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Folkecology, Cultural Epidemiology, and the Spirit of the Commons

A Garden Experiment in the Maya Lowlands, 1991–2001[1]

by Scott Atran, Douglas Medin, Norbert Ross, Elizabeth Lynch, Valentina Vapnarsky, Edilberto Ucan Ek′, John Coley, Christopher Timura, and Michael Baran

Using a variation on an experimental approach from biology, we distinguish the influence of sociocultural factors from that of economic, demographic and ecological factors in environmental management and maintenance. This is important to issues of global environmental change, where there is little empirical research into cultural effects on deforestation and land use. Findings with three groups who live in the same rain-forest habitat and manifest strikingly distinct behaviors, cognitions, and social relations relative to the forest indicate that rational self-interest and institutional constraints may not by themselves account for commons behavior and cultural patternings of cognition are significant. Only the area's last native Itza′ Maya (who have few cooperative institutions) show systematic awareness of ecological complexity involving animals, plants, and people and practices clearly favoring forest regeneration. Spanish-speaking immigrants prove closer to native Maya in thought, action, and social networking than immigrant Q′eqchi′ Maya (who have highly cooperative institutions). The role of spiritual values and the limitations of rational, utility-based decision theories are explored. Emergent cultural patterns derived statistically from measurements of individual cognitions and behaviors suggest that cultural transmission and formation consist not primarily of shared rules or norms but of complex distributions of causally connected representations across minds.

Scott Atran is a senior research scientist at the CNRS-Institut Jean Nicod, Paris, and the Institute for Social Research, University of Michigan, Ann Arbor, Mich. 48106-1248, U.S.A. [satran@umich.edu].

Douglas Medin is chairman of the Department of Psychology and director of the Cognitive Science Program at Northwestern University.

Norbert Ross is a postdoctoral fellow in psychology at Northwestern University.

Elizabeth Lynch is a postdoctoral fellow in psychology at Northwestern University.

Valentina Vapnarsky is a research scientist with CNRS-EREA in Villejuif, France.

Edilberto Ucan Ek′ is director of the Herbolaria Maya "Bo′oy Ch′iich" in Umán, Yucatán.

John Coley is an assistant professor of psychology at Northeastern University.

Christopher Timura is a law student at the University of Michigan.

Michael Baran is a graduate student in anthropology at the University of Michigan.

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This article reports an attempt to establish the causal pathways that determine how cultural ideas result in behaviors that affect the environment and commons management. In order to do so, it is important to separate cultural effects from those of demography, economy, ecology, and so forth. A critical case for the importance of cultural selection versus environmental determination comes from a variation on the "garden experiment" in biology. When members of a species have different phenotypes in different environments, samples are taken from both environments and replanted in only one. If the differences still exist, they are probably genetic (two genotypes); if not, then they are probably environmental (one genotype producing two phenotypes). In using a variation on this experimental approach, our aim is not to distinguish genetic nature from environmental nurture but to distinguish the influence of certain sociocultural factors (social networks, cognitive models) from that of economic (sources and level of income), demographic (family and population size), and ecological (habitat and species) factors in environmental management and maintenance. Evidence for the influence of culturally transmitted factors on behavior is data showing that groups of people with different cultural histories and cultural ideas behave differently in the same physical environment.

We adopt a threefold approach to understanding causal

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relations between individual cognitions, human behaviors that directly affect the biotic environment, and cultural patterns that emerge from populationwide distributions of cognitions and behaviors:

1. *Folkecology*. We aim to furnish a cross-cultural methodology for modeling people's cognitions of the ecological relationships between plants, animals, and humans. We verify the material implications of psychological measures of how people think about nature with physical measures of accompanying actions that modify nature (biodiversity, biomass, soil composition, etc.). The goal is to understand how people use what they know about their environment to sustain or destroy it.

2. *Cultural epidemiology*. We seek to provide ways of mapping individual variation and interinformant agreement in the flow of ecologically relevant information within and between societies. We use social network analysis to trace transmission pathways in the transfer of knowledge. We also ask whether cultural orientation affects how events in nature are interpreted independent of any specific social transmission. The goal is to track statistically emerging patterns of cognition and behavior in human groups to see how different cultures form, interact, and evolve in similar environments.

3. *The spirit of the commons*. We attempt to operationalize the role of "noneconomic" entities and values such as supernatural beings and taboo trade-offs in environmental cognition and behavior. We use projective valuation techniques to measure people's own preferences against others' preferences, including those of members of other groups, forest spirits, and God. The goal is to reveal how different cognitive strategies may causally contribute to environmental decisions that favor cooperative or selfish use of common-pool resources such as forest species. To foreshadow: nonhuman forest species may come to have intentions and act as negotiating partners through spirits.

We show that differences in folkecology are tied to differences in the way people act with regard to common-pool resources among three culturally distinct groups that live in northern Guatemala and depend on the same habitat. This is particularly relevant to issues of international global environmental change, where empirical research showing that culture matters in assessments of deforestation and land change is sorely lacking. Environmental management increasingly involves diverse groups with distinctive views of nature (Arizpe, Paz, and Velázquez 1996). Understanding ways in which local cultural boundaries are permeable to the diffusion of relevant knowledge may offer clues to success with more global, multicultural commons.

The lowland Maya region faces environmental disaster in part because of the open access to forest resources that is available to a host of nonnative actors (Schwartz 1995). A central problem concerns differential use of common-pool resources such as forest plants by different cultural groups exploiting the same habitat. Research on "the tragedy of the commons" indicates that individual calculations of rational self-interest collectively lead to a breakdown of a society's common-resource base unless institutional mechanisms restrict access to cooperators (Hardin 1968, Berkes et al. 1989). The reason is clear: in the absence of monitoring and punishment, exploiters gain the same benefits as cooperators but at reduced cost. Cooperators are driven to extinction, and exploiters flourish until the commons is destroyed. Still, economic rationality and institutional constraints on action may not sufficiently account for differences in environmental behavior (Ostrom 1998). For example, people may attach noneconomic, or "spiritual," values to resources to protect them. To make better sense of these differences, we examine links between environmental cognitions and behaviors.

Another concern is the relation of lowland Maya to their tropical limestone environment, including anthropogenic effects on biodiversity patterning, which continues to puzzle and inspire various disciplines with notions of how humans best manage their natural surroundings. Study of contemporary Maya thought and behavior informs attempts to understand how this ancient people endured (Lundell 1938, Flannery 1982, Rice 1993); however, operationally reliable and replicable data are rare (cf. Nations and Nigh 1980, Schwartz 1985). Previous results on Itza' focused exclusively on maize production for a better understanding of the cereal basis for ancient Maya civilization (Cowgill 1962, Reina 1967). Now there is increasing consensus that tree tending, multicropping, and varied sorts of landscape modification may have been critical to the survival of lowland Maya over the past two millennia of intermittent and catastrophic upheaval (Turner 1978, Fedick and Ford 1990). Our studies provide findings for the further development of this line of research.

