ENVIRONMENT, ETHICS, AND BEHAVIOR

The Psychology of Environmental Valuation and Degradation

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Editors

1997

The New Lexington Press
San Francisco

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KNOWLEDGE AND ACTION

Cultural Models of Nature and Resource Management in Mesoamerica

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IN THE MAYA LOWLANDS of northern Peten in Guatemala and the southern Yucatan peninsula of Mexico, Maya communities have existed for two millennia in a neotropical rain forest that outside forces have, within just a few decades, brought to the edge of extinction. The sudden turn from sustainable to unsustainable forest use suggests differences in how native Maya and immigrant communities conceive of and manage forest resource systems in the same area. This chapter reports the progress of ongoing research into what those differences are. Our design uses detailed case studies and comparisons of the ways such groups structure, communicate, and implement knowledge of common-pool resources (CPRs) over time. Here we present a preliminary assessment of some of the social and cognitive factors affecting the alarming cycle of deforestation, loss of biodiversity, and community breakdown in lowland Mesoamerica.

This chapter was prepared with the assistance of Elizabeth Lynch, Norbert Ross, Edilberto Ucan Ek', and Valentina Vapnarsky. The work described in this chapter is supported by National Science Foundation grant SBR 94–22587. We would like to thank Tom Simpson, John Coley, Willet Kempton, and the editors for helpful comments on earlier drafts of this chapter.

The research centers on three questions: (1) What is the structure and content of local ecological knowledge (such as biodiversity) that enables successful commons management? (2) What is the character of communication networks that make possible assimilation, distribution, and implementation of the information? (3) To what extent is loss of local knowledge and disruption of communication networks related to a breakdown of the commons? Another issue motivating this research, but not subject to direct empirical test, is, What lessons do microlevel approaches to commons systems hold for the future of global commons, such as the earth's forests, ranges, water, and air?

Breakdown of Mayaland Commons

It will hardly be news to the reader that the rain forests of Mesoamerica, rich in biodiversity, are being destroyed in a steady, systematic manner. Less obvious but perhaps equally important is loss of cultural diversity: cultural knowledge and traditions identified with the rain forest and the management of its biodiversity are also disappearing from the face of the earth. For the past several years, we have been studying folkbiological knowledge among the Itzaj Maya of northern Guatemala—an area where a long-standing rain forest and the indigenous culture it has long harbored are disappearing.

Our initial goal was a comparative study with an eye to determining universal and culturally varying aspects of categorization of and reasoning about the biological world. The pairing of these investigations with undeniable evidence of rain forest destruction led us to believe that knowledge and action may be closely linked. Before describing these observations and their relevance to the present project, we first need to place the issue of resource management in the specific contexts of Mayaland and the commons.

Mayaland

Our study targets two sites: northern Peten (Guatemala) and the southern Yucatan peninsula (Quintana Roo, Mexico). Both sites lie within the forested region of neotropical Mesoamerica known as the Maya lowlands. For more than two thousand years, lowland Mayan speakers have inhabited the area. During the first millennium, a great forest civilization developed in Peten (and, to a lesser extent, in Yucatan). At its height, this classic Maya civilization supported a population of perhaps three million people in Peten (thirty-five thousand square kilometers). Following its collapse toward the end of the first millennium, a postclassic civilization arose in Yucatan (and, to a lesser extent, in Peten) that maintained many of the classic traditions while incorporating elements of Toltec and Aztec cultures. Although the Spanish succeeded in exterminating the Maya priesthood and nobility, Mayan language and (to a recognizable degree) agro-forestry customs survive to the present day.

The demise of classic Maya civilization is associated with archaeological evidence of spiraling population growth, unrelenting warfare, acute nutrient deficiency in human populations, and geometrically increasing rates of deforestation. Dense forest covers reappeared in the postclassic period, when population levels had declined by about an order of magnitude. The Spanish conquest reduced the native Maya population of Peten yet another order of magnitude. From the Spanish conquest until the early 1960s, Peten's population did not exceed 30,000. Since then, government support of logging and agricultural colonization has again increased Peten's population to some 400,000; however, the last remaining native Maya community is now reduced to a few hundred souls. Forest cover has already declined by about half. After some two millennia of recognizable continuity, northern Peten-Maya language and forest culture verges on extinction.

Granted, there may be a causal connection between rising population and deforestation at the end of the classic period. The fact remains that native Maya sustained fairly dense forest cover for the better part of two thousand years with populations at least equal to, and probably much greater than, immigrant populations today. By contrast, the current immigrant population of Peten is poised to destroy the remaining forest within two decades. In the Yucatan peninsula, there are still a few hundred thousand lowland Mayan speakers. But the colonization, privatization, and commercialization of the forest is driven by a much greater influx of people and capital than in Peten, so that the rate of deforestation and degeneration of biodiversity is even more rapid.

In postconquest Peten, access to the forest was implicitly restricted by a combination of natural and cultural constraints—colonists found the forest inhospitable and the harvesting of its products practically worthless to European tastes and the accumulation of wealth (Atran, 1993b). More recently, pressures to "harvest" trees have increased and the Itzaj Maya of Peten have taken steps to legally and physically bound (by firebreaks) areas of the forest they wish to reserve exclusively for their community's use.

In south central Quintana Roo, Yucatec Maya "rebels" were intermittently successful in guarding their forests against intrusion by Spanish

speakers until the beginning of the twentieth century. The Mexican Revolution produced a constitution that provided some legal protection (Article 27) against open access to colonists, raiders, and "free riders" by vesting community rights of land possession and use rights in a commons institution known as the *ejido*. Today, however, the *ejidos* are beginning to break up under privatization pressures consequent to implementation of the North American Free Trade Agreement and the corresponding abrogation of Article 27 of the Mexican Constitution.

Tragedy of the Commons

A commons is a public resource pool that individuals use to physically sustain themselves. As such, a commons is typically subject to overuse if people individually act to maximize their personal gains. Indeed, Hardin's parable (1968) of the tragedy of the commons has framed much of the debate about how to deal with environmental degradation and its human consequences, where "rational" calculation of gains and losses for individual decision makers leads inexorably to overuse and ruin of resources. Individuals have little motivation to conserve if others are simply allowed to "free ride" and reap the fruits of that individual's labor. Actually, it is in that individual's self-interest to maximize (over)use, even though the collective outcome is disaster (see White, 1994, for a recent demonstration).

On the surface, the devastation of tropical forests seems to fit the bill exactly. The rain forest is being treated as a commons, and it is rapidly disappearing, despite increasing attention from the United Nations and other nongovernmental organizations. This attention has been paired with debates concerning how to preserve the forest in the face of realities driven by maximizing utility. In almost every case, two candidate solutions emerge: the imposition of some constraining central authority or privatization of the commons (North and Thomas, 1977; Liebrand, Messick, and Wilke, 1992).

There are, however, empirical problems with each of these alternatives. The problems are not unrelated to the inability of utility theories, with all externalities internalized and values measured and negotiated, to account for even the simplest human-environment interactions in small-scale societies, much less the diverse and complex behaviors in large-scale societies (Rappaport, 1979; Martinez-Alier, 1987; Costanza, 1991). For example, there seems to be no principled way to measure the future preferences of subsequent generations in a world of ever-changing values or to assign negotiable values to sacred or inviolable prescriptions. (Note that an inviolable prescription in society, such as "Do not sell your children," may be violated in practice but the violator is reckoned a sociopath, not a wrongheaded negotiator). In important respects, we believe that the commons discussion needs to be turned on its head; that is, we shall argue that the "normal" state of affairs is often successful management of the commons and that the commons breakdown should be analyzed accordingly, rather than as an inevitability. To make this point, we begin with a brief historical perspective on the commons.

Historical and Contemporaneous Background

In the first place, thousands of cases of local commons management have been catalogued (Martin, 1992), with numerous comparative studies of successful commons management by anthropologists and political scientists (McCay and Acheson, 1987; Berkes, 1989; Ostrom, 1990; Bromley, 1992). Until the forced enclosures at the dawn of the industrial revolution, most of Europe was organized in terms of commons (Stahl, 1969; Yelling, 1977; Rowley, 1981). In fact, until the expansion of the market economy to remote corners of the world, much of the world was so organized. Along with the industrial revolution came political revolution, as a "tragedy of enclosures" forced the breakup and displacement of English and French peasant communities (Darby, 1940; Bruhnes, 1978). In short, the tragedy of the commons is not everywhere and at all times a natural and inevitable state of affairs.

Second, while the debate rages over whether to privatize or collectivize, the track record for each of these options has so far been one of abysmal failure. Collectivization of the commons, as in parts of central Europe and the Soviet Union, for example, has often led to extreme impoverishment. Privatization schemes, as in forced titling of Middle East commons from the Atlantic coast of Morocco to the Swat Valley of Pakistan, has frequently led to the breakdown of social organization, environmental degradation, the rise of factionalism, and famine (Atran, 1986).

