Personal Statement: Research, Teaching, and Service Activities

John M. Anderies
August, 2007

My interest in the relationship between societies and the environment began 20 years ago when I first came into contact with large-scale clear cutting in the Pacific Northwest. Shortly thereafter, while teaching English in mainland China, I saw first-hand how intense human pressure on the environment can be. These experiences motivated me to embark on a research and teaching career focused on human-environment relationships. My engineering background predisposed me to seek out a graduate program combining quantitative techniques with the study of social and ecological process. I found such a program in the Institute of Applied Mathematics at the University of British Columbia where I completed my Ph.D. under Colin Clark, founder of the field of Mathematical Bioeconomics. My graduate training has provided a strong foundation for my research and teaching career which, to a significant degree, has extended the bioeconomic approach to a wider class of problems than the optimal management of renewable resources. Specifically, I use bioeconomic modeling to explore how institutional factors affect the capacity of societies to cope with uncertain social and ecological change. Enhancing this capacity is important for present-day societies who face the daunting challenge of maintaining critical environmental functions, about which we often understand very little, for present and future generations. Contributing to meeting this challenge is the main driver for the research and teaching activities summarized below.

My research thus far has made significant contributions to the continued development of mathematical bioeconomics through the application of bifurcation analysis and robust control techniques to the study of institutional performance and change in social-ecological systems (SESs). A bibliographic analysis indicates that annual citation rates for my publications are steadily growing, totaling 77 in 2006. My teaching efforts at ASU have focused on developing a vigorous interdisciplinary program combining mathematical thinking with the social and life sciences in the context of a range of interesting, pressing problems such as poverty and environmental degradation. In 2006, I received the Dean's distinguished teaching award in the College of Liberal Arts and Sciences at ASU in recognition of my teaching efforts. This is encouraging evidence that I am engaging students with this subject matter. Finally, the potential of my integrated research and teaching program has been recently recognized by the National Science Foundation through a CAREER award which will contribute to its continued development.

Research

My research focuses on characterizing the dynamics of systems composed of groups of humans, their collectively shared institutions, and ecological processes. Bioeconomics originally treated a narrow class of such systems: renewable resource exploitation in market economies. A portion of my early work focused on extending the bioeconomic approach to study the interaction between human demographics, economic growth, and renewable resource use. While the economic growth literature studies this interaction in the context of optimal growth with environmental constraints, my work casts it in the context of extended predator-prey systems and uses bifurcation analysis to determine how institutional and behavioral factors affect growth paths, i.e. how they either dampen or amplify boom and bust cycles common in predator-prey systems. My exploration of this question in specific contexts including New Guinea (Anderies, 1998) and Easter Island (Anderies, 2000; Pezzey and Anderies, 2003) and in general (Anderies, 2003) highlighted for me the delicate balances between human behavior, ecological dynamics, and institutions that generate thresholds between different classes of model behavior. These delicate balances drew me to explore the effect of more complex ecological dynamics on threshold behavior. I began to focus on specific SESs that, with increased

stress, can exhibit rapid, possibly irreversible change. If thresholds can be located, they can be effectively avoided in an optimally-managed system. In practice, however, they are very difficult to detect. Given this uncertainty, the resilience and robustness approaches, now central to my research trajectory, become important.

Resilience, the capacity to cope with shocks, can be defined mathematically as the size of a perturbation a system can tolerate and continue to function and deliver desirable services. I have applied this concept to rangeland and irrigated agricultural systems to explore how human actions affect resilience (Anderies *et al.*, 2002; Anderies, 2005) and how feedbacks between institutions and ecologies affect resilience over time (Anderies, Ryan, and Walker, 2006). Although a useful tool to understand the dynamics of SESs, the resilience concept is difficult to apply in practice. This fact prompted me to focus on the more practical concept of robustness and, with colleagues, to develop a framework to use it to analyze SESs from an institutional perspective (Anderies, Janssen, and Ostrom, 2004). This framework provides a basis for several projects in my present research portfolio and for my long-term research trajectory.