Our case study principally involves three linguistically distinct samples from three cultural groups exploiting the same habitat in the Municipality of San José in Guatemala's Department of El Petén: native lowland Maya (Itza'), immigrant Maya from the neighboring highlands (Q'eqchi'), and immigrant Spanish-speaking Ladinos (of mixed European and Amerindian descent). Studies with highland Q'eqchi' from Aldea Paapa in the Cobán region of Alta Vera Paz, Guatemala, were designed to complement and inform our main results. The choice of case study was motivated, in part, by a further consideration of timeliness: The Itza' Maya represent the last lowland Mayan-speaking group with demonstrable ties to pre-Columbian civilization in the north-central Petén. Although they survived violent conquest and three centuries of forced assimilation, they are threatened with imminent demise as a people with a viable linguistic and cultural identity.[2] This article, then, also elucidates the impending loss for us all.

2. In the 1930s the Guatemalan director General Jorge Ubico instituted a virulent ani-Maya language policy that led the Lacandón (Lakantun) Maya to flee Petén and resulted in the loss of Itza' as a first language in San José. Thus, one might argue that any attempt to link contemporary with pre-Columbian Petén Maya culture is unwarranted. Indeed, Hofling (1996:111–12) declares that "the small Mayan-speaking populations in the Petén have received scholarly attention all out of proportion to their numbers," reflect-

Folkecology

The most reliable research on environmental cognition stems from ethnobiology, or folkbiology, which reveals universal principles that reflect the mind's ability to bound and essentialize natural discontinuities (Atran 1998) and to organize them hierarchically into taxonomic kinds (Berlin 1992). Although the use of taxonomy to reason about the biotic world is roughly the same in diverse cultures, this leaves aside important insights into the behaviorally relevant ways in which people model the environment. There are precedents for our approach (e.g., Posey 1983), but to our knowledge this is one of the first attempts to show the role of cultural orientation in deforestation and land use in ways meaningful to natural science.

THE COMMON SETTING

In Petén, topographic and microclimatic variation allow for a dramatic range of vegetation over small areas, and sustaining both this diversity and people's livelihood over the past two millennia likely required correspondingly flexible agroforestry regimes.[3] Paleolimnological analysis of sediments in the central lakes region of Petén associates the demise of Classic Maya civilization toward the end of the 1st millennium with geometrically increasing rates of deforestation (Rice 1993). There is evidence of spiraling population growth (Culbert and Rice 1990), warfare (Chase and Chase 1989, Demarest 1993), and nutrient deficiency (Santley, Killion, and Lycett 1986). Economic infrastructure supporting perhaps 3 million people collapsed. Transport and communication links between central Petén (e.g., Tikal) and other production centers (e.g., Caracol in Belize) disintegrated. While the central lakes region may have suffered less drastic population loss than neighboring Tikal, resettlement of Petén seems never to have surpassed the 100,000 or so people estimated for the immediate preconquest era.

Dense forest cover reappeared during the Late Postclassic period, which preceded a brutal Spanish conquest in 1697 (Wiseman 1978). By and large, this cover endured through the mid-20th century. Since 1959, when the military government opened up Petén to "colonization and development," more than half of its forest cover has been razed and converted to agriculture (Schwartz 1995). The rate of deforestation, which averaged 287 km^2 yearly between 1962 and 1987, nearly doubled to 540 km^2 in 1988–92 as population rose from 21,000 to over 300,000. Population estimates for 1999–2000 range from 500,000 to 700,000 (Nations 1999, Shriar n.d.).

Most of southern Petén's rain forest has vanished. In a project engineered by the U.S. Agency for International Development (USAID) and supported by a debt-for-nature swap, Guatemala's government set aside remaining forests north of 17°10′ latitude as a Maya Biosphere Reserve, a designation recognized by UNESCO in 1990. Yet, even within the Biosphere, forest continues to burn (*Prensa Libre*, April 22, 1998). Deforestation is especially prevalent along migration routes into northern Petén (Sader 1999). A new European-financed paved road now links Guatemala City to Flores, virtually ensuring the breakup of Mesoamerica's largest remaining contiguous tropical forest. Projections based on remote sensing and ground measurements indicate a 14.5% increase in the rate of deforestation during 1999–2000 (Grunberg 2000). The major cause of deforestation, though, continues to be population pressure from the overcrowded and tired lands of southern Guatemala (Schwartz 1995). There, more than 11 million people live in an area roughly twice the size of Petén and nearly two-thirds of the land is controlled by about 2% of the population.

Each of the three cultural groups with which we are concerned has founded and predominates in a distinct locality: Itza' in the town of San José, Ladinos in the nearby settlement of La Nueva San José, and Q'eqchi' in the hamlet of Corozal. Interviews were in Itza', Spanish, and Q'eqchi' respectively. All three groups lie within the Maya Biosphere Reserve's official "buffer zone" between that latitude and Lake Petén Itza to the south (fig. 1). Here, vegetation is quasi-rain forest; mean annual tem-

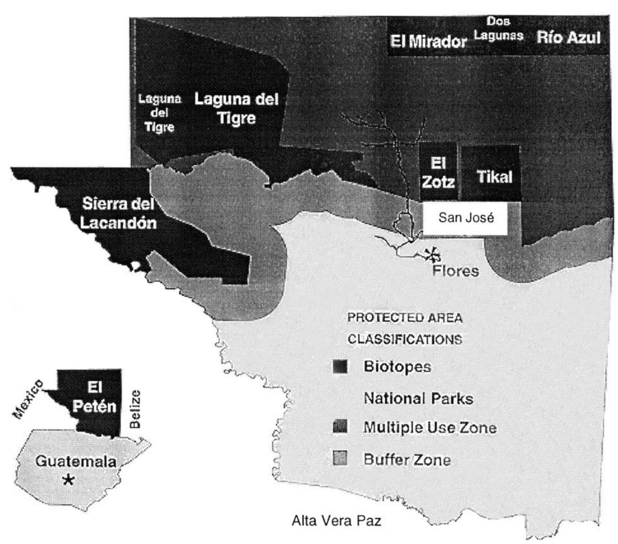

FIG. 1. *The Maya Biosphere Reserve, El Petén, Guatemala.*

ing in part "exaggerated claims about the uniqueness of Itza' knowledge of the forest environment." The only "scholarly work" cited is an article by Atran (1993) in this journal, but subsequent study shows a much wider range of culture-bound knowledge and practice, with greater historical depth, than suggested in previous work (López et al. 1997, Lois 1998, Atran 1999, Atran et al. 1999, Atran and Ucan Ek' 1999, Atran, Lois, and Ucan Ek' n.d.).

3. At the height of the growing season, July rainfall in Flores (site of the pre-Columbian Itza' capital) went from 121 mm in 1993 to 335 mm in 1996 and in nearby Tikal from 58 mm to 137 mm; in May, when crops are planted, there was no rainfall in Tikal in 1993 for 23 days, then 130 mm in 3 days, and so on (Guatemala Government Institute of Meteorology, INSIVUMEH).

perature is 25°C and mean annual precipitation 1,600–1,800 mm. In the Reserve and adjacent areas, Itza′ make up a majority of the population in only one settlement, Q′eqchi′ are a majority in 25 settlements, Ladino immigrants are a majority in 134 settlements, and Ladino "Peténeros" (in the area for at least three generations) are a majority in 6 settlements (Grünberg and Ramos 1998).

