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# ***Problem and Opportunity: Integrating Anthropology, Ecology, and Policy through Adaptive Experimentation in the Urban U.S. Southwest***

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Scott Yabiku, and Charles Redman**

Natural resource management agencies and governmental programs that fund research are increasingly calling for interdisciplinary research that integrates biological ecology and the social sciences in a way that can inform policy. One fundamental impediment to collaboration derives from the emphasis that biological scientists place on experimentation, which is generally not considered a viable option for anthropologists. We suggest that anthropologists could have additional influence on policy by collaborating with biological ecologists in manipulative experiments that include human subjects. Critical to this approach are the participation of research subjects in research planning and willingness on the part of social and biological scientists to rapidly adopt new hypotheses and control scenarios that may emerge from shifting political and ethical contexts—what we call “adaptive experimentation.” We provide an example of an adaptive experiment being conducted at Arizona State University, which situates urban landscaping, water conservation, and human behavior within the context of problem definition in water management policy.

**Key words:** urban anthropology, policy, research methods, ecosystem ecology, water

## **Introduction**

**W**e have a problem in the U.S. Southwest—a potentially big problem. Precipitation for nine of the last 11 years has been well below normal and many reservoirs are filled to less than half their capacity (ADWR 2006). Some reservoirs are nearly empty (Figure 1). In May 2006, the U.S. Department of Agriculture (USDA) designated 14 of Arizona’s 15 counties as drought disaster areas. Meteorologists are suggesting that this could be a 20- or 30-year drought (Reese 2004). The cities that depend on this water continue to grow at a staggering rate while

politicians and policymakers send conflicting messages to an ambivalent public. Agreements for sharing Colorado River water, a critical resource for 23 million people, are based on data collected during an unusually wet period at the beginning of the last century (Reese 2004). As a result, water allocations upon which planning and development have been based reflect assumptions about water that does not, in reality, exist—a situation that will surely complicate efforts to forge new water sharing strategies.

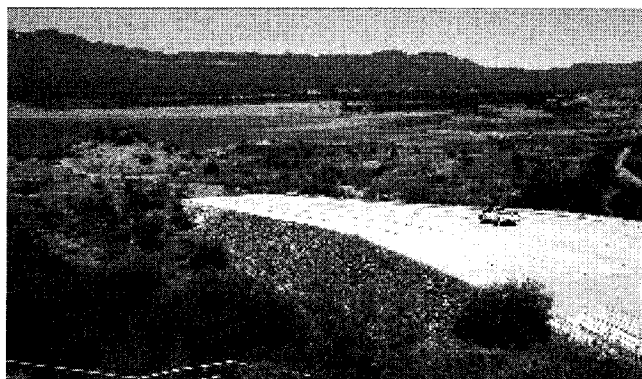
But what is really the problem? Is it insufficient rainfall, uncontrolled growth, an outdated legal framework based on spurious data, all of the above, or none of the above? If the drought ends next year, does the problem go away? Answers to such questions depend entirely on who gets to frame the questions. Policy analysts have written extensively about the politics, ethics, and negotiation of power involved in this process, which they call “problem definition” (e.g., Dery 1984; Weiss 1989). The most consistent point they make is that those who control problem definition also control how policies are developed and implemented. It would be beneficial if anthropologists, indeed any humanists or social scientists in addition to economists, played a role in problem definition. But the problem definition club is rarely open to new members.

On the other hand, innovation and institutional reorganization often occur during crises (Cibin and Grant 1996; Greiner 1972)—opening up political, organizational, and

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**Figure 1.** This abandoned boat launch ramp in Arizona's Lake Roosevelt illustrates a situation found on many reservoirs in the American Southwest that are nearly empty as a result of ten years of low precipitation.



legal systems that comprise policy institutions to new data and ideas (Gunderson 1999). Moments of crisis may provide anthropologists and other social scientists with brief windows of opportunity to engage the policy process. The current drought in the U.S. Southwest has placed researchers and policymakers in an environment of high technical and political uncertainty in which they are reconsidering long-term management strategies and are willing to entertain new ideas.

Opportunities for social scientists to engage environmental policy are further enhanced by developments within academia and research funding agencies. Since at least the 1940s, cultural anthropologists have been influenced by ecological theory (e.g., Rappaport 1984; Steward 1949; Winterhalder and Smith 1992) and ecologists by anthropological theory (Berkes 2004; Dove 2001; Harriss 2002). Odum's (1996) development of the *emergy* concept is an explicit attempt by an ecologist to evaluate the "work" of nature and society on a common basis. A current movement within biological ecology attempts to explicitly include humans—and their historical impacts on nonhuman biotic environments—in models and experimental research (e.g., Berkes and Folke 1998; Cook et al. 2004; Holling 2004). Indeed, the theme of the 2004 annual meeting of the Ecological Society of America was "Lessons of Lewis and Clark: Ecological Exploration of Inhabited Landscapes." As reciprocal influences between humans and the climate and biota of the world have become more global and difficult to manage, natural resource management agencies and government programs that fund research are calling for interdisciplinary approaches that integrate biological ecology and the social sciences (Colwell 2002; FEMAT 1993:831-855). Rather than reducing the human element to predictable, rational, homogeneous actors, some ecologists are interested in integrating richer descriptions of culture and social heterogeneity into the new ecological paradigms of complexity, uncertainty, and resilience (Berkes et al. 2003; Grimm et al. 2000; Hope et al.

2006). Thus, assuming that both parties are willing to learn how to communicate, at least some biological ecologists are interested in what sociocultural anthropologists have to say.

Here we briefly discuss one approach that integrates biological ecologists, anthropologists, and sociologists with policy stakeholders through a method we call "adaptive experimentation" (Cook et al. 2004:467). With this approach interventions are planned as experiments involving in situ human subjects who participate in research design. Hypotheses are added in an iterative process to reflect the uncertainty that accompanies ecological and social complexity. We describe this process using an example of water-related policy and research taking place at Arizona State University.

This discussion focuses on ecological and environmental anthropology, but the general themes are applicable to other fields of anthropology, and other social sciences. Our main points are: 1) anthropology could engage more with biological ecology (among other fields) as one way to enhance anthropology's relevance to society; 2) collaborative research can help social scientists participate as an integral part of the policy development process; and 3) adaptive experimentation enables anthropologists to collaborate with biological ecologists in development of new theory, broadening of public participation in policy, and in bringing more critical and ethical approaches to research and policy.

### **Why should Anthropologists and Ecologists Collaborate?**

Anthropologists have an ethical obligation to improve people's lives (Gow 2002) and ensure that their research becomes integrated into policy in a manner that empowers the general public (Sullivan 2000). Collaborating with other disciplines is one way for anthropology to better impact policy (Wallerstein 2003). It forces anthropologists to convey ideas in ways that are understandable to policy makers by encouraging anthropologists to reconceptualize beliefs and compare ideas with those from other disciplines (Boggs 1994; Hull 1999; Sillitoe 1998; Weaver 1985). Research projects that can integrate biological ecology's emphasis on the natural world with anthropology's emphasis on the human element are particularly needed by policymakers (Endter-Wada et al. 1998; Sillitoe 1998; Sullivan 2000). Increased funding for interdisciplinary collaborations with biological ecologists provides an important opportunity for anthropologists to be more integrated in problem definition.

Interdisciplinary collaboration is also crucial for theoretical and methodological development (Briggs et al. 2006; Kanbur 2002; Wallerstein 2003). Recent theoretical developments in biophysical ecology, such as complexity, resilience, and nonequilibrium dynamics, offer fruitful loci for engagement with contemporary anthropological theory (Berkes and Folke 1998; Scoones 1999; Sullivan 2000). Meanwhile, ecologists are increasingly focusing on human-dominated ecosystems (Collins et al. 2000; Grimm et al. 2000; Vitousek et al. 1997) and recognizing the importance of human social interaction,

perceptions, and behavior on ecosystem processes (e.g., Hope et al. 2006; Naveh 1998). Urban areas are a particular focus (Grimm et al. 2000) and the new challenge is to understand the complex feedback mechanisms between human and nonhuman ecosystem components (Dow 2000; Holling 2004; Scoones 1999; Stepp et al. 2003).

