responding to climate change: the need for an integral approach. Pages 1-12 Resource Paper No. 4. Integral Institute, Louisville, CO.

Orr, D.W. 1992. Ecological literacy: education and the transition to a postmodern world, State University of New York Press, New York, New York, USA.

Ostrom, E. 2009. A general framework for analyzing sustainability of social-ecological systems. Science 325:419-422.

Pickett, S. T. A., M. L. Cadenasso, J. M. Grove, C. G. Boone, P. M. Groffman, E. Irwin, S. S. Kaushal, V. Marshall, B. P. McGrath, C. H. Nilon, R. V. Pouyat, K. Szlavecz, A. Troy, and P. Warren. 2011. Urban ecological systems: scientific foundations and a decade of progress. Journal of Environmental Management 92:331-362.

Pickett, S. T. A., W. R. Burch, Jr., S. E. Dalton, T. W. Foresman, J. M. Grove, and R. Rowntree. 1997. A conceptual framework for the study of human ecosystems in urban areas. Urban Ecosystems 1:185-199.

Portney, K. E. 2003. Cities that take sustainability seriously? profiles of eight cities. Pages 178-219 *in* K. E. Portney, editor. Taking sustainable cities seriously: economic development, the environment, and quality of life in American cities. The MIT Press, Cambridge, Massachusetts, USA.

Portney, K. E. 2009. Sustainability in American cities: a comprehensive look at what cities are doing and why. Pages 228-254 in D. A. Mazmanian and M. E. Kraft, editors. Toward sustainable communities: transition and transformations in environmental policy. The MIT Press, Cambridge, Massachusetts, USA.

Ramírez, A., A. Engman, K. G. Rosas, O. Pérez Reyes, and D. M. Martinó Cardona. 2012. Urban impacts on tropical island streams: some key aspects influencing ecosystem response. Urban Ecosystems 15:315-325.

Redman, C. L., J. M. Grove, and L. H. Kuby. 2004. Integrating social science into the long-term ecological research (LTER) network: social dimensions of ecological change and ecological dimensions of social change. Ecosystems 7:161-171.

Salas Zapata, W., L. Ríos Osorio, and J. Álvarez Del Castillo. 2011. La ciencia emergente de la sustentabilidad: de la práctica científica hacia la constitución de una ciencia. Interciencia 36:699-706.

Turner, B. L. I., P. A. Matson, J. J. McCarthy, R. W. Corell, L. Christensen, N. Eckley, G. K. Hovelsrud-broda, et al. 2003. A framework for vulnerability analysis in sustainability science. Proceedings of the National Academy of Sciences 100:8074-8079.

United States Census Bureau. 2011. American fact finder. U.S. Census Bureau, Washington, D.C., USA. [online] URL: http://factfinder2.census.gov/