In 1998, San José had 1,789 habitants. Most identify themselves at Itza′, although only a minority speak the native tongue. Nearly all 625 people in neighboring La Nueva are Ladinos (people of mixed European and Amerindian descent). Most migrated to the area in the 1970s as nuclear families stemming from various towns of southern Guatemala. Corozal was settled at the same time by Q′eqchi′-speakers, a highland Maya group. Most of the 395 inhabitants speak only Q′eqchi′ (not mutually intelligible with Itza′). Q′eqchi′ filtered in as nuclear families, migrating in two waves that transplanted parts of highland communities to Corozal: (1) directly from towns in the vicinity of Cobán (capital of the Department of Alta Vera Paz, south of Petén) and (2) indirectly from Alta Vera Paz via the southern Petén town of San Luis (home to a mixed community of Q′eqchi′ and Mopan Maya). Q′eqchi′ immigration into Petén began as early as the 18th century, though massive population displacement into Petén is recent. The Q′eqchi′ now constitute the largest identifiable cultural group in Petén while maintaining the smallest number of dialects and the largest percentage of monolinguals (Wilson 1995:38; cf. Stewart 1980). This reflects the suddenness, magnitude, and relative isolation of the Q′eqchi′ migration.[4]

In all three groups, people pay rent to the municipality for a farm plot. Itza′ and Ladinos interact often, as their villages are 1 km apart. Q′eqchi live 18 km away, but daily buses connect them with the other two groups (who also farm regularly around Corozal). All groups practice agriculture and horticulture, hunt game, fish, and extract timber and nontimber forest products for sale. Each household (about five persons) has usufruct rights to 30 manzanas (21.4 ha) of *ejido* land (municipal commons). Farmers pay yearly rent of less than a dollar for each manzana cleared for swidden plots, known as *milpa*, whose primary crop is maize. Yearly crop patterns can vary widely, partly because of microclimate and rainfall fluctuation. People can hold plots in scattered areas and can change plots. Plots from all groups may abut. Hunting is tolerated on neighbors′ plots but not access to another′s crops or trees.

To ensure maximum social coverage from our sample, our initial informants could not be immediate blood relatives (children, grandchildren, parents, grandparents, siblings, first cousins, nieces, nephews, uncles, aunts), immediate affines (spouses, in-laws), or godparents (*compadres*). The distributional view of culture that we adopt leads to the use of sampling techniques that are likely to reveal cultural differences rather than estimating population parameters. We assumed that younger Itza′ Maya might have notions of biology that differed from those of Itza′ elders and that these differences might reflect assimilation to "Western culture." In addition, because Itza′ is a dying language and few younger Itza′ speak it, a random sample would have tended to hide rather than emphasize the differences we were interested in. Instead of randomly sampling, we restricted our initial sample to Itza′-speaking Maya as the best representatives of Itza′ Maya "culture." This is not to suggest that there was some pure Itza′ culture in the past that is now being degraded. In fact, Itza′ cultural life is a rich blend of ideas and habits stemming from different inputs, with much Spanish influence. We assume only that across time and (varying) outside influences the knowledge base differs between individuals.

REPORTED AGROFORESTRY PRACTICE

Although the three groups share a reliance on land and awareness of local species for survival, analyses of a three-year period of milpa practice among 12 to 16 informants in each group showed striking differences in the ways in which the groups utilize land and their knowledge of species. The data reported here are chiefly self-reports elicited from informants, but long-term spot checks and subsequent measurements (reported below) confirm a correspondence to actual behavior. Reports exhibit no evident bias (e.g., elicited maps of milpa plots depict land cleared more accurately and in amounts systematically greater than municipal tax records show).

Analyses of variance were used to reveal group differences between Itza′, Ladinos, and Q′eqchi′, with the Scheffe statistic ($p < .05$) used for post-hoc comparisons. The following abbreviations are used with the comparative statistics: I = Itza′ Maya, L = Ladino, Q = Q′eqchi′ Maya; M = milpa (swidden plot), G = *guamil* (fallow milpa), R = reserve (secondary forest). Analyses revealed no differences among groups in age, family size, land available for cultivation, or per capita income from all traceable sources.[5] Q′eqchi′ produce one set of crops per year, Itza′ and Ladinos usually two. Q′eqchi′ cut and burn forest for new plots every year, compared with an average of every 2.3 years for Itza′ and every 1.8 for Ladinos ($F[2,41] = 12.92$, $p < .001$; I, L < Q). Difference in burn frequency produces differences in destructiveness independently of need for income.

Q′eqchi′ clear in a contiguous S-pattern that rolls through the forest leaving few trees within or between plots, including hill crowns. Ladinos intermittently leave trees between and within plots. Itza′ regularly ring plots with trees, clear firebreaks around valuable trees inside plots, and change plots in a noncontiguous pattern. This is a strategy apparently shared with some

4. There is evidence for Q′eqchi′ migration in baptism and marriage registers beginning in 1718 for the Petén towns of Santo Toribio, Dolores, and San Luis (Archivo Apostólica, Flores, Petén).

5. Median family income, however, was lower for Q′eqchi′ (US$730) than for Ladinos (US$1,330) or Itza′ (US$1,460). In part, this may reflect less dependence on public works projects for supplementary wages and greater reliance on sales of surplus maize.

groups of lowland Lacandón and Yukatek Maya in Mexico, and there is evidence of a pre-Columbian origin (Gómez-Pompa, Flores, and Sosa 1987, Remmers and De Koeijer 1992). Itza' explain it in terms of forest regeneration: birds such as the chachalaca (*ix b'aach = Ortalis vetula*) roost in the milpa's outer ring (*t'ool che'*) but fly to inner stands (*watan che'*) to feed on crops and excrete undigested seeds of outlying trees. Left to fallow, areas around inner stands begin to emulate and bridge with the outer ring. Birds take undigested seeds of valuable inner-stand trees such as ramon (*'oox= Brosimum alicastrum*) to the outer ring, thereby increasing its value for people.