Nowhere is the debate over the commons and what to do about them more current or compelling than in Mesoamerica today. Although Mexico, for example, adopted many aspects of the Napoleonic Code, it rejected France's provision against maintenance of the commons *(nul n'est tenu de rester en indivision)* in order to preserve some vestige of the indigenous commons, or *ejidos* (Eckstein, 1966). In this last decade of the twentieth century, however, Mexico and Central American governments have decided to dismantle these enduring commons in order to encourage open access to the market and privatization. Coincidentally, the environments and the cultures that reside within them are suffering

ever-increasing rates of devastation and upheaval. Open-market access, unrestricted immigration, and enclosure may be the most powerful constellation of factors in contemporaneous rain forest destruction in Mesoamerica and elsewhere.

As mentioned earlier, the tropical forests of the Central Maya lowlands once supported a population at least an order of magnitude greater than today's population and sustained it for hundreds of years, or orders of magnitude longer than current rates of deforestation allow. At least on a relative time scale, there simply is no corresponding record of success for either collectivization or privatization of common-pool resources. Nor is it the case the successful commons are possible only under conditions of low population density.

Implications for Mayaland Commons

These observations—of historical continuity and contemporary demise—point to the possibility, directly contradictory to Hardin's thesis, that breakdown of commons occurs not because they are inherently unmanageable but because the long-standing conditions for their management are being destroyed. The challenge is to identify the conditions for successful commons management before this form of management is eliminated from the planet. Given that no other form of management has proven sustainability, it may be a rich source of ideas for successful global sustainability.

Elinor Ostrom and others have done case and experimental studies of the institutional conditions for successful commons, such as rule configurations for appropriating resources, monitoring access, and sanctioning violators (Ostrom, Gardner, and Walker, 1994). Our research focus is more on process than structure, that is, on the mix of psychological, cultural, and ecological factors that condition successful or unsuccessful commons behavior. We believe that a process focus is a good strategy for identifying factors that are candidates for generalization to other contexts.

Current Context

This section describes the populations we studied and their agro-forestry practices. It then outlines our present research focus.

Setting

We are looking at a number of populations that live off the same area or biotope, the lowland Maya forests of southern Mexico and northern

Guatemala. We selected these populations because they differ in their ability to sustain themselves in the same environment. So far we have begun looking at four groups of people: two groups of native Maya Indians and two groups of immigrant Ladinos. Ladinos is the term used to refer to people of mixed or Indian origin that no longer speak their native Maya tongue. The native groups are the Yucatec Maya in south central Quintana Roo, Mexico, and the Itzaj, who are the last Maya native to the Peten forest of Guatemala—once the center of classical Maya civilization. Each of the two immigrant groups is the closest settlement to its respective native group. The immigrant Ladinos that live near the Itzaj have been around on the average for more than one decade but in most cases less than two; immigrants in the group that live near the Yucatec Maya have been around on the average for less than a decade.

Itzaj Maya claim that Ladinos do not recognize that their behavior violates the "natural" rights and duties incumbent upon people and the forest to tend to one another because "there is no heartfelt affection for land they were not born to and which they will abandon." Immigrants, they feel, are detached from their roots *(u motz)* and lineage *(u ch'ib'aloo')*, with Maya using *roots* and *lineage* as interchangeable terms in both organic and social contexts. As a result, the Itzaj feel compelled for the first time in living memory to establish institutionalized mechanisms for delimiting boundaries and for monitoring and sanctioning intruders or freeloaders who appropriate the fruits of another's efforts. In the past, the Maya's cohesive social networks alone may have sufficed to rapidly convey the necessary information and sustain vigilance for forest maintenance.

In Yucatan, the state-supported structure of the *ejidos* helped local communities to maintain closed access until quite recently. Now, the government is forcing the *ejidos* to privatize common agricultural lands while encouraging the communities to "selectively cut" their vestigial forest lands with the aid of private logging concerns. Native Maya communities are attempting to resist in various ways, with sporadic success. A key aspect of social control is the community's periodic assignment of individuals to tend particular trees. These individuals may cut their assigned trees if mature, but premature or excessive cutting can lead to sanctions and loss of tree assignments.

With the reduction of the remaining forests, and the consequent rise in timber prices, the most valuable "high grade" trees (mahogany and tropical cedar) are being cut to the vanishing point. Secondary trees, which are still underexploited in Peten, have become prime timber in the Yucatan (for example, *tzalam,* or *Lysiloma bahamense,* and *chechem,* or *Metopium brownei*). Immigrant communities are felling these at an

awesome rate. Many of these immigrant groups, including influential elements in the community we are studying, are petitioning the government to declare the entire area cattle pasture *(zona ganadera)* so that all constraints on clear-cutting might be lifted. As it is, chain saws can be heard in the village throughout the day, as can the trailers that surreptitiously cart out the felled timber at night.

It is interesting to note that the Guatemalan Ministry of Agriculture is attempting to emulate the Mexican Forestry Department in encouraging selective cutting of remaining forest stands. Local and regional nongovernmental organizations (NGOs) operating in Peten have been granted concessions ostensibly designed to "sustainably develop" the forested areas inhabited by immigrant communities. Using the area of Yucatan that figures in our study as an example of "successful management," these NGOs are strenuously soliciting bids from logging companies to selectively harvest the stands under their "protection." So far, the Itzaj have declined the "protection" of the vice-minister of agriculture and many of the NGOs, but the political and economic pressure on them to "rationally develop" what little remains of a once mighty heritage is great and unrelenting.

Thus, together with the internal cognitive and social makeup of our populations, external political and economic conditions are clearly at work in determining the present and future course of commons management. As long as these external, market-driven pressures dominate, commons management will inevitably run down, although the pace of cultural and biological destruction will likely be different for different groups. Our study of internal factors may not indicate how destruction can be avoided in the face of these seemingly overwhelming external factors, but it might reveal modes of resistance and even recovery should those external factors change.

Groups and Practices

Both the Maya and Ladino groups practice a form of agro-forestry (increasingly supplemented by nontraditional sources of subsistence based on a money economy) and make use of wood in construction. The mainstay of subsistence for each group is so-called slash-and-burn, or swidden, agriculture. In the forest where this technique is applied, the trees are cut and the land fired and cleared so that crops can be planted for a few years, that is, until exhaustion of the nutrients released into the soil from the initial burning of trees and undergrowth compels the cultivator to move on to another section of the forest.

Rates of decomposition are very high in such moist, hot conditions, resulting in lack of humus formation and storage in the top soil (as in temperate forests). Instead, nutrients are cycled between living organisms and recently dead organisms, a network of fine roots and mycorrhiza absorbing mineral nutrients as they are released by decomposers. The result is a nutrient-rich litter layer overlying a nutrient-poor mineral soil with little storage capacity.

Slash-and-burn agriculture addresses two ecological problems inherent in agricultural production: plant competition (weeds) and nutrient recycling (Vandermeer and Perfecto, 1995). By burning off competitors before seeding a plot, the farmer provides an initial advantage to crop plants. Through burning, the nutrients normally stored securely in plant materials are released en masse to provide a rich growing environment for the crops.

A brand-new crop layer is able to use up only a portion of the nutrients suddenly released from a multistoried old-growth forest patch. After the first burning, there are usually enough excess nutrients to allow rapid regeneration of "weeds." If there were no further burning, the forest would also regenerate at close to a normal pace, that is, at about the rate of regeneration that follows a light gap in the canopy by natural processes of tree fall.

More often, the initial weed growth is burned or mulched to provide nutrients for yet another crop cycle. Additional burning further reduces the already diminished capacity of the forest floor to hold the nutrients. If the normal nutrient-cycling process of the forest continues to be interrupted in this way, runoff and leaching will produce a net export of nutrients and an inability to support vegetative growth. The land must be abandoned and new fields cleared and burned. With broad-scale clearing and forest degradation, remaining surface nutrients are rapidly leached by sun and rain, the few seeds that sprout die in the hot sterile soil of the clearings, massive species extirpation occurs (about ten to thirty animal species for every plant species), and soon the land is no longer able to sustain appreciable human population (Gomez-Pompa, Vazquez-Yanes, and Guevara, 1972; Hecht and Cockburn, 1990).

There are, however, at least six critical differences between Maya and Ladino swidden practices that lead to differences in sustainability (Atran, 1993b). In what follows, the "Maya" practices are most pronounced in the case of the Itzaj, and the "Ladino" practices most pronounced for the Yucatan group; nevertheless, such differences are also more or less discernible for the Yucatec Maya and Peten Ladino groups (see Nations and Nigh, 1980, for a similar distinction with respect to the Lakantun Maya of Chiapas).