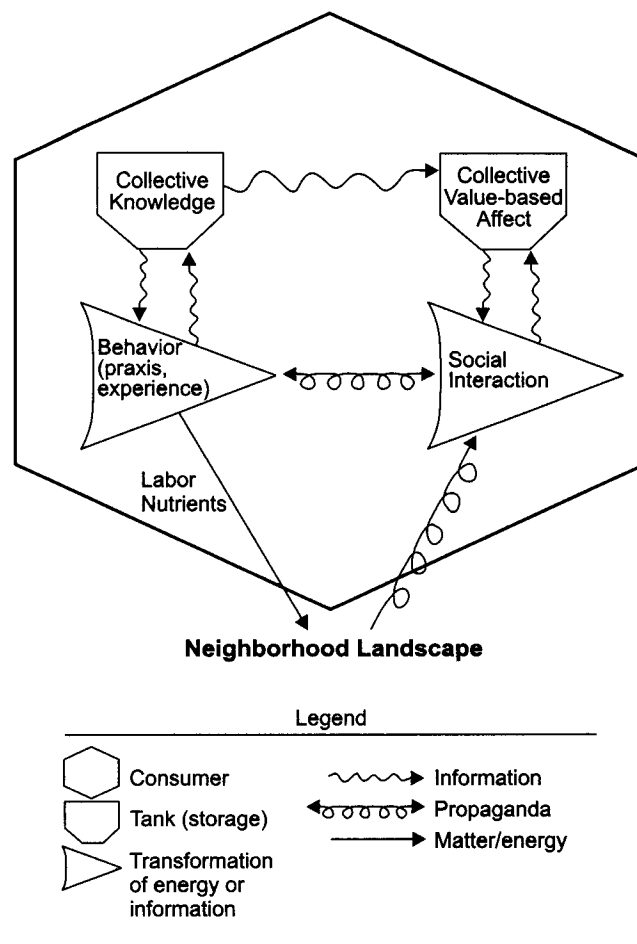
In addition to conceptual developments, there are pragmatic reasons for ecologists to be interested in the social sciences. Ecology has had a profound influence on public policy (e.g., Rachel Carson's *Silent Spring* [1962] and the case of the spotted owl), but research results are often distorted and politicized (e.g., Gray 2004; Myers et al. 2004). A major reason for politicization of ecological research is that it has traditionally excluded people, which allows it to be juxtaposed with social sciences for political purposes.<sup>1</sup> Ecology and toxicology are frequently pitted against economics in the United States. Because ecology has historically been based on nonhuman research, ecologists typically lack the tools to include humans in research (Endter-Wada 1998). Economists frequently fill this niche, but tend to reduce culture to rational actors or homogeneous systems (Cernea 1995).

Attempts to include anthropology and sociology in environmental planning and research include social impact analysis, ecosystem management, and adaptive management projects (Boggs 1994; Cordell et al. 1999; Orlove and Brush 1996). These approaches have helped with large-scale integration of social and biophysical data (e.g., Kusel 1996; Hope et al. 2006) and have encouraged interdisciplinary cooperation. Cognitive approaches like those of Paolisso and Maloney (2000) and Tesch and Kempton (2004) have bridged research on material and political interests with cultural constructions of identity in the policy arena. Policy-oriented social science could build on these approaches by focusing on microscale cultural processes driving behavioral responses to management decisions and providing replicability through experimentation, which can help to reduce the political obfuscation of research findings (Romesburg 1981; Sinclair 1991).

### What is Adaptive Experimentation?

Adaptive experimentation is a term we are using to describe attempts to balance management, policy, research replicability, ethnographic richness, and ethics. Within this framework, large-scale biophysical data, such as satellite imagery, vegetation cover, or biological diversity, are correlated with social data, such as census data or structured survey responses (e.g., Hope et al. 2006). Teams of natural and social scientists collaborate to develop conceptual models that highlight key components of the system and predict potential causal relationships between components (e.g., Figure 2). These models are compared with dominant problem definitions, and results are used to generate testable hypotheses. Interventions are planned as experiments involving in situ human subjects who also participate in research design. Researchers then revise predictive models and hypotheses based on feedback from human subjects.

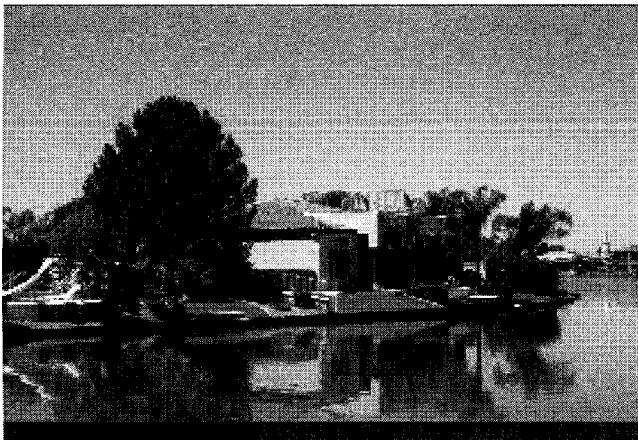
**Figure 2. A highly simplified model of neighborhood human ecosystem dynamics derived inductively from regional-scale data, discourse analyses and participant observation. (Symbols based on Pavao-Zuckerman 2000).**



Adaptive experimentation is based on the principles that underlie adaptive management. Here we discuss a few of these principles because adaptive management is a popular paradigm currently used in natural resource management and environmental planning (Grumbine 1994; Roe and van Eeten 2002; Szaro et al. 1998), hence providing a methodological locus for the integration of anthropology with environmental policy. It also embraces resilience, complexity and uncertainty, which provide theoretical loci of engagement between ecology and anthropology. Most importantly, It needs social science to work.

Adaptive management is a social learning process focused on improving policy and practice in the face of uncertainty (Armitage 2003; Gunderson 1999; Kusel et al. 1996). Social learning is accomplished by including managers, policymakers, researchers, and public participants in planning and implementation in a reflexive, iterative manner.

**Figure 3.** There are landscaping restrictions on new developments and incentives for planting desert vegetation, but many homeowners in metropolitan Phoenix prefer water-intensive landscaping. This upscale development in Gilbert, Arizona includes waterfalls, turf lawns, and 900 acres of artificial lakes on what would otherwise be desert.

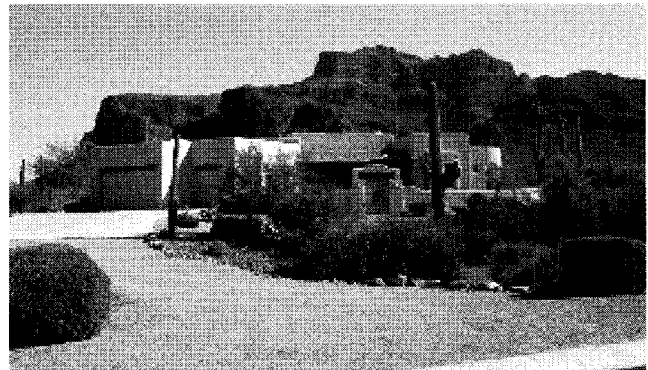


Adaptive management is a quasi-experimental approach used to test different resource management prescriptions, strategies, or policies (Armitage 2003). Adaptive management has included experiments, but almost never controlled replicated experiments. This reduces (but doesn't eliminate) the reliability of transferring lessons learned from one management situation to another (Miao and Carstenn 2006). We suggest that experimental studies that include replicated treatments and controls are also needed to minimize the effects of unknown variables (Eberhardt and Thomas 1991). Effects of experimental treatments can be more confidently attributed to a causative mechanism (i.e., the manipulation) than is possible with uncontrolled experiments (Romesberg 1981).

One of the primary strengths of adaptive management is the potential for social learning (Berkes et al. 2003; Kusel et al. 1996). We believe this not only helps management, but also can help researchers develop better hypotheses and reduce the level of uncertainty that accompanies complex systems research. Experimental design within adaptive experimentation, including the generation of hypotheses, requires public participation for social learning to occur.

Adaptive management is intended to reduce political conflict or create sustainable forms of resource use, with the advancement of knowledge a secondary goal. Adaptive experimentation is intended primarily to produce knowledge applicable to other cases, with more emphasis on controlled experimentation and less on creating specific outcomes. Both approaches share a willingness to embrace uncertainty and surprise that inevitably result from conceptualizing, modeling, and intervening in systems that explicitly include human values,

**Figure 4.** Native desert landscaping is becoming more common in metropolitan Phoenix despite preferences for other types of landscapes.



social organization, unique life histories, and, most importantly, behavior. Also similar to adaptive management, all participants in adaptive experimentation collectively reflect on the experiment to promote social learning, which we believe is crucial for producing high quality research when attempting to integrate biological ecology, social science, and policy.