Itza' differ from Ladinos and Q'eqchi' in reported amount of land cleared for cultivation ($F[2,41] = 5.45$, $p < .01$, I < L, Q), fallow length ($F[2,41] = 6.982$, $p < .002$, I < L, Q), and number of species cultivated ($F[2,34] = 13.94$, $p < .001$, I < L, Q) (table 1). To map these different patterns of use onto an overall measure of destructiveness, we make the strong simplifying assumption that destructiveness (D) is an increasing function of land used per cycle through a plot (L) and rate of cycling through a plot (R). That is, $D = L \times R$. To determine L and R we use A (amount of land a farmer clears), Yc (number of years a cleared plot is used continuously), and Yf (number of years the land is left fallow). From this it is straightforward to determine that $L = A \times (Yc + Yf)/Yc$ and that $R = 1/(Yc + Yf)$. Multiplying these two terms yields the result that $D = A/Yc$, which is simply land cleared per year. By this measure, Q'eqchi' destroy more than five times as much forest and Ladinos less than twice as much as Itza'.[6]

6. $F(2,41) = 25.04$, $p < .0001$, $D(\mathrm{I}) = .753$, $D(\mathrm{L}) = 1.39$, $D5(\mathrm{Q}) = 3.92$. Our equation oversimplifies the consequences of different patterns of use, which involve a trade-off between the costs of farming a plot longer and the benefits of fallowing longer. In theory, the costs and benefits could be quantified to assess sustainability, but we have already seen that these groups farm differently. One potential limitation of our formula is that a shorter growing period for Q'eqchi' could leave the land in better shape for recovery, but soil tests (reported below) reveal that nitrogen, a limiting factor in these calcified soils, is much more abundant in Itza' fallow land than in Q'eqchi' fallow.

BIODIVERSITY, FOREST COVER, AND SOIL CONDITIONS

Remote sensing confirms extensive deforestation along Q'eqchi' migration routes into Petén (Grünberg and Ramos 1998, Sader 1999, Grunberg 2000). Reported patterns of crop diversity and awareness of greater ecological complexity and reciprocity between animals, plants, and people should favor regeneration of forest used by Itza' versus Ladinos. Despite mutual imagined similarities between Itza' and Q'eqchi', on nearly all reported measures Ladinos are closer to Itza' than Q'eqchi' are to Itza'. This tendency is reliably confirmed by other measures.

To corroborate cultural behavior patterns, after a two-year lapse we measured for ten new informants from each group plot sizes, species diversity, tree counts (minimum circumference > 0.3 m at 1–1.5 m from ground), coverage (m^2 foliage for each tree crown), and soil composition (10-cm and 20-cm depths). For each informant, we sampled land held in usufruct in three locations: milpa, guamil (fallow milpa), and reserve (land uncultivated since initial clearance at the onset of usufruct). All locations were sampled after burning, planting, and weeding of a first-year milpa (when maize stalks reached 0.5–0.8 m before flowering). Reserve samples were one hectare, and guamil was three years old on average. Our initial study suggested that for all group measures relative to forest health and productivity, Itza' ≥ Ladino ≥ Q'eqchi'; hence, we report both two-tailed (Scheffe's $p < .05$) and one-tailed (Fisher's $p < .05$) post-hoc comparisons, the latter indicating marginal reliability in the predicted direction.[7]

Again, table 1 shows that Itza' plant more species (9.7) than Ladinos (6.4) or Q'eqchi' (6.2) and clear less land yearly (2.0 ha) than Ladinos (2.4 ha) or Q'eqchi' (3.6 ha); however, an analysis of variance of crop species/ha as a function of group shows a reliable difference only between Itza' and Q'eqchi' ($F[2,27] = 3.339$, $p < .05$). For all groups, the most frequent crops are maize, then beans, then squash. Overall, Itza' cultivate 43 different species

7. We normalized highly variable distributions of raw scores with a natural log transformation.

TABLE 1
Analysis of Variance of Petén Swidden (Milpa) Practices

	N	Crops/Year	Years of Land Use	Hectares Cleared	Years Fallow	Species/Year Cultivated
Itza' (R)	16	2	2.3	1.6	4.7	7.8
Itza' (O)	10	–	–	2	–	9.7
Ladino (R)	16	2	1.8	2.6	3.6	3.3
Ladino (O)	10	–	–	2.4	–	6.4
Q'eqchi' (R)	12	1	1	4.1	3.3	3.6
Q'eqchi' (O)	10	–	–	3.6	–	6.2
Other Q'eqchi'*	–	–	1.6	3.7	3.3	2.5

NOTE: R, reported two-year average; O, observed in year 3.
*Average of five Q'eqchi' settlements (Fagan 2000).

in milpas, Ladinos 26, and Q'eqchi' 23, with a greater yearly species mix for Itza'. We predicted tree diversity to parallel crop diversity as a biodiversity indicator: Itza' averaged 9.0 species/ha, Ladinos 7.2, and Q'eqchi' 4.4.

Number of tree species was examined with an analysis of variance using group (I = Itza', L = Ladino, Q = Q'eqchi') and location (M = milpa, G = guamil, R = reserve). Results show effects of group ($F[2,81] = 10.48$, $p < .0001$; I, L < Q), location ($F[2,81] = 171.98$, $p < .0001$; R > M, G), group × location ($F[4,81] = 4.45$, $p = .003$; M: I > L, Q; G, R: I, L[marginal] > Q). As a relative measure of biomass, average tree cover shows the same pattern (fig. 2), with effects of group ($F[2,81] = 6.17$, $p = .003$; I > Q, L(marginal)), location ($F[2,81] = 75.08$, $p < .0001$; R > M, G), group × location ($F[4,81] = 3.43$, $p = .01$; M: I[marginal] > Q; G: I > Q, L[marginal]; R: I > Q). For total land cleared (M + G), Itza' differ reliably from Q'eqchi' and Ladinos. Group differences cannot be due to base-rate differences in species frequency, given the adjacency of parcels across groups.

Soil analysis also suggests that Itza' agroforestry is least harmful and most productive. Each soil sample was rated on a scale of 1 to 22 as a joint function of texture (sandy clay loam < clay loam < silty clay loam < sandy clay < clay < silty clay) and structure (small grain < medium grain < large grain < small block < medium block < large block). The best soil (= 1) is sandy clay loam composed of small granular structures that become neither too hard when dry nor too compact when wet to prevent water and root penetration. The worst soil (= 22) is silty clay structured in large blocks which become rock-hard when dry and extremely compact when wet. This scale reflects the fact that not all possible combinations of texture and structure were present. Physical character of soils was subjected to an analysis of variance: group (I, L, Q), location (M, G, R) × level (1 = 10 cm, 2 = 20 cm). Only level proved significant ($F[1,162] = 11.37$, $p = .001$; 1 < 2). There were no reliable between-group differences for any location. Averages for each group across all locations fell within the range of clays with block structures (I = 14.1, L = 16.9, Q = 14.0). These are able to hold water and fix phosphorus but become unworkable and impede root growth during the very dry and wet spells frequent in Petén. Erosion and lack of tree cover magnify the effect.