1. Ladinos burn the crown of hills. This greatly impedes forest regeneration because hillside soils wash out more easily, exposure to sun is higher, and the wind-borne dispersal of seeds is reduced (seeds borne higher up disperse farther and wider through random weighted motion). The Maya, in contrast, spare hill crowns.
2. Ladinos build large fires that are often hard to control. The Maya, in contrast, clear an area with several smaller fires. Smaller, cooler fires may volatilize less nitrogen, a limiting nutrient for plant growth (Tom Simpson, personal communication). Moreover, Maya fires are calibrated to the requirements of different types of tree stands, which are interspersed throughout their agricultural plots, or milpas. (In fact, the Itzaj Maya have tried to provide Ladinos instruction in how to set proper fire breaks around and within their plots.)
3. The Maya habitually allow longer fallow periods (five to seven years) than Ladinos (two to three years) and traditionally leave a forest patch to recover to maturity after it has been alternately used and left fallow for the span of a person's lifetime (about fifty years).
4. The Maya avoid broad clearing by ensuring that the extent of forest surrounding a clearing is at least several times greater than the clearing. In Peten, the area of forest a given Itzaj tends is usually anywhere from five to twenty-five times the area of the clearing. This tended forest "reserve" is harvested for wood and other (nontimber) forest products but neither burned nor clear-cut. Where Ladino and Maya plots touch, the Maya ensure that tree stands *(t'ool~che')* ring their milpa plots.
5. In some cases, Maya forgo successive burning and shifting altogether. After the first burn, an Itzaj farmer may stay on the same milpa plot for a working lifetime (in one case, forty-six years to date), using mulch from weeds to provide a low but constant level of productivity. This is much more labor-intensive than burning but also much more sustainable in the long run.
6. Maya plant a greater multiplicity of crops, which probably supports a greater degree of associated biodiversity (such as insects and other animals). To an appreciable extent, the structure of a Maya plot emulates the layered and diverse structure of the surrounding forest. This provides the Maya a richer and more resistant stock of staples while also facilitating forest regeneration.

In short, unlike the Maya, the Ladinos tend to deplete the rain forest until it is no longer renewable. This is not to say that the Ladinos do not

appreciate the value of the forest or the future to themselves or their families. Like other developing-world colonists, they may well understand their dependence on biological diversity far more accurately and acutely than urban North Americans do and in ways that compare favorably with native peoples. As we shall see, however, this understanding of human-animal-plant interdependency may be asymmetrical, with little concern for or awareness of how reciprocity between people, animals, and plants sustains biological diversity and cultural survival. By contrast, Maya understanding of human-plant-interactions tends to be more symmetrical, involving reciprocal dependencies.

Research Focus

Why do the Ladino immigrants and Maya differ in their treatment of the rain forest? We are trying to understand these differences in behavior by experimentally probing a mix of psychological, cultural, and ecological variables. Our initial hypothesis was that the two groups had very different understandings of the rain forest, understandings that are tied to action. These understandings can be thought of as *tacit theories* (Medin, 1989) or *mental models* (Gentner and Stevens, 1983), that is, structured forms of causal knowledge that can be used to guide reasoning and make predictions. Specifically, we thought that the Ladinos might be destroying the forest not deliberately but rather through a form of ignorance, in other words, behaving in accordance with a mental model that, if it were accurate, would lead to sustainability. The problem from this perspective would be that they have the wrong mental model, either because it is insufficiently informed or because it qualitatively fails to capture the kinds of human-nature interactions that would actually sustain those interactions.

Of course, a variety of other possibilities may give rise to differential behavior in the Maya and Ladino groups. For example, we are also looking at differences in social networks. Differences in social structure may be tied both to cultural obligations (such as social sanctions for inappropriate land use) and to the diffusion of knowledge concerning practice. In addition, we have been attempting to develop measures of cultural and moral commitment to the rain forest: for example, perceptions of mutually shared obligations in tending the forest.

The general idea from the perspective of mental models is that the less you know about the natural world, the more you are liable to destroy it, either through ignorance or intention. Also, the denser your social network, the more redundant and assimilable the information about proper

and improper ways of dealing with the environment; but the more varied your social network, the greater the possibility of a cognitive division of labor and the more flexibly and efficiently information can be dealt with. In other words, there may be optimal forms of diverse but overlapping communication networks for processing and acting upon information (see, for example, Granovetter, 1973, Hammer, 1983). Finally, a moral—perhaps even sacred—concept of tending the forest, as a counterpart to the concept of the forest tending people, encourages awareness and action toward a mutually shared future.

Our project is at an early stage. We have some initial observations that reveal some surprising similarities across groups as well as some striking differences. This chapter represents a progress report, and we are far from any definitive conclusions. Nonetheless, our initial findings are quite intriguing. Before describing our research in detail, however, we further motivate it by placing it in the context of a more general project of studying people's understanding of the biological world.

We came to study the commons by a somewhat circuitous route. Our original focus was on universal principles of folkbiology, but this research led us inexorably to questions of culture and ecology. In particular, our previous and ongoing research on folkbiology among Maya and people who live in North America (specifically the Midwestern United States) suggested to us that Maya seamlessly integrate cognitive, cultural, and ecological factors whereas the Midwesterners do not.

For example, although both cultures seem to categorize and rank biological species in taxonomies that correlate significantly, and in almost identical fashion, with the Linnaean taxonomies used by biological systematists, the two cultures reason from their taxonomies differently. Our measure of reasoning is category-based induction (Rips, 1975). A number of phenomena associated with category-based induction have been identified (Osherson and others, 1990), and we focus on three of them. The first phenomenon is similarity, and the judgments of both groups conform to it: the closer the taxonomic distance between two categories, the more likely it is that people will believe that the two categories share some novel or unfamiliar biological property (such as susceptibility to some novel disease). For example, if people are told that eagles have some novel biological property, they are more likely to believe that falcons also have this property than that ducks do. The other two phenomena differ in character across cultures (Lopez and others, forthcoming).

First, consider typicality. Both groups more readily project properties to a whole category from properties of a typical category member than from an atypical one. For example, North Americans believe that novel properties true of sparrows are more likely to be true of all birds than are novel properties of atypical birds like turkeys. Itzaj also show typicality, but the basis for typicality is different. For the North Americans, typical birds are medium-sized birds similar to lots of other birds. In other words, typicality is based on central tendency. For Itzaj Maya, typicality is more like an ideal (see also Barsalou, 1985). For example, the wild turkey is the most typical Itzaj bird, whereas sparrowlike birds are judged atypical. So a novel property true of wild turkeys is more likely to be judged true of all birds than is a novel property true of sparrowlike birds.

For all plant and animal life forms, Itzaj Maya judge typicality on the basis of a combination of morphological, cultural, and ecological factors. Typical animals and plants, such as the jaguar and the guano palm, have high cultural value, but no single cultural dimension defines that value: jaguars are lords of the forest; guano palms are sources of shelter and food. Animals and plants judged to be typical tend to be large and otherwise physically striking, but size or physical salience alone does not suffice: cows are bigger than jaguars, but they are not typical. All typical animals and plants have notable roles in Maya conceptions of human ecology: the jaguar's home range, forty to fifty square kilometers, defines a forest section; the wild turkey's presence means that game abounds (in ecological terms, wild turkeys are "sentinel species"), and where guano palm is abundant, human settlement can be assured. In sum, for the Maya, cultural, ecological, and morphological properties are part of a single organizational scheme.

This does not mean that the Maya assign predefined special purposes or functional signatures to taxonomies and make inferences based on them. Instead, it implies a sound conceptual infrastructure for the widest range of human adaptation to surrounding environmental conditions. In other words, the aim appears to be to maximize the relevance of the biological world to human understanding. This is not the case with the North Americans' judgments using taxonomically based inferences. As with scientific systematics, for the North Americans the ideal goal appears to be to maximize inductive potential regardless of human interest. In other words, the motivating idea is to understand nature as it is "in itself." For Itzaj, and arguably for other small-scale societies, their structure works to maximize inductive potential relative to human interests.

The third phenomenon is diversity (see, for example, Osherson and others, 1990). Itzaj "fail" to apply the so-called diversity principle to biological reasoning with animal (such as mammal) and plant (such as palm) taxa, and concern with ecology is one key factor responsible for the results. According to the diversity principle, if other things are equal (as

when taxa are equally typical), then a biological property shared by two taxonomically close taxa (for example, a wolf and a coyote) is less likely to be shared by a superordinate group of taxa (such as mammals) than a property shared by two taxonomically distant taxa (for example, a wolf and a gopher). The diversity principle corresponds to the fundamental principle of induction in biological systematics: that is, a property found in any two organisms is likely found in the smallest or lowest-ranked taxon containing the two. Suppose, for example, that you find a property in a turkey and in the bacterium *E. coli*. Using the diversity principle, you can justifiably attempt to project that property to the lowest taxon containing *E. coli* and turkeys, namely, all organisms.