Robustness, Vulnerability, and the Dynamics of SESs

My long-term research goal is the generation of knowledge that helps address challenges associated with the impact of the emerging global economic system on environmental systems. I focus on the question of how different institutional arrangements cope with uncertainty, interact across scales, and change over time using the robustness framework outlined in Anderies *et al.* (2004). Robust control seeks to minimize sensitivity of system performance to a given class of disturbances. Unfortunately, increasing robustness to one class of disturbances typically reduces system performance and may increase vulnerability to other classes of disturbances. These trade-offs are important not only for policy, but also as a potential mechanism for social change. As SESs evolve, they may tend toward increased robustness to particular disturbances. They may then become vulnerable to other disturbances which can then induce (or amplify) large scale biophysical change (e.g. fire suppression leading to huge forest fires) and social change. As I have explored robustness-vulnerability trade-offs and institutional change in SESs, three fundamental issues have emerged: 1) the need for examples of change in SESs that span large time scales, 2) the need for data from many different examples of SESs and laboratory experiments upon which to base the development of theoretical models, and 3) the need to develop additional tools based on robust control and apply them to SESs. The three projects summarized below address these fundamental issues.

Long-Term Coupled Socioecological Change in the American Southwest and Northern Mexico

This collaborative project involving archaeologists, ecologists, and social scientists (I lead the bioeconomic modeling component) seeks to understand long-term stability and change in the prehistoric American Southwest. As part of this project, I developed a bioeconomic model to examine inherent robustness-vulnerability trade-offs associated with different patterns of investment in irrigation infrastructure and regional trade networks to reduce short-term fluctuations in resource availability (Anderies, 2006). I applied the model to the Hohokam cultural sequence to explore how these trade-offs may have induced the large-scale institutional and social change observed in the archaeological record and how they may induce change in SESs more generally.

Integrated Robustness Analysis of Dynamic Social-Ecological Systems

Here we focus on the use of robust control theory to improve both our understanding of institutional performance and resource management policy. The project has three distinct components: 1) modeling and analysis, 2) database development, and 3) lab experiments. Model development relies heavily on case studies of SESs assembled by E. Ostrom and colleagues at Indiana University. We

are building on her original irrigation and fisheries cases to eventually build an over-time database essential for the study of robustness. Finally, we are developing laboratory experiments to test how uncertainty affects behavior in common-pool resource games. The theory development component, which is leading the database and experimental work, has resulted in several manuscripts on robustness-vulnerability trade-offs (Janssen and Anderies, 2007a; Janssen and Anderies, 2007b; Anderies *et al.*, 2007a; Cifdaloz *et al.*, 2007).

CAREER: Local Context and the Dynamics of Social-Ecological Systems: Beyond One-size-fits-all Solutions to Environmental Problems

The subtitle of Colin Clark's first, and now classic, text is "The Optimal Management of Renewable resources" while that of his latest book on bioeconomic modeling is "Economic Models and Human Behavior". Clark's recent book focuses on how variation in human behavior resulting from changing context contributes to the failure of optimal fisheries management based on simple bioeconomic models. My CAREER project focuses on a this issue more broadly. Guided by the database being developed in my robustness project, a suite of bioeconomic models will be developed to study how local cultural, social, economic, and ecological context affects the performance of institutions and management policies.

Looking forward: My long-term research vision

My research for the next 10-15 years will focus on three tasks associated with improving our understanding of how institutions influence the dynamics of SESs: 1) developing theory through rigorous analysis of bioeconomic models, 2) developing a database consisting of systematically collected data on established variables describing institutional arrangements and ecological conditions in diverse social-ecological settings to inform theory building, parameterize and test models, and develop laboratory experiments, and 3) conducting laboratory experiments involving collective action problems in resource management contexts. To help facilitate this endeavor, I am working with my colleagues Elinor Ostrom and Marco Janssen to establish the Center for the Study of Institutional Diversity (CSID) at ASU (http://csid.asu.edu). CSID will serve as a center for intellectual activity concerning institutions and the dynamics of SESs and will eventually host an interactive database of mathematical models, case-study and experimental data, and advanced tools to visualize the effects of institutions and management policies on the dynamics of SESs. The database is intended to contribute to both the educational and practical policy arenas and will be publicly available to academics, students, and policy-makers alike.