All soils are moderately alkaline, with no significant group differences in pH or organic matter. Differences are most apparent for (normalized) measurements of phosphorus and nitrates. Neither is abundant in the geological materials of limestone regions, and their availability represents limiting factors on life-support systems (Rice 1993). Phosphorus and nitrate levels were subjected to analyses of variance using group × location × level. Phosphorus showed effects for location ($F[2,162] = 25.67$, $p < .0001$; M > G, R), level ($F[1,162] = 18.86$, $p < .0001$; 10 cm > 20 cm) and group × location ($F[4,162] = 3.79$, $p = .006$; M: I, L > Q; R: L > I). Itza' differ from Q'eqchi' in the upper milpa level ($p < .05$), where phosphorus is most abundant and useful to new plant growth. Overall, Itza' have the highest milpa and lowest reverse

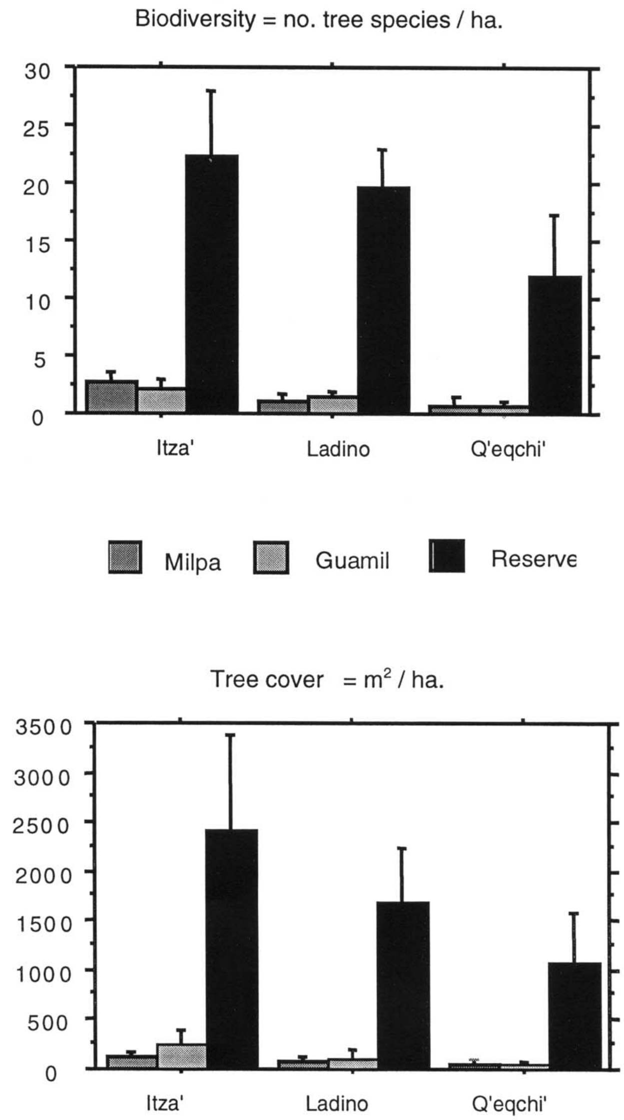

FIG. 2. *Biodiversity (number of tree species) and tree cover (m^2 per hectare) as a function of cultural group and location type* (error bars, *95% confidence interval*).

scores, indicating greater phosphorus storage by plants in reserve with more available for release in milpa.[8]

High levels of phosphorus in milpa arise from burning; however, intense heat volatilizes nitrates essential to

8. An analysis of variance was performed on a composite of standardized scores for basic nutrient elements P + (K + Mg − Ca). Calcium is antagonistic to the fixing of potassium and magnesium, so the composite represents a balance of the available nutrient elements: phosphorus for root growth, potassium for stem strength, magnesium for photosynthesis, calcium for cell formation. Results paralleled those for phosphorus for location ($F[2,162] = 15.15$, $p < .0001$; M > G, R), level ($F[1,162] = 34.10$, $p < .0001$; 1 > 2), and group × location ($F[4,162] = 4.02$, $p = .004$; M: I[marginally] > Q; R: L > I).

leaf formation. Thus, higher phosphorus levels should be correlated with lower nitrate levels (and perhaps less foliage cover in the long run), but for Itza' and, to a lesser extent, Ladinos the reverse is true. Nitrate levels show effects of group ($F[2,162] = 11.42$, $p < .0001$; I[marginally] > L, Q), location ($F[2,162] = 6.44$, $p = .002$; M > G), and group × location ($F[4,162] = 2.87$, $p = .02$; M: I, L > Q; G: I > L, Q). For total land cleared (M + G), Itza' differ marginally from Ladinos and significantly from Q'eqchi'. Interrelated factors allow Itza' to enjoy relatively high phosphorus and nitrate levels. Itza' cultivate more varieties of nitrogen-fixing pole beans that climb maize stalks than Q'eqchi' or Ladinos. Q'eqchi' and Ladinos weed only once shortly after planting; Itza' weed a second time before maize has flowered and leave the weeds as mulch. Intense rainfall at this time favors bacterial decomposition of mulch, which releases nitrogen (also phosphorus, potassium, and magnesium). Finally, Itza' tend to light smaller and more dispersed fires to clear land and to protect valuable trees with firebreaks 2 m in width. (A side effect is that the less intense heat causes less volatilization of nitrogen.)

In sum, physical measurements generally corroborate reported behaviors and track their consequences, indicating that Itza' practices encourage a better balance between human productivity and forest maintenance than do immigrant practices. However, significant differences in immigrant practices reveal that immigrant Spanish-speakers are measurably closer in behavior to native Maya than are immigrant Maya. Studies of milpa practices in other immigrant Q'eqchi' communities in Petén confirm the patterns in our study (Fagan 2000).

MENTAL MODELS

To determine whether group differences in behavior are reflected in distinct cognitive patterns, we elicited folkecological models. In preliminary studies, we asked informants "Which kinds of plants and animals are most necessary for the forest to live?" From these lists we compiled a set of 28 plants and 29 animals most frequently cited across informants (plant vouchers deposited at the University of Michigan Herbarium).[9] The 28 plant kinds in the study include 20 trees and 1 ligneous vine counted among the species in the preceding study (starred in table 2). Although these 21 species represent only 17% of the species enumerated, they account for 44% of all trees in Itza' parcels, 50% in Ladino parcels,

9. For plant stimuli we compiled a list of the 26 generic species most frequently mentioned by informants in earlier studies. Generic species (also called folkgenera) are basic building blocks of folkbiological taxonomies everywhere (Atran 1998). The generic species mentioned most were all trees, vines, or palms. We added 2 often-mentioned life forms: herbs/underbrush and grasses. Life forms are superordinate folktaxa that contain many generic species. For animals, the overlap among all our populations warranted use of the same 28 names in each case. In addition to the 28 animals generated by the task, we introduced the bat as a 29th animal because of its special status within Maya taxonomy. Colored drawings were taken from field guides.