North American folk seem to use their biological taxonomies much as scientists do when using unfamiliar information to infer what is likely in the face of uncertainty. Informed that goats and mice share a hitherto unknown property, they are more likely to project that property to mammals than if informed that goats and sheep do. By contrast, Itzaj tend to use similarly structured taxonomies to search for causal ecological explanations of why unlikely events should occur: to give one example, bats may have passed on the property to goats and mice by biting them, but a property would not likely need an ecological agent to be shared by goats and sheep. In short, common properties among ecologically associated but taxonomically distinct things imply a transfer of properties through a mediating agent, whereas common properties among taxonomically closely associated things imply inherent similarity. This seems to be a way Maya spontaneously think, but not a way people in the United States usually think. In other cases, the Maya employ a form of ecological diversity (which pair comes into contact with more other organisms), which is not necessarily correlated with morphological diversity. Apparently, context-sensitive causal concerns about the relationships between taxa serve to block context-free uses of diversity-based reasoning across taxonomies.

It is not that Itzaj do not understand the diversity principle. In tests with diversity-based reasoning in other domains, Itzaj performed successfully as a group. For example, when asked whether a person should spend a fixed amount of time visiting one part of a forest or many parts in order to determine if that forest should be settled or cultivated, Itzaj invariably opted for the latter alternative.

Note that in both the U.S. and Itzaj cases, similarly structured taxonomies are providing the distance metrics over which biological induction takes place. For the North Americans, taxonomic distance indicates the extent to which underlying causes are more likely to predict shared

biological properties than are surface relationships. For Itzaj, taxonomic distance suggests the extent to which ecological agents are likely to be involved in predicting biological properties that do not conform to surface relationships. A priori, either stance might be correct. For example, diseases are clearly biologically related; however, distribution of a hitherto unknown disease among a given animal population could well involve epidemiological factors that depend on both inherent biological susceptibility and ecological agency.

More generally, what "counts" as a biological cause or property may be different for folk, like the Itzaj, who necessarily live in intimate awareness of their surroundings and those, like North American folk, whose awareness is less intimate and necessary. For Itzaj, awareness of biological causes and properties may directly relate to ecology, whereas for most North American folk the ecological ramifications of biological causes and properties may remain obscure. Historically, the West's development of a worldwide scientific systematics explicitly involved disregard of ecological relationships and of the colors, smells, tastes, and textures that constitute the most intimate channels of recognition and access to the surrounding living world (Atran, 1990).

These results have led us to believe that ecological knowledge is crucial to Maya reasoning about the natural world. This understanding gives rise to two questions. First, to what extent is knowledge of the natural world, particularly ecological knowledge, influenced by cultural factors that are particular to the Maya? Second, to what extent are the behavioral differences that exist between the Maya and the Ladinos with regard to agroforestry (sustainability) driven by differences in knowledge and associated mental models? Our observations also suggest that ecological sensibility among the Maya is integrally bound up with cultural significance, though not in any direct utilitarian or functional sense. We aim to make corresponding observations among the Ladino populations.

Initial Measurements and Preliminary Results

To explore how ecological knowledge is culturally embedded, we devised a series of tasks. In one, we asked a set of informants in each population to tell us which kinds of plants and animals are most necessary for the forest to live. In another, we asked for explicit judgments concerning dependencies between plants and dependencies between animals. In a third task, we asked for dependencies between plants and animals. For all these tasks, we asked people to justify their answers at every point.

Biological Knowledge

KEY PLANTS AND ANIMALS FOR THE RAIN FOREST. To our surprise, we found that the overwhelming majority of informants in each of the four populations, inhabiting an area covering fifteen thousand square kilometers and thousands of species, name the same two dozen or so species as most important for the rain forest. For plants, the nominees are overwhelmingly canopy trees, followed by understory palms and tree vines. Nearly all of the nominated plants and animals have high cultural value; however, the reasons the Maya informants give for their choices almost always include ecological value.

Consider, for example, the small *Chamaedorea* palms called *xate* in Spanish and *ix-xyaat* in Maya. These have no traditional cultural value for Maya. Their current value is to the cash economy, where they are collected from the deep forest for export to Florida and elsewhere for use in floral arrangements. The locals have no idea what they are used for. Many informants mention *xate* as necessary for the forest to live but justify its choice in purely ecological terms: *xate* is a small palm that covers and protects the forest floor, preserving the humidity that allows the other plants to thrive and thereby ensuring that the animals, in turn, are fed and sheltered by the plants. Although from a scientific standpoint many other species would fit the bill, for the Maya there are no grounds for isolating cultural from ecological significance. A given species is vital to life in the forest—including, crucially, human life—only if it exhibits both dimensions. In other words, social or economic value renders salient the ecological value of certain species, and these species are represented in both cultural and ecological terms.

In a second task, we asked informants to describe what happens when each of these salient species disappears. Each folk species mentioned in the previous task was paired with every other species in its domain (plants with plants, animals with animals). Our purpose was to test whether these cultures make use of the notion of a keystone species. A species is a keystone of a given ecological community if its removal leads to a drastic change in the community's makeup and if its reappearance leads the community to recover something like its original state (Wilson, 1992). For each pair of species, we asked if the disappearance of one would positively or negatively affect the other, or not at all.

These three alternatives allow each species pair to be represented in terms of one of six ecological relationships. For example, if disappearance of one species negatively affects the existence of a second species and vice versa, then the relation is one where both partners derive benefit (something like the ecologist's notion of symbiotic mutualism, but perhaps at another level). If disappearance of the first species negatively affects the second but disappearance of the second species does not affect the first, then the relation is one where one partner derives benefit and the other is not harmed (akin to symbiotic commensalism). If disappearance of the first species negatively affects the second but disappearance of the second species positively affects the first, then the relation is parasitic with respect to the second species, and so on.

Again to our surprise, of the thousands of possible species interrelationships that could be represented in this way, only a very few species were deemed vital to the well-being of other species, and the species chosen were much the same in the four human populations. For animals, only the jaguar had a significant positive or negative role. For plants, only the broad relationships that directly reflect the storied structure of the forest were mentioned, that is, relationships between upper-story canopy trees as a group, understory palms as a group, and connecting-story vines as a group. In all the human communities we studied, there was evident ecological awareness of forest plants as structures for distributing shade and water.

These findings suggest two intriguing possibilities: First, at least certain first-order aspects of ecological understanding seem to be common to all the native and immigrant groups in our study and not dependent on long-standing tradition or cultural life in the forest. Second, the notion of keystone species is not particularly relevant to this understanding. Indeed, the whole organic metaphor of nature that is current in popular Western thinking about ecology seems to be entirely alien to these people. Ladinos never describe the forest as a living being, consisting of essential parts that are necessarily dependent upon one another, where some parts—or species—are so essential that the whole dies without them (Kempton, Boster, and Hartley, 1995).

ANALOGIES AND MENTAL MODELS OF THE RAIN FOREST. Among Ladinos, there is no view of the environment as being similar to the human body, which consists of integrated parts that vitally depend upon one another (for example, the spleen vitally depends upon the heart, but only disappearance of the heart leads to death of the body). This is basically true for Maya as well, except in the case of the jaguar, who gives order to the forest through his lordly rule and vies with man for the title of master of the forest *(u yumil k'aax)*. But the jaguar is essential not because it is a keystone species but because it is a mediator between animal and human relationships to the forest.

Instead, the model that both Maya and Ladino informants tend to use when they imagine the forest is more like a house or household. In fact, the Maya cosmos is classically represented as a house (*itzam-naj, itzam*-house). In this worldview, the parts are vitally linked to one another but not in any essential way. The kitchen and living room may be more important than the storage room or pantry, but you could always sleep in the rafters or cook in the pantry if you had to. Unlike the popular view of ecology current in the United States and Europe, neither the Maya nor the Ladino conception of the environment is something akin to a delicately balanced house of cards. Rather, the Maya and the Ladinos see the forest as naturally robust and recoverable, unless subject to sustained external disruption. In this, their views may be closer to ecological science than North American lay thinking.

Take the Itzaj Maya view of the tapir and the breadnut tree *(Brosimum alicastrum)*. The Itzaj refer to the tapir as the "animal of the seven fleshes" and the breadnut tree as the "milpa of the animals." Both the tapir and the breadnut tree are currently priority items in Itzaj attempts to preserve a vestigial section of their traditional forest, known today as the "Bio-Itzaj" Reserve. Itzaj acknowledge that people and jaguars will have other flesh to eat should the tapir vanish, and that the twoscore species of mammals and birds that feed off breadnut fruits and leaves can move on to a host of other trees and herbs should the breadnut disappear. But should the tapir vanish, "nobody will know what it's like to have the seven fleshes together"; and should the breadnut tree disappear, so many animals will never be found together again.