### **A Case Study in Adaptive Experimentation**

How resilient are the sociocultural, political, and water distribution systems in the U.S. Southwest if subjected to a disturbance like prolonged drought? Researchers at Arizona State University (ASU) received a grant from the National Science Foundation's (NSF) Decision Making Under Uncertainty program to investigate this question beginning in fall 2004 by creating a Decision Center for a Desert City (DCDC) at ASU. With the goal of improving decisions about water use, DCDC brings together regional policy makers, citizens, and academicians from a variety of disciplines who study decision making. The first meetings included managers from the Arizona Department of Water Resources, U.S. Bureau of Reclamation, Salt River Project, Central Arizona Project, and several municipalities. These water managers emphasized their concern about the drought, expressed their difficulties in making decisions given meteorological, political, and legal uncertainties, and noted serious concerns about reactions and behaviors of the general public. Although it is not certain if the drought will continue, it has increased public concerns about long-term water supply. Many policymakers see the drought as an opportunity to rethink long-term water management and use the crisis to lay a political foundation for future negotiations and sharing of water rights. As a result of the possible crisis, researchers and the general public have been provided with an opening to engage policymakers in a nonthreatening atmosphere of innovation provided by the DCDC, at least for the duration of the crisis. Social scientists affiliated with the

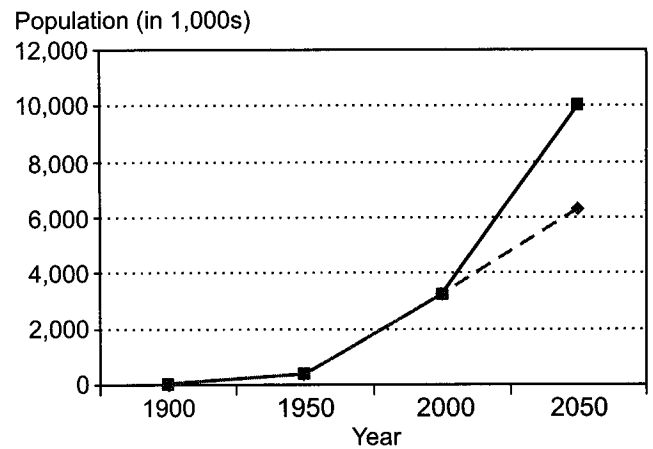
center intend to study all stakeholders, including members of the general public. Here, we briefly discuss the issue of water consumed through landscaping behavior, which is only one of the many relevant issues.

In Phoenix, 40 percent of all water is used for residential landscaping (Jacobs and Holway 2004). The other 60 percent includes industrial, agricultural, commercial, institutional, and indoor residential uses—all of which have seen steady reductions, either through active conservation or residential development of agricultural land. Water managers consider reductions in outdoor residential use a top priority for achieving additional per capita water consumption reduction goals as the population continues to grow. Outdoor residential water consumption in metropolitan Phoenix is largely a function of preferences for high water-use (mesic) landscapes (Martin 2001) (Figure 3). The popularity of desert landscaping is slowly emerging (Figure 4). This is predominately a top-down phenomenon directed by public and private interest groups (Martin et al. 2003). Policies promoting desert landscaping result from the need to meet per capita reductions in water use mandated by Arizona's Department of Water Resources in order to comply with the 1980 Groundwater Management Act's target of zero net loss of groundwater by 2025. Based on growth during the past 50 years and anticipated economic trends, the population of metropolitan Phoenix is projected to be between six and 10 million by 2050 (Figure 5). Given a finite supply of water, per capita use must be reduced to allow development and population growth to continue. Attempts to change residential landscaping behavior include economic incentives, public education, and landscaping restrictions on new residential developments (Jacobs and Holway 2004).

Reducing per capita water consumption is complex and somewhat problematic. Here we present preliminary data from an ongoing adaptive experiment, which suggest a difference between problem definitions of residents we interviewed and policymakers. All qualitative content analysis is based on thematic coding of verbatim transcriptions using the NVivo software. Data included open-ended question responses from 57 interviews and two focus group meetings with residents in the experimental area, and seven in-depth open-ended interviews with residents from throughout the metropolitan area. Data for policymakers include official documents and publications, verbatim transcriptions of recorded meetings and presentations, transcriptions of public television interviews and news broadcasts, and printed news.

Policymakers, including elected officials, municipal board members, and managers from federal, state, and local institutions that supply water, are a heterogeneous group who disagree on many aspects of water regulation and management. However, the recent drought does appear to have created consensus on three key points. First, most appear to agree that the supply of water is finite, at least for the near future. New delivery projects, such as dams, reservoirs, desalination plants or major river diversions are rarely mentioned (Table 1).<sup>2</sup> Arizona's Groundwater Management Act specifically states that pumping of groundwater must be reduced because

**Figure 5. Past population growth in the Phoenix metropolitan area and the range of population projections for 2050 (Sources: Greater Phoenix 2100 Project 2003:19-21; MAG 2004).**



it is a nonrenewable resource. This can be accomplished by either significantly reducing per capita water use or finding additional surface water sources (e.g., rivers and lakes). Attempts to deliver additional surface water are neither financially nor politically feasible at this time. The Central Arizona Project (CAP), which brings Colorado River water to Phoenix and Tucson, cost \$3.8 billion and considerable political capital before it was completed in 1993. The bonds are currently being repaid. Arizona was only able to secure the project through an agreement that they would abdicate CAP water to other states in the event of a crisis. Future negotiations of Colorado River water are not likely to result in more water for Arizona, given the powerful California lobby and an existing underallocation for Nevada.<sup>3</sup> As a senior official of the Arizona Department of Water Management put it: "Though the states are willing to sit down and talk...at a certain point the states are very territorial...I mean, we're not giving up our 2.8 million [acre-feet] and trying to make a deal somewhere, and neither are they."

Further development of in-state surface waters is untenable given that every suitable river within the state is already being used for its water. Although there have been proposals in the past to divert water from rivers in wetter states like Washington, the cost would dwarf that of CAP. Political opposition from within those states, especially regarding environmental issues like salmon habitat, would present formidable obstacles. Finally, a desalination plant built at the Arizona-Mexico border has been an expensive technical failure, not having operated since its completion in 1992.

The second component of the dominant problem definition is that, despite widespread recognition of a finite water supply, policymakers tend not to question the need for urban growth and development (Table 1). According to the director of Phoenix's Water Service Department: "Though the City of

**Table 1. Ranking of Possible Solutions for Southwest Water Shortages Based on the Frequency with which They Were Volunteered by Water Managers and Residential Interviewees from throughout the Phoenix Area During Interviews, Meetings or Spontaneous Discourse (i.e., neither managers nor interviewees were specifically asked to rank a list of solutions).**

Solution	Managers' Ranking	Public Ranking
Desert landscaping	1	1
Water banking and trading of water rights	2	11
Public education	3	9
Waste water reclamation	4	4
Pricing	5	3
Household efficiency (e.g., improved appliance efficiency)	6	8
Enforced water conservation measures	7	10
Diversion of more water from northern states (e.g., secure more Colorado River water or divert rivers from Washington state to flow to Phoenix)	8	7
Desalination	9	6
Limit population growth and development	10	2
Infrastructural efficiency (e.g., cover delivery canals to prevent evaporation)	11	5

Phoenix has been growing continuously for over 20 years, the annual growth rate has only been about three percent with growth in water demand being even lower, about 2.35 percent. Thus, stopping growth would not result in significant water savings." According to a senior official from the Arizona Department of Water Management:

The linkage between water and growth—that gets political. That's hard for state agencies to talk about too much. Our view at the Department of Water Resources is we have nothing to do with the problem. We make sure you have the water for it [growth]. But we don't tell you whether it's too much growth, too little growth, or even what the impacts are of bringing that water in.

Elected and bureaucratic officials, instead, promote a discourse on how to manage growth, or "smart growth" (Morrison Institute for Public Policy 1999:21). As expressed by an elected municipal official:

I believe we will sustain growth. The way we grow in the future will change a bit. The water that we use inside our homes, we get back and clean and bring it right back to you almost gallon for gallon...but what we find bad is how we use our water outside. We will continue to grow, it's going to look a little bit different. You'll find less turf areas. You'll find more xeriscape, smaller yards, but we will continue to grow, and we can sustain it. We will do it right. I know we will.

Reducing per capita use (Table 2) to maintain anticipated levels of growth as far ahead as 2050 (Figure 5) is highly ambitious. The city of Phoenix achieved a 40 percent reduction in per capita water use between 1990 and 2002. This resulted primarily from conversion of heavily irrigated agricultural land (i.e., a small population using high amounts of water) to residential development. Eventually, enough agricultural land throughout the metropolitan area will have been converted that significant reductions in individual residential use will be required.

**Table 2. 2002 Daily Per Capita Water Use for Phoenix Compared with other Municipalities in Arizona and the National Average (Source: American Water Works Association).**

Location	Gallons Per Person Per Day
Phoenix, AZ	226
Paradise Valley, AZ (suburban Phoenix)	400
Tucson, AZ	160
US Average	100

This brings us to the third and final element of the water-management problem definition that we will discuss here. According to the conservation coordinator for the Phoenix Department of Water Services: "The mind-set in Phoenix is that we live in an oasis." Most residents would probably agree, as indicated by these statements:

I came to visit when I was 16. I took one look at the palm trees and I said "This is it. This is where I have to live!"