TABLE 2
Petén Forest Plants and Animals

Ref.	Common Name	Scientific Name
Plants		
Fruit trees		
P1*	ramon	*Brosimum alicastrum*
P2*	chicozapote	*Manilkara achras*
P3*	*ciricote*	*Cordia dodecandra*
P4*	allspice	*Pimenta diocia*
P5*	strangler fig	*Ficus obtusifolia*
		F. aurea
Palms		
P6*	*guano*	*Sabal mauritiiforme*
P7*	broom palm	*Crysophilia stauraca*
P8*	corozo	*Orbignya cohune*
		Scheelea lundellii
P9	*xate*	*Chamaedorea elegans*
		C. erumpens
		C. oblongata
P10	pacaya	*Chamaedorea tepejilote*
P11	*chapay*	*Astrocaryum mexica*
Grasses/herbs		
P12	herb/underbrush	(various families)
P13	grasses	Cyperaceae/Poaceae
Other plants		
P14	mahogany	*Swietenia macrophylla*
P15	cedar	*Cedrela mexicana*
P16	ceiba	*Ceiba pentandra*
P17	*madrial*	*Gliricidia sepium*
P18	*chaltekok*	*Caesalpinia velutina*
P19	*manchich*	*Lonchocarpus castill*
P20	*jabin*	*Piscidia piscipula*
P21	Santa Maria	*Calophyllum brasiler*
P22	amapola	*Pseudobombax ellipticum*
		Bernoullia flammea
P23	*yaxnik*	*Vitex gaumen*
P24	*kanlol*	*Senna racemosa*
P25	*pukte*	*Bucida buceras*
P26	water vine	*Vitis tilaefolia*
P27	cordage vine	*Cnestidium rufescens*
P28	killer vines	(various epiphytes)
Animals		
Arboreal		
A1	bat	Chiroptera
A2	spider monkey	*Ateles geoffroyi*
A3	howler monkey	*Allouatta pigra*
		A. palliata
A4	kinkajou	*Potus flavus*
A5	coatimundi	*Nasua narica*
A6	squirrel	*Sciurius deppei*
		S. aureogaster
Birds		
A7	crested guan	*Penelope purpurascens*
A8	great curassow	*Crax rubra*
A9	ocellated turkey	*Meleagris ocellata*
A10	tinamou	*Tinamou major*
		Crypturellus sp.
A11	toucan	*Ramphastos sulfuratus*
A12	parrot	Psittacidae in part
A13	scarlet macaw	*Ara macao*
A14	chachalaca	*Ortalis vetula*
A15	pigeon/dove	Columbidae
Rummagers		
A16	collared peccary	*Tayassu tacaju*
A17	white-lipped peccary	*Tayassu pecari*
A18	paca	*Cuniculus paca*

A19	agouti	*Dasyprocta punctata*
A20	red-brocket deer	*Mazama americana*
A21	white-tailed deer	*Odocoileus virginianus*
A22	tapir	*Tapirus bairdii*
A23	armadillo	*Dasypus novemcintus*
Predators		
A24	jaguar	*Felis onca*
A25	margay	*Felis wiedii*
A26	mountain lion	*Felis concolor*
A27	boa	*Boa constrictor*
A28	fer-de-lance	*Bothrops asper*
A29	laughing falcon	*Herpetotheres cachinnans*

*Species counted in tree-frequency study.

54% in Q'eqchi' parcels. This confirms the salience of the species selected for the folkecological study.

How plants affect animals. Instructions and responses were given in Itza', Spanish, or Q'eqchi. Equal numbers of informants (six men and six women in each community) were asked first to explain how each plant helped or hurt each animal. The task consisted of 28 probes, one for each plant. On each trial, all animal picture cards were laid out and the informant was asked if any of the animals "searched for," "went with," or "were companions of" the target plant and whether the plant helped or hurt the animal. Questions were pretested for simplicity and easy applicability across cultures. Unaffiliated animals were set aside. For each animal, informants were asked to explain how the plant affected the animal, and their explanations were recorded. We used principal-components analysis to determine if a single underlying model of ecological relations held for all informants in a population. Analysis was done on each of three 12 × 12 subject-by-subject matrices. Each matrix was adjusted for guessing. Consensus was assumed if (1) the first eigenvalue was notably larger than the second and accounted for most of the variance and (2) the first eigenvector was all positive. Under these conditions, the agreement pattern among informants should reflect a common model, and first-factor scores provide indices of the degree to which individuals' responses reflect the consensus (Romney, Weller, and Batchelder 1986). Each person's first-factor score, then, may be considered a measure of that person's individual cultural "competence" with respect to the aggregated cultural "model." To establish consensus, all tasks involved a minimum of 12 participants from each group.[10] Finding consensus justifies further study of groupwide patterns.[11] Analyses of residual agreement were used to reveal differences among groups (Nakao and Romney 1984, Medin et al. 1997).[12] To compute residual agreement, we first calculated the agreement predicted by the model for any pair of actors by multiplying their first-factor scores. Residual agreement was then correlated with observed agreement. Systematic residual agreement suggests distinct group patterns beyond overall consensus. If residual agreement is correlated with observed agreement, then patterns of observed agreement among informants occur beyond what is explained by participation in the consensus (cf. Boster 1986).[13] If not, participation in the consensus basically accounts for the entire pattern of observed agreement. If a single model fits all individuals, there should be only chance residual agreement.

Two results are apparent (fig. 3): Itza' and Ladinos showed very similar patterns of relations, and Q'eqchi' perceived many fewer and those tended to be a subset of those seen for the other two groups. The overwhelming majority of interactions within each group involved plants helping animals by providing them food.[14] Plants' providing shelter to animals was also a common response. An analysis of variance for plants helping animals shows Q'eqchi' reporting on average many fewer relations (46.8) than either Ladinos (163.2) or Itza' (187.5), who did not differ from each other ($F[2,33] = 23.10$, $p < .001$). Itza' and Ladinos showed a large overlap for which plants helped which animals (r [I, L] = .82 versus r [I, Q] = .42 and r [L, Q] = .54). This picture is supported by consensus and residual analyses.

Using agreement adjusted for guessing as the dependent variable, a large cross-group consensus emerged (the first eigenvalue, 23.98, was 12.3 times the second and explained 67% of the variance). Moreover, consensus scored for Q'eqchi' (mean competence = .89) were reliably higher than for Itza' (.79) or Ladinos (.85), who did not differ from each other ($F[2,33] = 8.82$, $p < .001$, Scheffe post-hoc p's $< .05$). Even if a majority of Ladinos and Itza' agreed that a plant helped an animal, often all Q'eqchi' reported no effect, making the modal answer no effect. Thus, Q'eqchi' responses drove the overall consensus. Given this situation, residual analyses are more

10. With certain formal qualifications (cf. López et al. 1997:263), our analysis is based on the culture consensus model of Romney, Weller, and Batchelder (1986). When the three conditions above are met, a sample as small as 12 informants with average competence of 0.5 is enough to signal consensus.

11. Pairwise agreement was calculated between all informants separately for plant-animal and animal-plant relations. All animal-plant pairs for which either informant did not know one or both species were excluded. If both gave the same response (either positive, negative, or no relation), they were counted as agreeing; if they reported different relations or if one reported a relation and the other none, they were scored as disagreeing. Each pair of informants was given a score ranging from 0 to 1.0 representing the proportion of species pairs on which they agreed. Observed agreement was adjusted for guessing: adjusted agreement = ([observed agreement × number of possible responses] − 1)/(number of possible responses − 1).

12. Multiple regressions were performed within and between all three groups using age, gender, and residence (for Itza', residence = informant age) as independent variables against first-factor consensus scores. There were no significant differences within or between populations (though gender together with judgments of expertise was significant for Ladinos [see below]).

13. Boster's (1986) method of determining residual agreement motivated our initial interest in this method; however, his method does not work if the items are not all of equal difficulty. Accordingly, we use within-versus between-group residual agreement as our measure.