Both Ladinos and Maya say that the forest is structured like a household, with canopy plants protecting understory plants like parents protecting children. Moreover, both groups talk of the forest as a house in a more directly functional way: walking in the forest, one sees and obtains everything one needs to physically make a house, and looking about a house, one sees in its materials much of the variety and structure of the forest (hardwood from the canopy trees providing the frames; palms providing thatch; grasses, earth, and understory softwoods for the marl walls; vines for the ties, and so on).

But there are differences between the groups. Maya, but not Ladinos, say that the animals that move within the forest also see their homes in the forest and the forest in their homes (nests, lairs, and so on). As one man put it: "The forest is like a house because it is life, shade, cool air. Its animals and trees live as a family lineage. There is everything that is necessary, like where to rest and also happiness" *(A'k'aaxej je'b'ix a'naj mentik yanil kuxtal, b'o'oy, siis ik'. U b'a'al-che'iloo' u cheoo' b'ayil uchib'aloo kuxutaloo'. Yan tulakal b'a'al kuk'ab'etil je'b'ix tu'ux kuwenel b'ay xan kiyolal).*

Moreover, the Maya say that people and animals need the forest to live just as the forest needs people and animals to live. For example, in one study in Peten, we found that 73 percent of the Maya said humans are much more likely to help rather than hurt plants, compared to 45 percent of the Ladinos. The forest is a place that satisfies not only material wants but also the desire to see beauty *(yutzilil)*. For Maya, then, the forest is not just a metaphorical house but literally "our home" *(ki wotoch)*.

INTERACTIONS BETWEEN PLANTS AND ANIMALS. Perhaps the most striking group differences arise for the descriptions of interspecies relationships. Even for the few nominated integral species like the jaguar and the vines on the one hand and other animal and plant species on the other hand, native Maya tend to consider these relationships to be reciprocal, whereas Ladinos tend to view them asymmetrically. Ladinos explicitly deny that birds and animals help the rain forest, whereas native Maya believe that the animals, the birds, and the trees tend to one another. The Maya groups generally and the Itzaj in particular also have a tighter cultural consensus than do the immigrant groups in their understanding of plant-animal interactions. We use factor analysis in order to measure consensus, that is, levels of agreement and disagreement between and across subjects (Romney, Weller, and Batchelder, 1986).

An interesting illustration of the relationship between scientific and folk-ecological principles is the case of the strangler fig (*Ficus involuta*, Maya = *kopo'*, Spanish = *amate* or *matapalo*, which means tree-killer). Unlike most trees, the strangler fig does not grow from the ground up but germinates arboreally far above the ground. After germinating, it sends out aerial roots that drop downward into the vascular system of the host tree. In time, the roots reach the ground and graft together. The strangler roots envelop the host tree, gradually killing it by reducing its ability to transport nutrients.

Like other pioneering trees that are adapted to rapidly fill light gaps in the forest, the strangler has a high rate of growth and fecundity, producing numerous small-seeded fruits. Unlike the large-seeded species, whose exemplars are widely scattered so as to avoid nonspecific competition for scarce resources, small-seeded pioneering species rely on a large seed shadow. This increases the plant's ability to get a seed into an appropriate spot so as to take advantage of virgin resources as soon as possible (Forsyth and Miyata, 1995). As a result, the strangler can be found almost everywhere that the climax forest has been disturbed. It is often seen

dominating secondary growth areas and frequently found climbing over the limestone face of an ancient Maya temple.

Only the Maya believe that this tree can help people, and that animals can help this tree. Like tank bromeliads and certain lianas, which live or originate above the ground where water is hard to capture, the strangler's vinelike roots evolved to store water. This makes the strangler an important emergency water source for Maya in northern Peten, where there is a dry season (February through April) and few permanent water sources. The Maya also use the strangler's sticky sap to poultice swellings and to block up the skin holes made by burrowing botfly larvae (so as to suffocate them before they pose a serious health threat).

The Maya, however, do not cite the strangler as one of the most important trees to the forest just because of these advantages. Many other trees that are not cited have more important nutritional or medicinal functions. Rather, the strangler is singled out because of the large range of animal life it supports. Its broad canopy attracts many birds, bats, and monkeys, which feed on its sweet and pulpy fruit. Its creviced trunk and base serve to host and protect numerous species of lizards, insects, and small rodents. Peccaries and large rodents, such as agoutis and pacas, congregate around the base to eat the ripe figs that the monkeys and larger birds drop or knock to the ground.

Unlike temperate forest trees, most tropical forest trees use fleshy fruits to disperse their seeds instead of wind or hook. Only canopy trees can take much advantage of the wind, and even they tend to rely on frugivory, or fruit eating. This is because the intense competition in the rain forest makes it unlikely that members of a single species can cluster sufficiently in a given area to profit from the random wind-borne dispersal of pollen or seed. As a result, mobile animals like birds, bats, and monkeys are indispensable to effective seed dispersal and rain forest survival.

Maya notions of reciprocity appear to acknowledge these basic facts about tropical rain forest ecology. Although individual informants may differ significantly in their ideas of which animals help or hurt a given tree like the strangler, there is an overall sense of reciprocity. Thus for the Itzaj, bats, birds, monkeys, peccaries, and large rodents may both help and hurt the strangler, depending on whether they destroy the seed when they eat the fruit (with bats considered the least destructive and peccaries and large rodents the most destructive).

Even agoutis and pacas, which usually eat and destroy the seed, may be faced at times with such an abundance of fruit and seed that they hide away a few and then neglect them, as squirrels do with acorns. This is the principle of predator satiation or saturation. Such saturation can result

from the absence or scarcity of other (fruit) predators: if some of the fruit eaters are no longer around, then there may be too many fruits left over for the remaining fruit eaters. (Note that mast fruiting—the huge production of seeds at irregular intervals that characterizes oaks and other temperate forest trees—is rare in tropical rain forests because the weather fluctuations that trigger the process are usually not severe enough).

Like rain forest tree species, no rain forest animal species are overly abundant in the neotropics. This makes obligatory dependencies between species potentially disastrous; for if one partner vanishes the other is also liable to disappear. Fortunately, nutrient and seed dispersal systems in the tropical forest are buffered. If a given tree species is no longer available, the animals that feed on it can usually find other food sources in nearby trees. And should any animal species become scarce for any reason, then the seeds of a given tree species can be dispersed by the remaining animal species. The metaphor of the forest as the "Maya house," with partially redundant and substitutable parts, clearly accords with this buffered nature of the tropical rain forest.

Social and Knowledge Networks

Another data-driven observation is that the social networks within which information concerning the environment is conveyed are structured differently for Maya and Ladinos. In our ongoing research, we use variations of standard techniques for elicitation and analyses of social networks (Wellman, 1979; Scott, 1988). For each population, we selected an initial set of informants and asked them: (1) "Outside of your household, who are the people you most depend upon in your life?" For each informant, we then elicited an extended social network from the persons ranked most important and least important by that informant. We are looking at different kinds of networks, including networks of mutual dependence in everyday life versus networks geared solely to getting information about the forest, for example: (2) "Who do you talk to about the forest?" and (3) "Who do you go to when you want to find out something you don't know about the forest?" Each person listed is scored on a coding sheet for sex, age, occupation (farmer, logger, and so on), social role (kin, workmate, friend, and so on), location (same or other neighborhood, village, province, place of origin as informant), and frequency of contact (for example, twice daily equals 720 contacts per year).

For both the Maya and Ladino groups, the responses intimate a social division of cognitive labor (see, for example, Ford, 1976, for a comparable social division of medical knowledge in a small-scale Amerindian society).

Most everyday information seems to circulate among people cited in answer to question 1; most highly specialized information about the forest is obtained from people cited in answer to question 3; much everyday information about the particular topic of the forest is obtained from those people in question 1 that the informant considered most knowledgeable, and from those people in question 3 considered most accessible. There is a great overlap in Maya responses to question 3; that is, the experts cited tend to be the same across Maya informants. There is considerably less overlap in Ladino responses to question 3; however, in Peten much of what overlap Ladinos report is owing to the fact that the majority of Ladinos cite Itzaj experts. By contrast, no Maya ever cites a Ladino as an expert.

In the Maya case, individual networks elicited from question 1 tend to be more kin-based than Ladino networks. Immigrant networks tend to be less densely and more diversely composed (neighbor, congregation, workmate, Itzaj) and the different networks do not seem to overlap as much, despite the fact that the Ladino communities in our study are smaller than the Maya communities. Thus, even if the right information were to enter one part of the overall network, it would more likely be lost before it became entrenched throughout the community as a whole.