I have, and will continue to, connect my work to the broader community at ASU through participation in the Global Institute of Sustainability (GIOS), the New School of Sustainability (SOS), and the IGERT program in Urban Ecology. I have developed IGERT courses and have worked with many graduate students to develop their ideas using mathematical modeling which, in several instances, has lead to dissertation topics, journal articles, and conference posters. I have also supervised GIOS postdoctoral researchers focusing on the effects of urbanization on bird population dynamics (Anderies *et al.*, 2007b). Finally, the robustness approach I am developing to study SESs will contribute to several sustainability-related research and teaching activities in GIOS and SOS and will be carefully integrated into the SHESC and SOS curricula as discussed below.

Teaching

My teaching focuses on helping students 1) understand the fundamental collective action problems and institutional failures that lead to the inefficient use of resources and the under-provision of public goods, and 2) develop formal quantitative reasoning skills. I have made significant strides toward developing a strong teaching program at ASU and my recent NSF CAREER award will

enable me to continue its development. In every course I have taught at ASU, I have focused on generating interest in quantitative reasoning in students outside traditional mathematical disciplines. My approach, rather than focusing on the logic and mechanics of mathematics, encourages students to learn to use quantitative techniques to "speak" about the world around them.

I have invested heavily in developing several avenues for students to further pursue their mathematical interests at ASU. Through my role as Co-Director and Co-PI of the NSF-sponsored Mathematics and Biology REU program at ASU, I have worked to provide undergraduate research opportunities at the intersection of mathematics and the social and life sciences. I have designed a new course, ASM/BIO 394 *Numeracy in the Life and Social Sciences* to help students take the first critical step in developing their mathematical skills: to see how mathematics is actually used to study social and biological systems. As a follow-up to ASM/BIO 394, I have developed BIO/ASM 424, *Mathematical Models in Ecology* through which interested students can actually become conversant in mathematics. Finally, as part of my CAREER award, I will be developing a practical skills course that will "plug in" to my graduate course, ASB 591 *Institutions, Environment, and Society* along with advanced visualization tools to allow students to further develop their modeling skills in the context of analyzing the dynamics of SESs. At the graduate level I, along with several colleagues in the School of Human Evolution and Social Change (SHESC) have begun to develop a program in Environmental Social Sciences at ASU. This broadly conceived new degree program will include components of mathematical bioeconomics, environmental and resource economics, experimental economics, and computational social science.

Finally, I have been very active in training and mentoring graduate students interested in research at the intersection of the social and life sciences. Many of these students are either associated with the IGERT in urban ecology or have taken one of my courses. Several have taken projects from my BIO 424 course and made them central to their dissertations or transformed them into conference papers, posters, and journal articles. I have directed one M.Sc. thesis looking at the early development of irrigation in the Phoenix Basin post European contact. I am now chairing and co-chairing Ph.D. committees in the School of Human Evolution and Social Change and the Department of Mathematics and Statistics that focus on using mathematical techniques to study the interaction between people and the environment in a range of settings.

Service

While at ASU I have engaged in both professional an national service activities including peer-review of manuscripts, editorial duties, review of research proposals, and participation in proposal review panels as summarized on my CV. In addition to my work on various committees, much of my university service has focused on building new research capacity and restructuring both undergraduate and graduate education in the context of ASU's highly interdisciplinary "New American University" vision. For example, during my appointment in the School of Life Sciences (SoLS), I served on two search committees for new interdisciplinary faculty. While on the SoLS Graduate Programs Committee, I grappled with restructuring the graduate program to integrate the four degree programs from which SoLS was formed.

As ASU evolved, the Department of Anthropology expanded into SHESC to include a broader conception of human-environment interactions and I shifted my appointment from SoLS to SHESC to participate in the development of CSID and a new degree program in Environmental Social Science. As such, my recent service activities have largely focused on getting CSID up and running. This has involved co-chairing a search committee for two new faculty, serving on a search committee for a new coordinator, coordinating the development of the CSID website, and helping prepare the necessary documents for proposing the establishment of a new center.