14. For nearly all respondents, a given plant helps a given animal or does nothing for it. Only two Itza' said of one epiphyte that it harmed animals by killing the plants those animals feed upon.

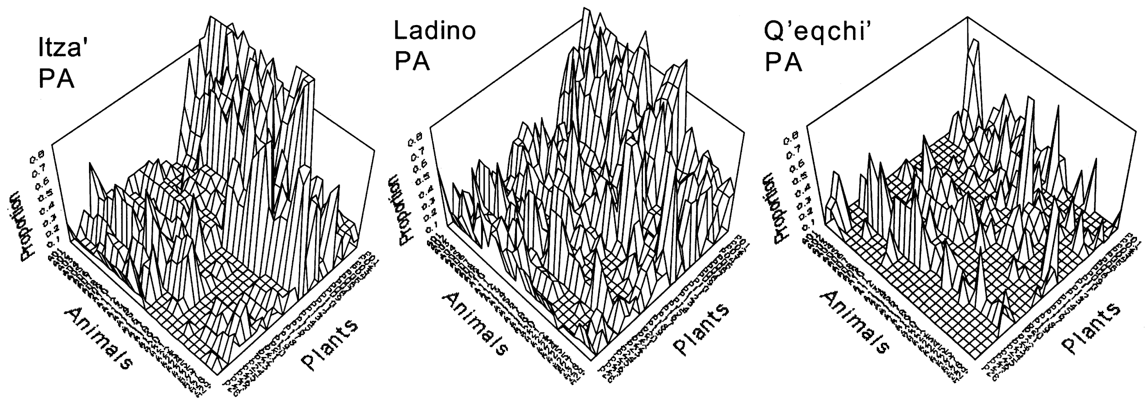

FIG. 3. *Frequency of reports of effects of plants on animals for Itza', Ladinos, and Q'eqchi'. Plant and animal numbers refer to the ordering of species in table 2. The height of each point reflects the proportion of informants reporting such interaction.*

effective in revealing cultural models than simple measures of interinformant agreement.

We analyzed a 3 × 36 residual agreement matrix. For each of 36 informants (12 in each group) there were three measures: average residual agreement of that informant with members of the same group and that informant's average residual agreement with members of each of the other two groups. Within-group agreement was reliable: for each group, $F[2,22] > 23$, $p < .001$. Itza' and Q'eqchi' had greater within- than between-group residual agreement. Ladinos showed higher within- than between-group residual agreement vis-à-vis Q'eqchi' but did not share more residual agreement with one another than with Itza'.[15] This indicates that the Ladino model was a version of the Itza' model. One distinction between Itza' and Ladinos was the latter's tendency to generalize the beneficial effect on animals of economically and culturally important plants such as mahogany (the prime wood export) and ceiba (Guatemala's national tree) without apparent justification. Overall, Ladino and Itza' models converged on how plants helped animals; the Q'eqchi' model was a severely limited subset.

How animals affect plants. Reports of how animals affect plants yielded larger differences (fig. 4). Q'eqchi' signaled too few interactions for consensus analysis (only 13 interactions of 812 possible animal-plant pairings for each of 12 participants). Itza' and Ladinos showed strong cross-group consensus (ratio eigenvalue 1:2 = 18.9, variance = 72%) but also greater residual agreement within than between groups ($t[11] > 4.5$, $p < .0001$). Negative reports of animals hurting plants occurred with equal frequency (8.0% of cases by Itza', 8.2% by Ladinos), but Itza' were 4 times more likely to report positive interactions ($F[2,33] = 3.74$, $p < .05$) and 3.4 times more likely to report reciprocal relations (a plant and animal helping each other) ($t[22] = 3.31$, $p < .005$).

Itza' reported that classes of animals (arboreal, bird, rummager, predator) differentially affected classes of plants (fruit, grass/herb, palm, other), whereas Ladinos reported more universal effects.[16] Arboreals were reported to be much more likely to interact with fruit trees than with other plant groups; birds were reported to be most likely to interact with fruit trees but also to have moderate levels of interactions with palms; rummagers were reported to interact primarily with grasses/herbs and to a lesser extent with fruit trees; predators were reported to have few if any interactions with plants. An analysis of variance reveals a plant-by-animal interaction for Itza' but not for Ladinos ($F[9,99] = 26.04$, $p < .0001$). The absolute level of interactions was much lower for Ladinos, who reported that all animal groups (save predators) interacted with all plant groups in roughly the same ways. Animals reported to be most likely to affect plants were rummagers, birds, and arboreals, and the plants most likely to be affected were said to be fruit trees and "other" plants.

On a qualitative level, although both groups acknowledged that animals had a large impact on fruit trees, Itza' differed from Ladinos in understanding these relations.

15. Results of *t*-tests were: for Itza' $t(I, L) = 6.71$, $t(I, Q) = 8.88$; for Q'eqchi' $t(Q, L) = 16.7$, $t(Q, I) = 20.9$; for Ladinos $t(L, Q) = 4.38$, $t(L, I) =$ n.s.

16. Participants were given two scores for each pairing of animal and plant group, reflecting the proportion of possible positive and negative interactions acknowledged. A score of .25 for negative arboreal-fruit interactions indicates that the participant identified negative interactions between one-quarter of all possible pairings of arboreal animals and fruiting plants. Scores were entered into 2 (type of interaction: positive, negative) × 4 (animal group: bird, rummager, arboreal, predator) × 4 (plant: fruit, grass/herb, palm, other) analyses of variance. Thus, tests of plants had 3,33 degrees of freedom, as did tests of animals, and tests of plants by animals had 9,99 degrees of freedom. Ladinos showed main effects of interaction type ($F[1,11] = 6.95$, $p < .05$), plant ($F[3,33] = 9.89$, $p < .0001$), and animal ($F[3,33] = 14.40$, $p < .0001$) but no animal by plant interaction.