I love the desert. Where else can you live in a place with no humidity and be only five minutes from the [golf] course.

Since the 1950s, growth has been intentionally linked with the marketing of the Phoenix area as an oasis in the desert (Figure 3). And yet, as expressed by the director of a public water utility, "achieving per capita goals will require significantly changing lifestyle expectations through education." Public education, especially targeted at landscaping behavior, represents one of the most common strategies being discussed and implemented by water managers (Table 1). According to another public official: "The City of Phoenix has been focused on this [education] for many, many years. Working with [others], we have developed conservation plans. That's part of an education plan that's been out there, talking to people about conservation, about lifestyle."

Several managers concurred with the idea that education is:

...a step-by-step process. If we went in and said you've got to cut 50 percent of your water use, people wouldn't know how to deal with that. What we're doing is educating the public on how to address this issue. And we're trying to provide them with a way that they can do it comfortably. When the problem gets to a point to where it has to be uncomfortable, then we will implement something more drastic.

Sustaining growth by reducing per capita water consumption through a transformation of public values, perceptions, and "lifestyle expectations" will require undoing 60 years of successfully marketing Phoenix as an oasis. The tourist and development industries are not likely to abandon highly successful marketing strategies that will be competing with water conservation messages. An advertising campaign launched by the Greater Phoenix Convention and Tourism Bureau in 2005 boldly proclaims "the desert is a myth."

To summarize, our preliminary picture of how the problem is defined by elected officials and managers from federal, state, and local water management institutions is: 1) there is a limit to the supply of water; 2) growth must continue; and 3) growth will be achieved by steadily reducing the amount of water each person uses.

How difficult is it to change people's behavior? Millions of dollars in advertising and public education to promote car-pooling apparently failed to stem the steady increase in the proportion of people who drove to work alone in the United

States between 1970 and 1990 (House Committee on Public Works and Transportation 1991:102). Clearly, we need to achieve a better understanding of behavioral and attitudinal reactions to policies by studying behavior in social, cultural, biophysical, and historical context—what anthropologists do best.

Abundant research shows that attempts to increase knowledge, perceptions, or attitudes through environmental education or media campaigns in order to change behavior are often ineffective (Kollmuss and Agyeman 2002). This is primarily because environmental behaviors are normative. Our behavior is largely based on what we think other people are doing and how we want other people to perceive us (Stone et al. 1997). Landscape water use is probably based as much, if not more, on conformity to perceived norms as individual preferences or knowledge (Dickerson et al. 1992).

Beliefs and attitudes about water conservation, behavior, and knowledge are integrated into information networks, social relationships, and identity-based constructions of landscapes. Biophysical conditions like microclimate, groundcover, shade, vegetation type, and biological diversity further influence how people interact with their children, family members, and neighbors in the landscape. Policymakers are convinced that they need to educate the public to change behavior. But public knowledge is tied to neighborhood social relationships and personal constructions of the landscapes through which behavior is expressed (Figure 2). The policymakers and the public represent different subcultures with different beliefs, social and informational networks, behavioral norms, and knowledge systems. Conservation education and mandatory restriction programs negotiate subcultural differences with results that can be difficult to predict. The policymakers are privileged because the public abdicates responsibility and trust to them, but the policymakers tend not to value public knowledge or attitudes, instead asserting that they must be changed. This type of situation can easily lead to resistance (Escobar 1996).

We have attempted to capture this type of complexity with a simple experimental question. What would happen if we were to change people's landscapes while holding other social and infrastructural variables constant? As an interdisciplinary team of researchers at ASU, we are conducting this adaptive experiment with support from ASU's NSF-funded Central Arizona-Phoenix Long-Term Ecological Research (CAP LTER) project. CAP LTER is a multiyear grant that supports the study of greater Phoenix as an urban ecosystem, with a focus on humans as an integral component.<sup>4</sup> The principle investigators and other researchers associated with the CAP LTER program overlap with the new DCDC, which integrates research into the policy process.

The goal of the experiment is to determine biophysical and human reactions to vegetation change by manipulating residential landscapes at 24 of some 152 homes that form the North Desert Village at Arizona State University's Polytechnic campus. The houses are rental units for staff and student family housing. Four experimental treatments will be

**Table 3. Percent of Interviewees Preferring Different Landscape Types while Viewing Computer Generated Images of Different Landscaping Scenarios for their own Neighborhoods (n = 30).**

Landscape type	Description	Preference
Mesic Oasis	high water-use vegetation and turf grass mixture of drip-irrigated high and low water-use plants, including palms, desert shrubs, succulents, and turf grass	80%
Xeric Native Desert	low water-use, desert-like, non-native plants with drip irrigation native trees, shrubs and cacti with no supplemental irrigation	17%
		3%
		0%

installed, designed to recreate the prevailing residential yard styles and methods of water delivery found in the Phoenix metro area (Table 3) (Martin 2001; Martin et al. 2003). Each landscape type will be replicated at six homes, arranged in mini-neighborhoods around an adjacent common area, which will be landscaped using the same design and plant species. An additional mini-neighborhood of six homes and a common area will be monitored as a control. Residents will be allowed to modify the landscape in the yard immediately around their own home, but not in the common areas.

Pretreatment and long-term, posttreatment data will be gathered for soil respiration, net primary production, soil microflora, arthropod communities, bird and small mammal diversity and behavior, and microclimate. Human social variables and methods include: 1) direct observation of recreation and landscaping behavior using time allocation spot checks and trace behavior surveys (Bernard 2002:402-409,420-424); 2) structured surveys of ecological knowledge, social networks, environmental values, and landscape preferences; 3) content analysis of discursive data; and 4) participant observation. Similar to the garden experiment of Atran et al. (2002), we hope to capture the complex interactions between landscape, social organization, cognition, and meaning. But in our case we will also directly monitor changes in behavior (Figure 2) and we employ an experimental control. Interpretation of experimental results, revisions of explanatory models, and addition of new hypotheses will be greatly enhanced by the qualitative data. Furthermore, we plan to continue monitoring these neighborhoods for at least 10 years, and hopefully more, which will yield a rich historical perspective. We plan to eventually expand the experiment beyond the original 30 houses with multiple replications of the different landscape types.

Pretreatment data were collected between August 2004 and May 2005. The new landscapes were installed during spring and summer 2005. The landscapes require a full year to become established and affect residents. We have only recently begun posttreatment data collection. In this paper we focus on pretreatment data and the adaptive hypotheses, interdisciplinary innovations, and policy implications deriving from the first phase of this project. Our analysis of pretreatment structured surveys includes a linear regression

to predict respondents' ratings of the four different types of landscape treatments. In each of our four models, we include predictors that correspond with the four dimensions that are hypothesized to influence landscape preference: environmental attitudes and beliefs; socialization; aesthetics; and demographic variables. Qualitative content analysis included thematic coding as described above.

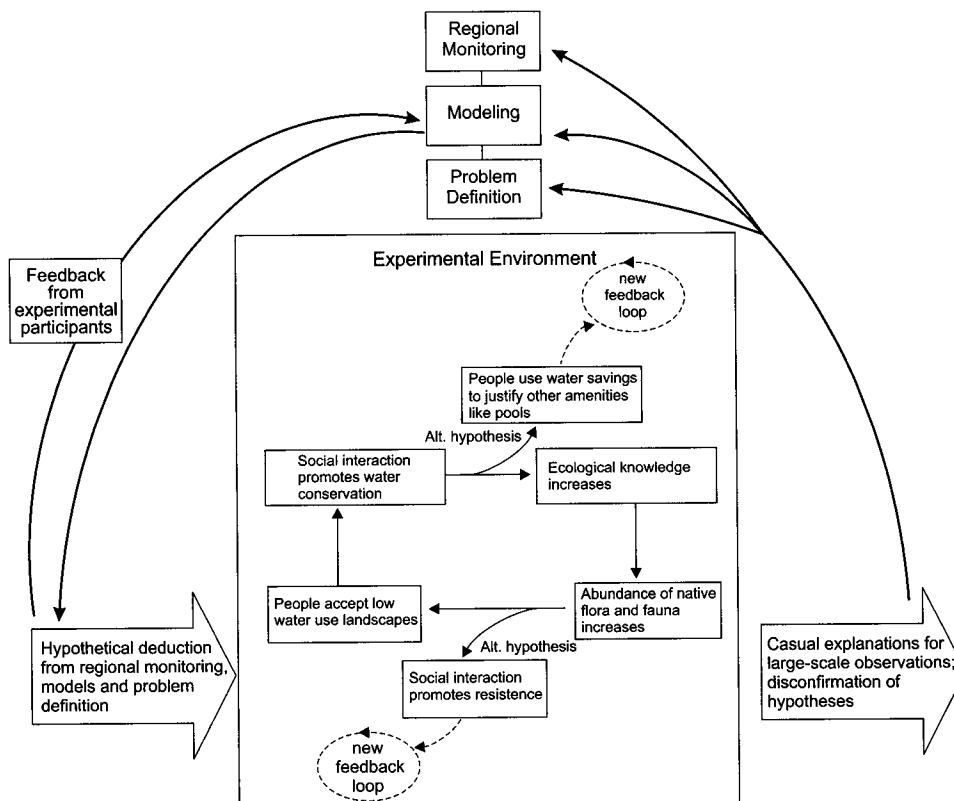
Initial hypotheses about changes in human behavior that might result from habitat manipulation were based on hypothesized causal relationships between biophysical and social variables (Figures 2 and 6). Causal relationships were inductively derived from CAP LTER's large-scale regional monitoring of biophysical and social patterns and processes (e.g., Hope et al. 2006; Larsen et al. 2004; PASS 2003). We are currently modifying hypotheses and predictive models based on analyses of data from public meetings, individual interviews with experiment participants, and emerging problem definitions (Figure 6). Here, we provide two examples of how hypotheses developed as a result of this adaptive process.