Nevertheless, there is some evidence that Itzaj experts provide a steady source of information that affects Ladino knowledge and behavior concerning the forest. The Peten immigrants overwhelmingly cite native Maya as expert sources of information about the forest. The Peten immigrants often describe the manner in which people help (or should help) plants in ways that are often explicitly attributed to Itzaj. So far, however, the fundamental Maya belief about the reciprocal relations between plants and animals has not taken hold in either of the Ladino immigrant groups.

In sum, there are intriguing indications of important relationships between some of the kinds of ecological information (reciprocal, nonreciprocal) and social communication networks (densely overlapping, diverse) pertinent to successful or unsuccessful commons management. On the one hand, there is a main effect in our studies of population: native Maya and immigrants differ significantly with regard to ecological information and social networks (assuming the Yucatec data turn out to show corresponding differences). For Maya, but not Ladinos, ecological interactions are reciprocal. The ultimate sources of information about the forest are virtually all native Maya, at least in Peten. On the other hand, there may also be a main effect of significant differences between the Guatemalan groups and the Mexican groups. For example, preliminary

analyses suggest that the Itzaj subjects may have more pervasive and detailed beliefs than the Yucatec subjects about how animals help plants, especially in regard to seed dispersal. The Peten Ladinos appear to differ from immigrants in the Yucatan in their belief that people help many important plants and that important animals interact with important plants (albeit mostly in harmful ways). Peten Ladinos also crucially incorporate native Maya into their communication networks whereas preliminary data suggest that the Yucatan immigrants do not.

These differences appear to be associated with differences in how the actors actually treat the forest. Although our studies of forest practices have just begun, it is already clear that native Maya make greater efforts to preserve their forest as a closed-access system (discussed in the next section) and are relatively more successful than immigrant populations in preserving the forests they use. Also, Peten groups are apparently more knowledgeable and successful than the Yucatan groups in sustaining the human-plant-animal interactions that they believe are important to the forest and their life within it. In other words, grades of success (or failure) in commons management may be differentially linked to conditions of culture and environment, with the positive role of lowland Maya culture being strongest in more richly forested Peten.

Other Observations: Moral Commitment as a Semantic Value

Other factors, possibly interrelated with ecological knowledge and social networking, may be responsible for the commons breakdown in Mayaland. For example, native Maya readily conceive of the forest as a closed-access system (see Ciriacy-Wantrup and Bishop, 1975). A closed-access system has aspects of both the private and public domains of classical economists but is not exclusively one or the other. Like public domain, all (and only) members of the community have rights of usufruct. But as in the private domain, the fruits of one's labor cannot be appropriated by another (note that this dual aspect of the commons renders it opaque to the theoretical and legal apparatus of both individual-based and collective-based economies and worldviews). Peten Ladinos, however, refer to the forest as "land for anyone's taking" (*tierra agarrada de nadie*); that is, they define it as open access. They have a nomadic view of the forest, so that what would be considered cheating or free riding in a closed-access system would not be perceived as such in an open-access system.

So far, one might be tempted to argue that our observations demonstrate cultural differences in discounting the future rather than having concern for others. Almost by definition there are differences in discount-

ing, but we have reservations about the explanatory value of this perspective. Managing forest commons is related to both discounting and concern for others. Much of the data we provide seems directly related to discounting, which may be explainable in terms of perceived ownership of the land (Maya case) versus temporarily using it (Ladino case). Yet no Maya feels that the land belongs to him or her alone; rather, it is shared with the community that defines the rights and obligations of each member. Maya do not imagine the future in terms of individual agents, or atoms, disconnected from a meaningful social context. Rather, they see the long-term relationship between forest and community as a contract of mutual assistance, which individuals today may or may not "freely" chose to follow. If they do not, they have no valor *(chich muk)*.

For Ladinos, a jaguar is a striking, powerful, and significant animal. For native Maya, the jaguar made the first sound of the world. When you ask Maya, "How do you know whether the forest will survive?" they answer, "Listen for the sound of the jaguar. When there are no more jaguars, there will be no more forest and there will be no more Maya." Ladinos say nothing of the kind. True, Ladinos admire jaguars or fear them for the livestock. Yet the Ladinos would no more cease to be who they are should the jaguar vanish than people in the U.S. would cease to be who they are should the bald eagle disappear. In other words, no purely extensional value can be assigned to culturally important or "sacred" resources. These resources also appear to have intensional, or semantic, value that utility theories have no principled way of capturing.

We would also like to develop indices of cultural "closeness" to the rain forest. For example, we asked informants how they learned what they know about the rain forest. The Ladinos frequently mentioned parents and other people, whereas the Maya mentioned these but also frequently said they obtained their knowledge by walking alone in the forest. Obviously, some cultural intervention is needed if one is to learn culturally appropriate linguistic labels, so the Maya answer may reveal a sense of closeness more than anything else.

Further evidence comes from people's beliefs concerning how important stories and legends about the rain forest are to understanding the forest. All the Maya, but less than half the Ladinos, said that stories were important. For the Maya especially, forest legends were never "false" but always carried a message about what a person should expect when walking in the forest and how the animals, spirits, and ancestors would expect that person to behave with respect and valor so as to profit from the forest while avoiding misadventure and misfortune. Interestingly, the only repeated stories of the forest told to us by Ladinos were variations on

Hansel and Gretel (which conveys the idea that the forest is scary and that you can get lost in it), and stories of how Maya turn themselves into animals (the Maya themselves believe that there are *waay* among them who can transform themselves into animals in order to carry out witchcraft). A systematic exploration of the stories and justifications associated with species interactions may allow us to operationally tease out a sense of moral commitment as a factor in sustainable commons management.

A final observation was made only for Peten. When asked what the greatest change is among the people of Peten, including Ladinos as well as the younger generation of Spanish-speaking Itzaj, Itzaj elders tend to reply that "people no longer know how to walk in the forest" and that "people no longer know how to talk and visit with one another." Itzaj say that for people who know how to walk in the forest and talk "the true tongue" *(jach t'an,* that is, Maya), the forest is "truly beautiful" *(jach yutzil)*. Unlike Ladinos, they express no fear of the forest, which is simply called Mayaland *(u-lu'um-il maayaj)*.

Thus, in addition to data that appear to demonstrate differences in discounting the future (with the Maya striving not to compromise the future), justifications of their own and others' behaviors suggest that what defines Maya readiness to preserve their commons is a moral commitment to the living kinds they live with, including concern for other Maya. This commitment may account for the differences in behavior associated with the striking similarities and subtle differences in the kinds of first-order ecological knowledge (see also Rappaport, 1979). In other words, a commitment to context, culture, and identity may be so mutually defining in Maya eyes that one could no more conceive of cheating on the forest or the community, or living within a web of entirely nonreciprocal human-plant-animal interactions, than a mother could imagine starving her children for some marginal utility, such as another bit of meat. This moral commitment could be expressed as a sacred obligation to preserve the cognized structure of the forest. Unlike a theory, which may be more or less responsive to changes in fact and negotiable, a sacred scenario would be fairly immune to changes in fact and nonnegotiable.

To be sure, given the momentous changes occurring, actors that failed to be cognizant of change would be doomed. Yet to abandon sacred obligations could equally condemn a long-standing way of life to oblivion. There may be compromise solutions to this dilemma. Traditionally sacred prescriptions and unavoidable monetary negotiations might be "hybridized," with the sacred rendered less than absolute and the edges taken off raw calculations of utility. Or actors might learn to operate simultaneously in both of these very different worlds, sometimes behaving

from one vantage and sometimes from the other. These alternative solutions, although distinguishable in principle, may require a much more nuanced appreciation of the role of cosmology in the structuring of fact and action than current notions of folk theory insinuate.

Our native Maya groups do appear to operate with hybridized or distinct sets of values. Individuals often appear to be consciously aware of what they are doing when distinguishing what the ancestors would undoubtedly do from what they may now be forced to do by novel circumstances. Use of Maya versus Spanish may also play a role, because sacred obligations generally are couched in Maya alone. As the younger generations rely more on Spanish than Mayan, sacred cultural prescriptions may recede into the background. In other words, the relationship between language loss and cultural practice bears further scrutiny.

Discussion

Current Picture

The preliminary nature of our observations precludes any strong conclusions. On a first pass, nominations of important species as well as first-order interactions within plants and within animals reveal comparable results for the Ladino and Maya populations. Furthermore, this common pattern reflects both cultural importance and biological reality. Finally, both populations depart from a normative ecological model in favor of a mental model where the rain forest is seen as being like a house.

A second pass reveals important differences. The Ladinos almost uniformly reject the idea that animals help the forest whereas Maya see the relationships between plants and animals as being more symmetrical. The analogy of the forest to a house can accommodate both positions because the house metaphor is fairly abstract. Other observations suggest that the Ladinos think of the forest as more like a rental property than a permanent home; but it is too early to tell how widespread and entrenched the house analogy is in either population.