In the first case, a CAP LTER survey of 217 residents throughout Phoenix indicated that 68 percent of respondents who viewed computer-generated landscape photos preferred landscapes with turf grass, while 32 percent preferred desert landscaping (PASS 2003). High preference for water-intensive landscapes in yards, particularly those including turf grass, has been replicated by studies throughout the Southwest, including Texas (Lockett et al. 2002; Thayer 1982), New Mexico (St. Hilaire et al. 2003:4), and Tucson, Arizona (Kennedy and Zube 1991).<sup>5</sup>

However, nearly half the respondents in the regional CAP LTER study in Phoenix (PASS 2003) do not have the landscape they prefer, which indicates that they must compromise their preferences. The water managers' problem definition asserts that one such compromise derives from a willingness to conserve water, and this appears to be the case in the nearby city of Tucson (Table 2; McPherson and Haip 1991). Ninety-two percent of Phoenix residents surveyed by CAP LTER (PASS 2003:25) were concerned about the future supply of water. This led to the hypothesis that people in our experimental area will accept desert vegetation in contradiction to their preferences because of concern about water supplies.



**Figure 6. Research Protocol and a Potential Feedback Loop Involving Human-environment Interactions at CAP LTER's Residential Landscape Experiment Site, including Examples of Testable Hypotheses. Note that alternate hypotheses exist, each of which could send the experiment into alternate loops.**



At first, this seems like a straightforward hypothesis. Survey data from the pre-experiment phase of our adaptive experiment replicated the high preference for water-intensive landscaping in yards (Table 3). Residents were shown four photographs of typical homes in their neighborhood that had been digitally altered to resemble the four landscape types that will be installed—ranging from high to low water use. When asked which landscape residents preferred for their own houses, most chose high water use landscapes. Some reasons people in our interviews prefer water-intensive landscapes include:

It doesn't look hot. I mean, the desert landscape looks hot and dry.

It just looks more homey. The others just seemed naked, and exposed, barren...a cactus here and there... I don't know, a naked house.

This gives you the illusion that you live in a cool place, with all this shade. I love the idea it's got shade.

At the same time, interviewees from the experimental area appreciate that there is a water shortage. In our structured survey, 80 percent of respondents agreed that the Phoenix area is facing

a "water crisis." This is partly due to extensive news coverage of the drought, but is also based on first hand experiences:

I've seen it. I've seen it in Arizona. When I was a kid we used to go fishing up in this lake, it's was huge...for miles you could see the lake. Now it's not there.

Furthermore, people we interviewed clearly appreciated that water-intensive landscapes are part of the water shortage problem (Table 1). Several people who preferred water-intensive landscapes were also compelled to add comments like these:

That, I would love, but in this climate it's definitely not practical.

If it's going to deplete other parts of the planet, then why do it? Why make some other part of it a desert and make this a non-desert? That doesn't make any sense.

These anecdotes suggest that behavior and attitudes may change as predicted by the hypothesis derived from regional data and the water management problem definition. Likewise, the linear regression model derived from structured interviews showed that environmental values were negatively associated with preference for high water use (mesic) landscapes ( $p <$

0.05). Other data, however, indicate that this hypothesis may be compromised by fundamental differences between problem definitions of the management and the public. Here we summarize our preliminary interpretation of the public's problem definition and contrast it with that of the policymakers.

Almost every resident we interviewed for this experiment indicated that current and future water shortages are the result of excessive growth and development (Table 1). One interviewee, a realtor, summed it up this way:

When I moved here there was a 250 year water plan. There was enough water for the amount of people in Phoenix at the time to survive 250 years with no rainfall. It wasn't but 10 years later it was a 50-year plan. We don't even have a five-year plan now.... What do I attribute it to? Misuse, overuse, overpopulation, overgrowth. Look at the growth. The growth is outrageous. Look at a map.

Surveys of residents in greater Phoenix conducted by the Morrison Institute of Public Policy (1999) show that 75 percent or more of respondents believe the area is growing too fast. Our interviewees, especially those on the urban fringe, would prefer that more people do not move into the area after them—exhibiting a typical not-in-my-back-yard attitude. For example:

We have the best of both worlds. There's the Tonto National Forest right there and [my husband] is only a half hour from the airport. It's great so long as nobody builds there. I really don't want more people here.

Several people we interviewed were not pleased with the possibility that water needed for new residents must somehow be squeezed out of existing residents. For example:

Every time we turn around there's a housing development. It irritates me.... I think our resources are diminishing, and our water supply.

We have plenty of water, just too many people. And with more coming, I don't know how much I'm willing to conserve before we'll leave.

Comments from residents also suggest belief in a technological fix, with government agencies or private enterprises delivering new technologies to solve the problem.

I think we're running out of the natural water. However, I remember being in 5<sup>th</sup> grade and doing an experiment taking salt water and converting it into desalinated water... we haven't looked at how to utilize the natural resources we have—the oceans.

I think if people want to live here, they're going to find a way to do it.... Come hell or high water, they'll do it.

Meanwhile, the agencies that would be responsible for such innovations are looking for behavioral changes from the general public to fix the problem.

To summarize our preliminary interpretation of the problem as defined by the residents: 1) the supply of water is nearly exhausted; 2) this is a result of too much growth; and 3) we haven't fully explored our technical options for increasing the water supply. Most importantly, the residents clearly do not want desert yards, nor do they want to compromise their lifestyles to allow for additional growth. This problem definition is clearly in conflict with that of the water managers, which led us to an alternative hypothesis: people in our experimental area will resist the imposition of desert landscapes by planting and watering nondesert plants, organizing political opposition to the desert landscaping, or possibly even vandalism.

In our second example, a completely new hypothesis emerged through public participation in research design. CAP LTER's large-scale monitoring has found correlations between biodiversity and socioeconomic variables like income (Hope et al. 2006). The causal mechanisms that drive this relationship are unclear. Thus, we especially wanted to study human reaction to desert plants by planting them in our native desert experimental neighborhood. During public meetings and individual interviews, participants expressed concern about children playing near desert plants with spines. We adjusted the landscape designs by including more nonspiny plants which serve similar ecological functions, placing remaining spiny plants out of harm's way, and placing cages around them to keep children out but not interfere with wildlife. Residents' concerns about spiny plants, combined with their preference for turf grass (Table 3), led to the additional hypothesis that recreational activity is lower in yards with desert landscapes. Thus we might expect less soil compaction or recreational impacts on flora and fauna in native desert yards. We might also expect lower social network density and less exchange of ecological knowledge (Figures 2 and 6). Adaptability on the part of researchers in this case led to a win-win situation in which the concerns of experiment participants were addressed while researchers gained new insights into the interaction of landscaping decisions, behavior, and ecosystem function and structure.

### **Interdisciplinary Collaboration, Complexity, and Problem Definition**

Here we discuss two important outcomes specific to the collaboration of social scientists and biological ecologists. In the first case, we discovered that, over time, Phoenix residents develop a conceptual difference between undeveloped desert and residential desert landscaping similar to biological ecologists. The linear regression model based on landscape preferences showed that the longer people live in Phoenix, the less they prefer xeric or desert landscaping for yards ( $p < 0.10$ ). This is consistent with previous research that found natives to Southwestern areas have lower preferences for xeric and desert landscapes (e.g., Martin et al. 2003; Spinti et al. 2004), leading Martin to suggest that "familiarity breeds contempt" (Christopher Martin, personal communication).

However, we also found that long-term residents are more likely to appreciate natural desert landscapes. This paradox is resolved by content analysis of open-ended questions, which indicate that many long-term residents conceptualize “real desert” as something that belongs “in its place,” not in people’s yards. The tendency of our survey respondents to aesthetically appreciate the desert was significantly correlated with knowledge of desert biota (regression ANOVA  $p = 0.02$ ). Our bioecological collaborators similarly view desert landscaping as inferior to native desert—often referring to it as “Disney desert.” They view desert yards as highly fragmented habitats that cannot support desert fauna, including charismatic species like Gambel’s quail.

Correspondence between ecologists and public participants’ views in this study suggests a fundamental tendency for humans to recognize patterns in desert ecology over time, and to place values on those patterns. These findings further support our adaptive hypothesis discussed above that people in our experimental area will resist the imposition of desert landscapes. Regarding the expert problem definition, it appears that this will be even more difficult for longer-term residents.

We should note that many people in Phoenix prefer native desert landscaping in their yards. This is especially true for high-income residents living on the urban fringe where homes are often built on large parcels of native desert that support more desert species than the urban core. Public policies to overcome the “oasis mentality” may need to differentiate between long-term residents and newer immigrants.

The second important collaborative outcome is an enhanced theoretical perspective for understanding complex feedback mechanisms between human and nonhuman ecosystem components. The large-scale surveys of Hope et al. (2006) found that variation in plant diversity in urban Phoenix cannot be explained using biogeophysical factors that influence diversity in undeveloped desert (i.e., slope, aspect, moisture, soil type, and soil nutrients). By including social variables in a spatial multivariate statistical analysis, Hope et al. found that current and former land use, income, housing age, and elevation best explained spatial variation in plant diversity. They argued that a deeper understanding of the processes shaping the biological and social landscape would require researchers to combine biophysical and cultural “legacy effects”—some of which are easier to link than others.

Historical ecology provides methods for finding patterns of mutual causation between past human activities and biogeophysical processes (e.g., Crumley 1993). In a recent example from the Phoenix area, Briggs et al. (2006) found that 700 years after prehistoric agricultural fields were abandoned, past agricultural behavior still influences plant community structure through legacy effects on soil nutrients and soil structure. Hope et al. (2006) found that recent agricultural legacies were an important predictor of variation in plant diversity throughout metropolitan Phoenix. So far we have not been able to link these biogeochemical processes to current knowledge or behavior.

Hope et al. also found housing age predicted landscape structure, which has been easier to link with current behavior. Technological changes like air conditioning reduced the need for water-intensive landscaping, which previously served as a cooling mechanism. Likewise, the popularity of ornamental species has shifted over the years, but elements of these landscapes remain. Our interviews show that landscaping behavior and water use preferences are constrained by plants people inherit when they occupy a home. This can range from water intensive landscapes in older homes to native desert in newer homes. Other legacy effects deal with expectations tied more to cultural memory. Many people in our experimental group remember the North Desert Village when it was maintained as a lush, mesic landscape by a previous owner. Despite water restrictions and considerable effort involved in hand watering, many residents still seek to recreate that idealized landscape, even if only on a small part of their yard. In all of these examples of biogeophysical and cultural legacy effects, it was possible to identify relationships between behavior (either past or present), space, and time.

But cultural and cognitive legacies can also operate at spatial and temporal scales in contradiction to biophysical processes—leading to cycles and historical trajectories that do not intersect in space or time. In our research it has become clear that expectations about lawns that children can play on, or oases-type yards, are latent cultural expectations derived from other cultural places. They do not conform to ecological constraints without considerable effort, and yet persist over time.

Cycles and historical trajectories that do not intersect in space or time, unanticipated technocultural changes like air conditioning, cultural distinctions between “real” and “Disney” deserts that develop over time, and periodic disturbances like drought combine to form complex socioecological systems that tend to be unpredictable. Per complexity theory, this is because the relative importance of variables cannot be known a priori (Berkes et al. 2003). Our adaptive experiment shows that predictions about the relationships between variables are possible. Hence, even if we fail to predict large-scale systemic behavior, at least we know why. This is an important first step toward understanding complex feedback mechanisms between human and nonhuman ecosystem components.

From a policy perspective, it is often impossible to predict that a policy will have a desired effect and only that effect. Much of policy analysis involves attempts to understand why. It is our opinion that a greater appreciation for complexity should encourage collaboration by all stakeholders. Our research suggests a low potential for the behavioral change desired by water policy experts. On the other hand, the long-term effects of a technological fix widely desired by the general public are not predictable.

## Conclusion

Problem definitions are constructed in particular social settings. Managers, politicians, and powerful developers have cooperated to shape the landscape and water policies in Arizona over the last 100 years—often excluding public

input. Organizational behavior within water bureaucracies further shields managers from public opinion. The public, meanwhile, have formed their own perceptions based on personal histories, observations, and social networks, with limited and often confusing information from managers, politicians, and developers. Paolisso and Maloney (2000) showed that although knowledge of environmental experts and farmers about *Pfiesteria* in Maryland was similar, their views and attitudes differed. The authors attributed this to identity and political and material interests that we suggest are constructed in social networks. In our case, the goal is to merge social networks to produce new problem definitions and, hopefully, sustainable policies.

In a recent meeting we pressed water managers to specify how growth could continue given the water supply. Several managers admitted having some reservations about the sustainability of current growth projections. One municipal water manager admitted that the levels of growth being pursued by developers and elected officials in his city would make it necessary to treat sewage effluent to meet demand for drinking water by 2025. Perhaps this is an example of the unspecified technological fix that our interviewees suggested. In any case, it appears that the water managers can question growth, which suggests a potential point of negotiation between problem definitions.

We also anticipate that managers will reconsider the notion that projected growth can be achieved by steadily reducing per capita water use. Research indicates that public concern about water shortage is high, which could encourage conservation. But comments from interviewees also point out a potentially problematic assumption of the policymakers—that people will accept personal responsibility for the shortage. The not-in-my-backyard attitude and beliefs in a technological solution are exacerbated by the visual impact of water-intensive golf courses and housing developments (Figure 3), all of which make it easier to blame others.

What new problem definition might arise out of this adaptive experiment? We don't know, because the problem will be defined as a result of political and ideological negotiation in a new type of social setting. This setting will be highly dynamic as managers continue to struggle to meet increasing demand for water and experimental participants are forming reactions to their new landscapes and gaining a more detailed understanding of the water shortage. As researchers who initiated this process, it will be our responsibility to make sure that all voices are heard.

Gow (2002) has suggested that anthropology lacks a framework for the application of its knowledge. The North Desert Village experiment and its integration into the DCDC represent steps that can be taken toward building such a framework, including an opportunity to include the local voice in problem definition. We are not suggesting that all social scientists should do this type of research. Thick description, critical theory, and cross-cultural research, for example, will continue to enrich our society, provide new insights, and serve as an ethical "critique of modernism and science" (Gow 2002:301).

Boggs (1994) has argued that anthropologists need to exert influence earlier in the policy process. The North Desert Village adaptive experiment and its integration into the DCDC represent an attempt to involve social scientists and members of the general public in the problem definition phase of water policy in metropolitan Phoenix. The situation we now face is the result of past policies, which did not include input from an empowered citizenry. Existing policies present us with many problems, but crises may provide opportunities to change the very way we define problems in our society. Perhaps we can do better this time around.

## Notes

<sup>1</sup>The recent debate on global warming presents a salient and alarming example. For 30 years messages coming from the scientific community about the reality and cause of global warming were mixed. More recently, consensus has developed that anthropogenic global climate change is very real, but the political discourse continues to exploit past scientific ambivalence. As a result, scientists are organizing politically around a unified message (Kennedy 2004). It will be increasingly difficult for politicians and policymakers to ignore scientific consensus; leading to other strategies such as pitting whole disciplines against each other. Mainstream economists generally favor inaction on global climate change because future costs tend to be externalized or discounted (Bohannon 2004). We will likely see the political discourse shift completely from whether anthropogenic climate change is real, to how much we're willing to pay to fix it.

<sup>2</sup>Although not a "new" source of water, sewage effluent (the "clean" water produced by treating sewage) is often mentioned by policy makers as a way to meet increasing demand. Currently, most golf courses and new developments with large water-intensive landscapes are required to use effluent. The supply of sewage increases with population, so many water providers are investing in effluent treatment infrastructure to meet future demand. According to a municipal water manager, we might see effluent put into the drinking water system by 2025. So far, this topic has not been introduced into the public discourse. This raises an interesting perceptual question: will residents meet the required reductions in per capita use, or decide not to live in metro Phoenix, in order to avoid drinking treated sewage?

<sup>3</sup>A series of laws, agreements, court decisions, and treaties between seven states and Mexico allocate 7.5 million acre feet of Colorado River water to Wyoming, Colorado, Utah and New Mexico. Arizona has rights to 2.8 million acre feet per year, California is entitled to 4.4 million acre feet, Nevada has an annual allocation of 300,000 acre feet, and Mexico receives 1.5 million acre feet. One acre foot of water equals 325,851 gallons, approximately the amount used by a family of four in Phoenix in one year. The agreements were made between 1928 and 1944 when Nevada had little population or political clout. The allocations were based on an estimated total river flow of 16 to 18 million acre feet per year. These estimates derive from data collected during an abnormally wet period. Hydrologists now believe the normal flow may be as low as 12 million acre feet (USGS 2004).