The same must be said for the social and knowledge networks. Here we find that the Ladino networks are more diffuse and show less overlap than those of the Maya populations. This certainly sets the stage for significant differences in the transmission of knowledge and social values; however, we have yet to show that this is a difference that makes a difference with respect to agro-forestry practice. These cautions notwithstanding we can begin to see the outlines of group differences in models of biological knowledge and action.

Cultural Models of Knowledge and Action

Consider the forest as a network of persons and nonhuman animal and plant species that help or harm one another. The persons and species are the nodes or agents of the network. The life-support interactions, notably the food-web interactions, are the pathways that link together the nodes (Holland, 1989). Through the pathways flow the nutrients and other resources that humans and nonhuman agents process in the forest network.

Two important and interrelated properties characterize the flows and agents, respectively, of the tropical forest network: recycling and diversity. Although science still knows little about the mechanics of how tropical forests maintain themselves, ecologists generally agree that recycling and diversity are mutually sustaining in complex ways. A diverse array of agents is much better than any single agent at capturing and recycling resources before they are removed from the network (leached, extracted, and so on). Reciprocally, the more resources that are retained, the more they can be exploited in varied ways and provide multifarious niches for diverse agents. Moreover, the combined effect of recycling and diversity is nonlinear: the cycling of resources by an aggregate of diverse kinds of agents yields a much richer product than the sum of individual actions (Holland, 1995).

A rich ecological system, such as a tropical forest, differs from a less rich system in that it supports a higher degree of adaptation through agent (for example, species) substitution. Convergence and mimicry are two examples of adaptation through agent substitution. Substitution occurs when one kind of agent becomes temporarily or permanently absent from the system and another agent moves in to occupy its niche. A niche in a rich system is characterized by the multiple interactions centering on each kind of agent. When the pattern of interactions is disturbed or sundered, the multiplicity of vestigial connections tends to favor the rapid emergence of a substitute—an agent that will quickly "fill the gap" and provide most of the missing interactions. Such biological substitution is almost never a process of mere replacement but involves manifold subtle changes that are crucial to further adaptation, evolution, and diversification of life (Wilson, 1988).

Suppose that these are among the basic facts about life in the tropical forest. To sustain itself in such an environment, an agent would need some sort of internal structure that would enable it to appropriately respond to the relevant facts. At the very least, an agent's internal structure would have to capture regularities in its environment's stimulus-structure.

Furthermore, it would have to capture them in such a way as to anticipate consequences likely to follow from encountering—or failing to encounter—those regularities.

For people, the appropriate internal structure plausibly includes a mental model. In this regard, a mental model is an internal structure that allows the agent (and other people who inspect the agent's model, including researchers) to infer something about the environment. It also motivates the agent's actions. Such a model includes criteria (rules) for input selection, inference, and performance. These criteria may be tacit or overt. If the resulting behavior effectively anticipates future consequences for the environment, then the agent has a sustainable model; otherwise the model is unsustainable (see, for example, Holland, 1995).

In light of the preliminary results of our study of resource management in lowland Mesoamerica, it is tempting to say that native Maya have a more or less sustainable model of the forest and that immigrants have a more or less unsustainable one. Assuming that the results of our tasks capture relevant aspects of these models, and given the statistical consensus in each of our populations on the tasks, we may use our results to recreate Maya and Ladino "cultural models." Thus far, there appear to be four outstanding candidate elements of the Maya model: (1) selecting crucial input (that is, relevant species) jointly on the basis of perceptual (morphology), cultural (function), and ecological (dominance) salience; (2) inferring recycling through the reciprocal interactions between humans, plants, and animals; (3) inferring the substitutability of agents through the image of the forest as the "Maya house"; and (4) performing in accordance with an effective understanding of the forest through milpa practices that emulate and maintain forest biodiversity and the recycling of nutrients.

First, native Maya select the species that are most important to the life of the forest in ways similar to the selection of those species considered most typical, or "true." We have yet to determine whether this also applies to Ladinos. Criteria for what is typical or true seem to be very different for native Maya and urbanized North Americans, although we have still to inquire into North American selection criteria for ecologically important species.

Second, the reciprocal relationships that Maya infer between themselves and nonhuman species evince at least some awareness of resource flow and recycling. For the Itzaj, the most common rule of inference is that those animals that eat or play with the fruit of certain plants but do not digest the seeds help to spread those plants around the forest and to fertilize them. Ancillary inferences are made on the basis of the size and hardness of the fruit and seed relative to the animals that interact with them.

A more common rule of inference among Yucatec Maya is related to the ecological notion of saturation. Saturation occurs when a plant species produces more than enough fruits for an animal species that feeds on it. For example, over time oak trees tend to produce more acorns than local squirrel populations can consume. By scattering and hiding acorns that they will not eat, the squirrels help to spread and generate oaks. For the Yucatec Maya, certain animals help certain plants by hiding away excess fruit and otherwise preparing the ground for growth and the spread of the plants throughout the forest.

Quite possibly neither Itzaj notions of seed fertilization by animals nor Yucatec notions of ground cleaning by animals are completely accurate by scientific standards. But the appreciation that animals and plants help one another by channeling resources necessary to life and growth may represent an effective "truth" about the tropical forest that has other important concomitants in inference and performance. This, of course, is a matter for further study.

A third candidate element in the cultural model of native Maya is the conception of the forest as a house, ruled by people and jaguars. Recall that none of our subject populations seemed to isolate species that are akin to the ecologist's notion of keystone species. Rather, they appeared to view the ecological structure and content of the forest as a house, with (partially) substitutable agents, connectors, and resources. A legitimate question arises as to whether this conception of convergent species is more appropriate to understanding the stability of tropical forests than the concept of keystone species (the latter, perhaps being more apposite to temperate environments). Where native Maya and immigrants differed was in their appreciation of reciprocal interactions and of the moral obligations required to sustain these interactions indefinitely.

A fourth element concerns the realm of performance, although the putative connection between knowledge and action is presently more conjectural than causal or even correlational. Earlier on we alluded to the difference between Ladino and Maya agriculture in terms of recycling. Ladino agriculture tends not to recycle resources. The forest is clear-cut and burned, and little effort is made to retain the surface nutrients that tropical downpours then swiftly leach from the shallow soil. By contrast, Maya agriculture tends to recycle resources. Examples include ringing agricultural plots with trees to prevent nutrients from being washed away; letting weeds have more fallow time to reuse nutrients; emulating the forest's biodiversity structure with multiple crops in storied arrangements

(for example, root crops with low-lying vine crops, cereal crops, and fruit trees); protecting and tending some of the forest trees and animals, thus allowing them to also recycle critical nutrients (for example, Itzaj are currently deepening natural water holes in shaded areas so that jaguars and tapirs will not venture out of the Maya reserve in the dry season, where they are more liable to be shot by immigrants).

To be sustainable, these and other critical elements of the model would have to cohere under change. How this might happen is a long-term goal of our research. Should the native Maya possess a sustainable cultural model (or class of models) of the tropical forest—capable of anticipating and adapting to forest cycles—then lowland Maya culture might prove to be a privileged agent in the maintenance of the forest's integrity. If sustainable, such a cultural model would be privileged over the internal structures of nonhuman agents simply because it is a mental model that can infer, anticipate, and accommodate prior to any action taking place. Such a sustainable model would be a potentially dynamic factor in the evolution of forest biodiversity because of the range of interactions it could conceivably represent and help to implement.

Historical and archaeological evidence provides intriguing suggestions to this effect. If so, then the relationship between the survival of cultural diversity and the survival of biological diversity in Mesoamerica may be as close as the Maya themselves suggest: if the Maya and the forest do in fact live by and for one another, then neither might long endure without the other. Maya anticipation that this is indeed the case may be a critical aspect of a sustainable model that others lack. Again, this strong conclusion awaits further systematic investigation.

Projections for Research

Perhaps it is a bit naive to expect simple answers to complex questions. At this point, the reader may despair of possibilities for future progress in this research, for it seems that we are going to be confronted with a host of differences between the native and immigrant groups and that any of the differences, either alone or in combination with other factors, may be critical. How do we proceed?

We believe that there are three strategies that can be profitably be pursued. First of all, we need to move our analyses to a more specific level of detail and to tie them to action. In one extension, in ongoing work we are using the overlapping species lists already elicited as "important for the forest to live." In this task, we place all of the nominated animal cards in front of the informant and then, for each plant, we ask which animals

depend on that plant for shelter, food, or shade or in any other way the informant considers vital to the animal. This allows us to identify plant-mediated ecological networks among animals, and animal-mediated ecological networks among plants. We will then compare these ecological networks to the plant and animal taxonomies that we have already elicited and continue to elicit among these populations. This will allow us to get a closer look at the largest difference in ecological knowledge that we noted between the two populations.