<sup>4</sup>This is an example of how opportunities for social science research have developed via some nontraditional funding sources in an administrative environment created intentionally to integrate the natural and social sciences.

<sup>5</sup>These studies also found that people are somewhat more likely to prefer desert landscapes in front yards as a statement of identity, but prefer lawns in backyards where it is more private and more recreation occurs.

## References

- Arizona Department of Water Resources (ADWR)  
2006 April Drought Monitor Report. Phoenix, AZ.
- Armitage, Derek R.  
2003 Traditional Agroecological Knowledge, Adaptive Management and the Socio-Politics of Conservation in Central Sulawesi, Indonesia. *Environmental Conservation* 30:79-90.
- Atran, Scott, Douglas Medin, Norbert Ross, Elizabeth Lynch, Valentina Vapnarsky, Edilberto U. Ek, John Coley, Chistopher Timura, and Michael Baran  
2002 Folkecology, Cultural Epidemiology, and the Spirit of the Commons: A Garden Experiment in the Maya Lowlands, 1991-2001. *Current Anthropology* 43:421-450.
- Berkes, Fikret  
2004 Rethinking Community-Based Conservation. *Conservation Biology* 18:621-630.
- Berkes, Fikret, Johan Colding, and Carl Folke  
2003 Introduction. *In Navigating Social-Ecological Systems: Building Resilience for Complexity and Change*. Fikret Berkes, Johan Colding, and Carl Folke, eds. Pp. 1-29. Cambridge: Cambridge University Press.
- Berkes, Fikret, and Carl Folke  
1998 Linking Social and Ecological Systems for Resilience and Sustainability. *In Linking Social and Ecological Systems: Management Practices and Social Mechanisms for Building Resilience*. Fikret Berkes and Carl Folke, eds. Pp. 1-26. Cambridge: Cambridge University Press.
- Bernard, H. Russell  
2002 *Research Methods in Anthropology: Qualitative and Quantitative Approaches*, 3rd edition. Walnut Creek, Calif.: AltaMira Press.
- Boggs, James P.  
1994 Planning and the Law of Social Impact Assessment. *Human Organization* 53:167-174.
- Bohannon, John  
2004 Development Spending: Economists Rate Greenhouse Gas Curbs a Poor Investment. *Science* 304:1429.
- Briggs, John M., Katherine A. Spielmann, Hoski Schaafsma, Keith W. Kintigh, Melissa Kruse, Kari Morehouse, and Karen Schollmeyer  
2006 Why Ecology Needs Archaeologists and Archaeology Needs Ecologists. *Frontiers in Ecology and the Environment* 4:180-188.
- Carson, Rachel  
1962 *Silent Spring*. New York: Houghton-Mifflin.
- Cernea, Michael M.  
1995 Socialorganization and Development Anthropology. *Human Organization* 54:340-352.
- Cibin, Renato, and Robert M. Grant  
1996 Restructuring among the World's Leading Oil Companies, 1980-92. *British Journal of Management* 7:283-307.
- Collins, James P., Ann Kinzig, Nancy B. Grimm, William F. Fagan, Diane Hope, Jianguo Wu, and Elizabeth Borer  
2000 A New Urban Ecology. *American Scientist* 88:416-425.
- Colwell, Rita R.  
2002 "NSF's Investment in Converging Frontiers." Speech delivered to the American Chemical Society Presidential Symposium, Boston, Massachusetts. URL: <<http://www.nsf.gov/od/lpa/forum/colwell/rc020818acsboston.htm>> (August 18, 2002)
- Cook, William M., David G. Casagrande, Diane Hope, Peter M. Groffman and Scott L. Collins  
2004 Learning to Roll with the Punches: Adaptive Experimentation in Human-Dominated Systems. *Frontiers in Ecology and the Environment* 2: 467-474.
- Cordell, H. Ken, Anne P. Hoover, Gregory R. Super, and Cynthia H. Manning  
1999 Adding Human Dimensions to Ecosystem-Based Management of Natural Resources. *In Integrating Social Sciences with Ecosystem Management: Human Dimensions in Assessment, Policy, and Management*. H. Ken Cordell and John C. Bergstrom, eds. Pp. 1-12. Champaign, Ill.: Sagamore.
- Crumley, Carole L.  
1993 Analyzing Historic Ecotonal Shifts. *Ecological Applications* 3:377-384.
- Dery, David  
1984 *Problem Definition in Policy Analysis*. Lawrence: University Press of Kansas.
- Dickerson, Chris Ann, Ruth Thibodeau, Elliot Aronson, and Dayna Miller  
1992 Using Cognitive Dissonance to Encourage Water Conservation. *Journal of Applied Social Psychology* 22:841-854.
- Dove, Michael R.  
2001 Interdisciplinary Borrowing in Environmental Anthropology and the Critique on Modern Science. *In New Directions in Anthropology & Environment: Intersections*. Carol L. Crumley, ed. Pp. 90-110. New York: AltaMira Press.
- Dow, Kirstin  
2000 Social Dimensions of Gradients in Urban Ecosystems. *Urban Ecosystems* 4:255-275.
- Eberhardt, L.L., and J.M. Thomas  
1991 Designing Environmental Field Studies. *Ecological Monographs* 61:53-73.
- Endter-Wada, Joanna, Dale Blahna, Richard Krannich, and Mark Brunsona  
1998 A Framework for Understanding Social Science Contributions to Ecosystem Management. *Ecological Applications* 8:891-904.
- Escobar, Arturo  
1996 Constructing Nature: Elements for a Post-Structural Political Ecology. *In Liberation Ecologies: Environment, Development, Social Movements*. Richard Peet and Michael Watts, eds. Pp. 46-68. New York: Routledge.
- Forest Ecosystem Management Assessment Team (FEMAT)  
1993 *Forest Ecosystem Management: An Ecological, Economic, and Social Assessment*. Report of the Forest Ecosystem Management Assessment Team to the President of the United States. Washington, D.C.: U.S. Government Printing Office.