We will also target probes at the ecological significance of specific agro-forestry practices. It is possible that the reason that Ladinos are destroying the forest is that they simply do not know enough about how it works. Just as physicians distinguish between physiology and pathophysiology, we intend to extend observations on normal forest ecology to situations of disturbance, where (human) interventions upset normal conditions. Ladinos and Maya may differ in their appreciation of and monitoring for abnormal conditions. In short, our goal is to move to a level of detail where mental models can be potentially linked to agro-forestry practice.

The second research strategy is to look for populations and contexts that may serve to disentangle what otherwise might be confounded factors. Thus, in order to control for the combined effects of social networks and ecological knowledge, we will be testing immigrant Maya groups who have moved into the lowlands from the highlands. We expect that their social networks will look very much like native Maya networks in terms of an interlocking clan-based structure, and very unlike the Ladino networks, which are based on residence, church affiliation, and work. The immigrant Maya, however, should not have the detailed ecological knowledge seen in our indigenous Maya groups. One possibility is that the immigrant Maya will initially engage in destructive agro-forestry practices but quickly assimilate more sustainable practices when appropriate knowledge is introduced into the social and cosmological structure. Language and cosmology are decidedly more robust among Kekchi immigrants than Itzaj. An initial encounter between Itzaj and Kekchi Maya immigrants resulted in an exchange of Itzaj forest knowledge for Kekchi prayers (see Atran, 1993a).

Another possibility is that the closed character of immigrant Maya social networks will continue to impede learning from native groups. Recent satellite imagery gathered by Conservation International tends to confirm our preliminary observations that the slash-and-burn practices in Peten of the Kekchi Maya, who originate from the highlands of Alta Vera Paz, are significantly more destructive than the practices of certain groups of immigrant Ladinos. It also appears that these immigrant Ladinos have

more intense and redundant social contacts with native Maya in matters concerning forest knowledge and practice than do Kekchi. Immigrant Ladinos are beginning to understand and employ certain Itzaj agroforestry techniques such as protecting valuable trees, whereas the Kekchi are not. If these trends prove significant and enduring, that will suggest that sustainable management may depend more on (ecologically) context-sensitive versus context-free cultural traditions than on indigenous versus nonindigenous cultural traditions (compare Arizpe, Paz, and Velázquez, 1996). In fact, there is long-standing evidence of cultural borrowing and exchange between "Petenero" Ladinos and native Maya. Some families that primarily identify themselves as Ladino have Itzaj surnames that antedate the Spanish conquest, and even more have orchards and milpas that are virtually indistinguishable from those of the Itzaj (see Schwartz, 1990).

Another set of populations we plan to look at consists of lowland Lakantun Maya and highland Tzeltal Maya immigrants in the Sierra Lacandon of Chiapas. The Lakantun have preserved significantly more of their cosmological system than the other lowland Maya groups. A number of Lakantun still refuse to be Christianized, to sport Western garb, or to abandon the sacred rituals associated with farming and hunting. Accordingly, the role of cosmology should be more important, or at least more salient, in Lakantun community conceptions and practice of agroforestry than in all of our other groups. The influence of the Lakantun on the Tzeltal (and vice versa) may also reveal differences between those Tzeltal who are allied with the Lakantun in attempting to preserve the Lacandon forest as joint commons and those Tzeltal seeking to enter the forest reserves in order to clear them for agriculture and pasture.

The third research strategy involves a combination of systematic observations with laboratory research. In some parts of southern Mexico, the forest commons have closed access and are managed by formally institutionalized *ejido* councils. These common-pool resource councils represent communities of varying social compositions of Ladinos, native Maya, and immigrant Maya. A sampling of these local councils provides variation on dimensions such as group composition and size, and nature of resource. The group decisions with respect to timber sales can thus provide a natural dependent variable, and *ejido* discussions represent a rich source of less formal observations.

In the long term, our plan is to bring these various factors into the laboratory so that they can be systematically manipulated in well-controlled experiments. Most laboratory studies of resource dilemmas have used participants who do not know each other, and the studies do not attend to variables such as degree of moral commitment to some resource. But there is no principle that would bar these sorts of considerations from laboratory studies. Furthermore, these studies can be conducted with higher fidelity than has been common. For example, studies of island biogeography suggest that biodiversity can be calculated on the basis of the fourth power of the land area (Myers, 1988). These observations can be built into resource dilemmas and further validated by field observations (using remote sensing), linking biological inventories to amount and quality of forest cover.

Implications for Global Conservation and Development

Today, remaining commons regimes—even those that have survived centuries and perhaps millennia—are very unlikely to endure far into the next millennium, or even next century. They are largely unacceptable to leading world legal, political, and economic institutions, which concentrate instead on exclusively private or public management. Most conservation and development projects have focused on physical rather than human capital, thus allowing the accumulated human capital to rapidly deteriorate. But with the disappearance of this social capital comes the need to learn from scratch how to match cultural institutions to the physical environment and how to make commitments of mutual trust in joint undertakings related to common survival. Given the exponential rate of deforestation, species loss, and population growth, learning from scratch how to manage commons problems is plausibly not the best strategy.

There is no obvious solution to the problem of upscaling the lessons of the local commons to a worldwide context. Opening access to a multicultural world with myriad values and reference schemes seems to undermine the very foundations of successful commons management, which are based on closed access, shared values, and a common system of reference. Moreover, there is strong empirical evidence that traditional local commons generally have not been able to physically survive the intrusion of the world market for very long. Thus we do not expect that conditions for acquisition and exchange of information relevant to successful commons management in Maya forests can be automatically extended to the diverse ecological zones that span the globe.

Nevertheless, we do envisage findings that will be practically and theoretically instructive. Practically, they may better equip us to avoid the likely failure of many of the more expensive conservation and development schemes that are unwittingly designed to take the place of local commons regimes, albeit on an empirically less firm but more grandiose scale.

For those schemes that do seek grass-roots involvement, our research might show that prescriptions for including local peoples make little sense and may even be counterproductive unless they include an informed assessment of variations in local knowledge and belief. Theoretically, we may be able to discover to what extent mismatches in mental models are hazardous to cross-group cooperation, and what properties of social networks are most likely to predict the success of commons solutions.

More generally, suppose for the sake of argument that humans are not solely, or even by evolutionary design, self-interest maximizers in the narrow senses of utility theories. Consider, instead, that under certain empirically identifiable conditions humans are cognitively disposed to share resources, risks, reference systems such as language, and plans for the future. Imagine, that is, that maximization of self-interest asserts itself not so much by nature as by default, when ordinary ties with the environment and community are severed. Even then, people may sense the moral failure of a rationally unassailable Faustian bargain.

Consider this analogy. Context-free, extensional theories of rational choice and marginal utility may be related to context-sensitive, intensional theories of value and decision making much as formal logic is related to the natural logic of everyday language. Like formal logics, extensional theories of choice involve a rather coherent, limited set of explicit assumptions and axioms. Any formal logic initially derives its limited syntax of conjunctions and rules of inferences from the richer but more complex "natural logic" of everyday language and then manipulates these derivative forms to enhance clarity and inferential power in rhetoric or the sciences. Similarly, extensional theories of choice may derive assumptions and axioms from richer, more complex forms of "natural reasoning," where loss and gain are not equal, the future is not discounted, and so on, in order to enhance the precision and predictive power of decision making in government or markets. Nothing else around rivals formal logic for clear communication or utility theory for precise prediction. Nevertheless, clarity and precision may not be the only, or even the primary, conditions for successful communication or resource-use decisions in everyday life. Other considerations of relevance may be important and even paramount (see Sperber and Wilson, 1986).

If so, then the lessons of local commons for global problems may be something like the lessons of representational grammars for learning unfamiliar natural languages or relearning impaired ones. The grammars of schools are not themselves natural grammars, they are—ideally—lawfully related to natural grammars and derivative from them, but they are much harder to use and master than natural grammars. Education and insight

are required—education about what should come naturally to us, if only the normal triggering conditions of physical sensitivity to stimuli and social intercourse were readily available.

Conclusion

What is the overall perspective of this project? We are trying to understand the cognitive and cultural processes that drive people to preserve or destroy their common resources. We hope this focus on process will yield insights that can be applied to global commons, although we are well aware of inherent problems in upscaling the lessons of successful local commons to a wider planetary context. One of the lessons our data seem to show is that whatever the final mix of factors responsible for successful commons management among Maya in the rain forest, it does not consist exclusively or primarily in calculations of marginal utility, unless one could assign a uniform measure of utility that conveys substitutability across one's children, community, and the species one lives with.

To put it another way, on the surface it may seem to make sense to talk about how people value things in terms of extensional measures like utilities. But that does not seem to hold much promise for getting at the meaning of the forest to the Maya or even to ourselves. If utility represents a syntax for comparisons, then a severe limitation is that it does not get at the intensional semantics of human interaction with the natural world.

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