- Gow, David D.  
2002 Anthropology and Development: Evil Twin or Moral Narrative? *Human Organization* 61:299-313.
- Gray, A. J.  
2004 Ecology and Government Policies: The GM Crop Debate. *Ecological Applications* 41:1-10.
- Greater Phoenix 2100 Project  
2003 Greater Phoenix Regional Atlas: A Preview of the Region's 50-Year Future. Tempe: Greater Phoenix 2100 Project, Arizona State University.
- Greiner, Larry E.  
1972 Evolution and Revolution as Organizations Grow. *Harvard Business Review* 50:37-46.
- Grimm, Nancy B., J. Morgan Grove, Steward T. A. Pickett, and Charles L. Redman  
2000 Integrated Approaches to Long-Term Studies of Urban Ecological Systems. *Bioscience* 50:571-584.
- Grumbine, R. Edward  
1994 What Is Ecosystem Management? *Conservation Biology* 8:27-38.
- Gunderson, Lance  
1999 Resilience, Flexibility and Adaptive Management: Antidotes for Spurious Certitude? *Conservation Ecology* 3:7.
- Harriss, John  
2002 The Case for Cross-Disciplinary Approaches in International Development. *World Development* 30:487-496.
- Holling, C. S.  
2004 From Complex Regions to Complex Worlds. *Ecology and Society* 9:11.
- Hope, Diane, Corinna Gries, David Casagrande, Charles L. Redman, Nancy B. Grimm, and Chris Martin  
2006 Drivers of Spatial Variation in Plant Diversity Across the Central Arizona-Phoenix Ecosystem. *Society and Natural Resources* 19:101-116.
- House Committee on Public Works and Transportation  
1991 Hearing Before the Subcommittee on Investigations and Oversight to Consider UMTA FY92-FY96 Authorization Request for Federal Assistance to State and Local Mass Transit Programs under the Urban Mass Transportation Act of 1964. Washington, D.C.: U.S. Government Printing Office.
- Hull, David L.  
1999 Interdisciplinary Dissonance. In *Folkbiology*. Douglas L. Medin and Scott Atran, eds. Pp. 477-500. Cambridge, Mass.: MIT Press.
- Jacobs, Katharine L., and James M. Holway  
2004 Managing for Sustainability in an Arid Climate: Lessons Learned from 20 Years of Groundwater Management in Arizona, USA. *Hydrogeology Journal* 12:52-65.
- Kanbur, Ravi  
2002 Economics, Social Science and Development. *World Development* 30:477-486.
- Kennedy, Christina B., and Ervin H. Zube  
1991 Attitudes Towards Vegetation in a Desert Urban Forest: Creating a Sense of Place. *Journal of Arboriculture* 17(6):159-166.
- Kennedy, Donald  
2004 Climate Change and Climate Science. *Science* 304:1565.
- Kollmuss, Anja, and Julian Agyeman  
2002 Mind the Gap: Why Do People Act Environmentally and What Are the Barriers to Pro-Environmental Behavior? *Environmental Education Research* 8:239-260.
- Kusel, Jonathan, Sam C. Doak, Susan Carpenter, and Victoria E. Sturtevant  
1996 The Role of the Public in Adaptive Ecosystem Management. In *Sierra Nevada Ecosystem Project: Final Report to Congress. Vol. II, Assessments and Scientific Basis for Management Options*. Pp. 611-624. Davis: University of California, Davis, Centers for Water and Wildland Resources.
- Kusel, Jonathan  
1996 Well-Being in Forest-Dependent Communities, Part I: A New Approach. In *Sierra Nevada Ecosystem Project: Final Report to Congress. Vol. II, Assessments and Scientific Basis for Management Options*. Pp. 361-374. Davis: University of California, Davis, Centers for Water and Wildland Resources.
- Larsen, Larissa, Sharon L. Harlan, Bob Bolin, Edward J. Hackett, Diane Hope, Andrew Kirby, Amy Nelson, Tom R. Rex, and Shaphard Wolf  
2004 Bonding and Bridging: Understanding the Relationship between Social Capital and Civic Action. *Journal of Planning Education and Research* 20:64-77.
- Lockett, Landry, Thayne Montague, Cythia McKenney, and Dick Auld  
2002 Assessing Public Opinion on Water Conservation in the Semiarid Southwestern United States. *HortTechnology* 12:392-396.
- Maricopa Association of Governments (MAG)  
2004 View of the Valley in 2040. URL: <<http://www.mag.maricopa.gov>> (November 29, 2004)
- Martin, Chris A.  
2001 Landscape Water Use in Phoenix, Arizona. *Desert Plants* 17:26-31.
- Martin, Chris A., Kathleen A. Peterson, and Linda B. Stabler  
2003 Residential Landscaping in Phoenix, Arizona, U.S.: Practices and Preferences Relative to Covenants, Codes, and Restrictions. *Journal of Arboriculture* 29:9-16.
- Miao, ShiLi, and Susan Carstenn  
2006 A New Direction for Large-Scale Experimental Design and Analysis. *Frontiers in Ecology and the Environment* 4:227.
- McPherson, Gregory, and Renee A. Haip  
1991 Emerging Desert Landscape in Tucson. *Geographical Review* 79:435-449.
- Morrison Institute for Public Policy  
1999 What Matters in Greater Phoenix: Indicators of Our Quality of Life. Tempe, Ariz.: Morrison Institute for Public Policy.
- Myers, Ransom A., Simon A. Levin, Russell Lande, Frances C. James, William W. Murdoch, and Robert T. Paine  
2004 Hatcheries and Endangered Salmon. *Science* 303:1980.
- Naveh, Zev  
1998 Ecological and Cultural Landscape Restoration and the Cultural Evolution Towards a Post-Industrial Symbiosis Between Human Society and Nature. *Restoration Ecology* 6:135-143.

- Odum, Howard T.  
1996 *Environmental Accounting, Emergy and Decision Making*. New York: John Wiley.
- Orlove, Benjamin S., and Stephen B. Brush  
1996 *Anthropology and the Conservation of Biodiversity*. *Annual Review of Anthropology* 25:329-352.
- Paolisso, Michael, and Shawn R. Maloney  
2000 *Recognizing Farmer Environmentalism: Nutrient Runoff and Toxic Dinoflagellate Blooms in the Chesapeake Bay Region*. *Human Organization* 59:209-221.
- Pavao-Zuckerman, Mitchell A.  
2000 *The Conceptual Utility of Models in Human Ecology*. *Journal of Ecological Anthropology* 4:6-30.
- Phoenix Area Social Survey (PASS)  
2003 *Community and Environment in a Desert Metropolis: Summary Results of the Pilot Study*. Central Arizona — Phoenix Long-Term Ecological Research Contribution No. 2. Tempe: Arizona State University, Department of Sociology.
- Rappaport, Roy  
1984 *Pigs for the Ancestors: Ritual in the Ecology of a New Guinea People*, 2nd Edition. New Haven, Conn.: Yale University Press.
- Reese, April  
2004 *Drought Tests Limits of Colorado River Compact*. *Land Letter* 10:9.
- Roe, Emery, and Michel van Eeten  
2002 *Reconciling Ecosystem Rehabilitation and Service Reliability Mandates in Large Technical Systems: Findings and Implications of Three Major US Ecosystem Management Initiatives for Managing Human-Dominated Aquatic-Terrestrial Ecosystems*. *Ecosystems* 5:509-528.
- Romesburg, H. Charles  
1981 *Wildlife Science: Gaining Reliable Knowledge*. *Journal of Wildlife Management* 45:293-313.
- Scoones, Ian  
1999 *New Ecology and the Social Sciences: What Prospects for a Fruitful Engagement?* *Annual Review of Anthropology* 28:479-507.
- Sillitoe, Paul  
1998 *The Development of Indigenous Knowledge: A New Applied Anthropology*. *Current Anthropology* 39:223-252.
- Sinclair, Anthony R. E.  
1991 *Science and the Practice of Wildlife Management*. *Journal of Wildlife Management* 55:767-773.
- Spinti, Jane E., Rolston St. Hilaire, and Dawn VanLeeuwen  
2004 *Balancing Landscape Preferences and Water Conservation in a Desert Community*. *HortTechnology* 14:72-77.
- Stepp, John Richard, Eric C. Jones, Mitchell Pavao-Zuckerman, David Casagrande, and Rebecca K. Zarger  
2003 *Remarkable Properties of Human Ecosystems*. *Conservation Ecology* 7:11.
- Steward, Julian  
1949 *Cultural Causality and Law: A Trial Formulation for the Development of Early Civilizations*. *American Anthropologist* 51:56-82.
- Stone, Jeff, Andrew W. Wiegand, Joel Cooper, and Elliot Aronson  
1997 *When Exemplification Fails: Hypocrisy and the Motive for Self Integrity*. *Journal of Personality and Social Psychology* 72:54-65.
- St. Hilaire, Rolston, Jane E. Spinti, Dawn VanLeeuwen, and Curtis Smith  
2003 *Landscape Preferences and Attitudes Toward Water Conservation: A Public Opinion Survey of Homeowners in Las Cruces, New Mexico*. Las Cruces: New Mexico State University, Agricultural Experiment Station. Research Report No. 750.
- Sullivan, Sian  
2000 *Getting the Science Right, or Introducing Science in the First Place? Local "Facts", Global Discourse—"Desertification" in North-West Namibia*. In *Political Ecology: Science, Myth and Power*. Philip Stott and Sian Sullivan, eds. Pp. 15-44. London: Arnold.
- Szaro, Robert C., William T. Sexton, and Charles R. Malone  
1998 *The Emergence of Ecosystem Management as a Tool for Meeting People's Needs and Sustaining Ecosystems*. *Landscape and Urban Planning* 40:1-7.
- Tesch, Danielle, and Willett Kempton  
2004 *Who is an Environmentalist? The Polysemy of Environmentalist Terms and Correlated Environmental Actions*. *Journal of Ecological Anthropology* 8:67-83.
- Thayer, Jr., Robert L.  
1982 *Public Responses to Water Conserving Landscapes*. *HortScience* 17:562-565.
- United States Geological Survey (USGS)  
2004 *Climatic Fluctuations, Drought, and Flow in the Colorado River*. USGS Fact Sheet 3062-04. Tucson: U.S. Geological Survey, U.S. Department of the Interior.
- Vitousek, Peter M., Harold A. Mooney, Jane Lubchenco, and Jerry M. Melillo  
1997 *Human Domination of Earth's Ecosystems*. *Science* 277:494-499.
- Wallerstein, Immanuel  
2003 *Anthropology, Sociology, and Other Dubious Disciplines*. *Current Anthropology* 44:453-465.
- Weaver, Thomas  
1985 *Anthropology as a Policy Science: Part I, a Critique*. *Human Organization* 44:97-105.
- Weiss, Janet A.  
1989 *The Powers of Problem Definition: The Case of Government Paperwork*. *Policy Sciences* 22:97-121.
- Winterhalder, Bruce, and Eric A. Smith  
1992 *Evolutionary Ecology and the Social Sciences*. In *Evolutionary Ecology and Human Behavior*. Bruce Winterhalder and Eric A. Smith, eds. Pp. 3-24. New York: Aldine de Gruyter.