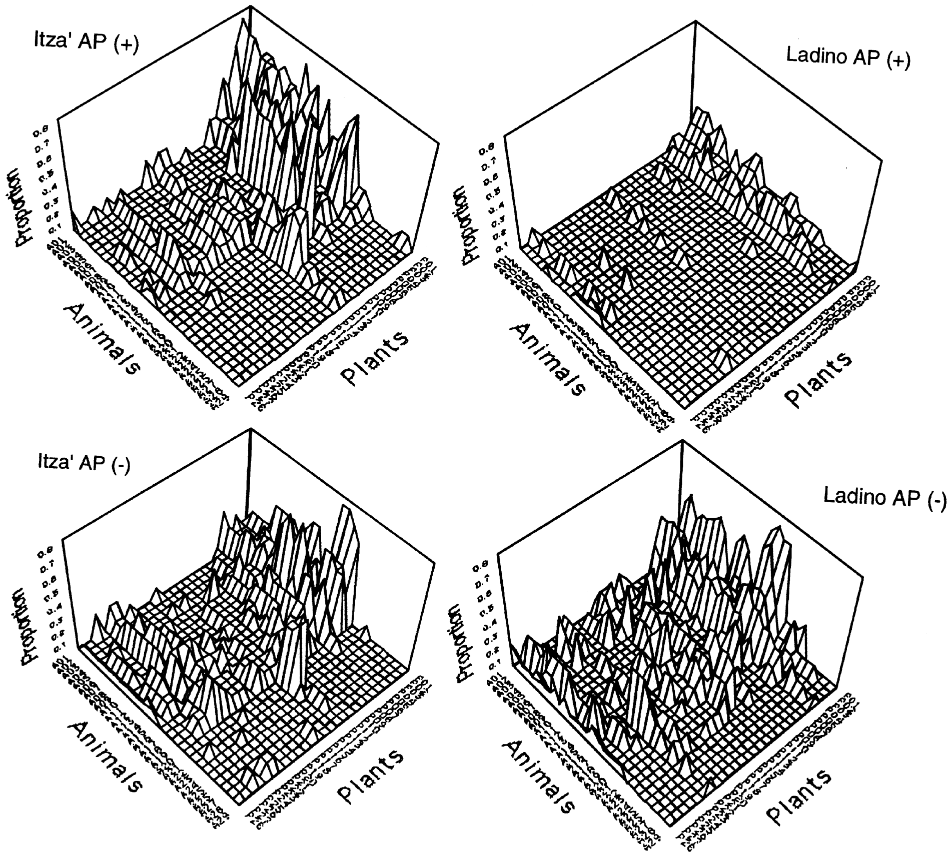

FIG. 4. *Frequency of reports of effects of animals on plants for Itza' and Ladinos. Animal and plant numbers refer to the ordering of species listed in table 2. The height of each point reflects the proportion of informants reporting such interaction.*

Ladinos inferred that animals harmed plants by eating fruit. Itza' had a subtler view based on the properties of the seed and on how the animal chews and digests. If the seed is soft and the animal crunches through the fruit casing, the interaction is harmful because the animal is likely to destroy the seed; but if the seed is hard and digestion is rapid, the interaction is likely to be helpful if the seed passes through the animal's body, for the animal assists seed dispersal and fertilization.

The picture thus far suggests common models with distinct variations for each group. On plants helping animals, Itza' and Ladinos had similar models with over 80% overlap on pairwise interactions. The Q'eqchi' model was much less elaborated, being a proper subset with less than one-sixth of the relations reported by the other groups. An examination of how animals are reported to affect plants further reveals the paucity of the Q'eqchi' folkecological model. Q'eqchi' reached a nonzero consensus on only 10 out of 812 possible relations. These findings suggest a complex Itza' folkecological model of the forest wherein different animals affect different plants and relations among plants and animals are reciprocal. Ladinos also possess a relatively elaborate model, but relations were more unidirectional and less specific. Q'eqchi' acknowledge a much reduced role and almost no role of animals in the folkecology of the forest.[17]

Bidirectional plant-animal relations. Analyses were performed on pairwise relations among plant and animal species reported by the three groups. For each plant-animal pair, an informant could report that the plant either helped, hurt, or had no relation to the animal and vice versa. Although responses were coded as to the specific nature of the helping or hurting relation, for these analyses those differences were glosses over and relations were scored only as helping or hurting. Thus, the bidirectional relation between each plant and animal could be classified as one of the following: "mutualist" (+ 1, + 1), "commensalist" (+ 1,0), "parasitic" (+ 1,−1), "destructive" (−1,0 or −1,−1) or "neutral" (0,0). Itza'

17. These variations represent interactions, not general differences in response thresholds. Thus, Ladinos responded at the same rate as Itza' for plant-animal relations and for negative animal-plant relations but reported dramatically fewer positive animal-plant relations. Q'eqchi also showed an interaction. Difference in knowledge is therefore the most parsimonious description of our results.

recognized reliably more mutualist relations than did Ladinos; Q'eqchi' recognized almost none.

Relations between people and plants. For the last few millennia Petén forest ecology has been intensely anthropogenic, and so we might expect awareness of the human role to be critical to long-term forest maintenance. To explore perceived interactions among people and plants, we asked each informant whether people in their community helped (+1), hurt (−1), or did not affect (0) each item on the plant list and vice versa, thereby assessing actual practice rather than ideal behavior. We also asked informants to explain their responses. No overall consensus emerged, but each population showed within-group consensus (ratio eigenvalue 1:2 > 3, variance accounted for > 50%). Analyses of variance confirm that each group had a distinct pattern ($F[2,33] = 5.92$, $p < .01$). Itza' reported more instances of humans' affecting plants than Ladinos, and both groups reported many more than Q'eqchi' ($F[2,33] = 157.37$, $p < .0001$). On average, Itza' reported helping over twice as many plants (18.7) as they hurt (7.1), Ladinos reported that they helped (10.8) and hurt (10.2) in equal numbers, and Q'eqchi' reported that they hurt (3.4) over three times as many plants as they helped (1.0). Finally, Itza' and Ladinos together showed consensus.

Explanations of responses regarding how plants help people focused on use. Response patterns for Itza' and Ladinos were similar; Q'eqchi' provided considerably fewer uses. Even so, at least two-thirds of the Q'eqchi' informants mentioned a use for the overwhelming majority of plants.[18] The rank order of primary use categories for each population reveals the priorities in each population's mental model of utility. The major difference between Itza' and Ladinos concerns the relative priorities of artisanry and firewood. Itza' were loath to consider the use of ecologically or economically important trees for firewood if the wood could be used for other purposes. Although all three populations considered nourishment among the top priorities, only the Q'eqchi' considered it primary. Even more significant, whereas Q'eqchi' also considered cash value a high priority, Itza' and Ladinos assigned cash value relatively low priority.

To assess reported human impact, we tallied individual responses to whether their community helped, hurt, or did not affect a given plant and computed each group's mean response to each plant. Each "impact signature" ranged from entirely beneficial (+1.00), through neutral (0) to entirely harmful (−1.00). Impact signatures for Itza' and Ladinos were moderately correlated ($r = .65$, $p < .001$), suggesting somewhat similar views of how humans affect plants. Signatures for Q'eqchi' were negatively correlated with those of Itza' ($r = -.28$) and Ladinos ($r = -.16$), suggesting a very different model of human effects on plants. Itza' reported beneficial impact on all ecologically and economically important plants and absolute commitment to protect ramon and chicle (*Manilkara achras*). Itza' call ramon "the milpa of the animals" because many bird and mammal species feed on its fruits and leaves (Atran 1993). The chicle tree is also visited often by animals and, as does ramon, had a long history of local use. Extraction of chicle latex for chewing gum has been Petén's prime cash source for a century. Itza' report variable impact on herbaceous undergrowth, strangler figs (*Ficus* sp., which nourish many animals but kill other trees), and *yaxnik* (*Vitex gaumeri*), which they characterize as a marginally useful "forest weed," Itza' report harmful impact on *pukte* (*Bucida buceras*), another "forest weed," on *kanlol* (*Senna racemosa*), a "village weed," and on vines cut for water and cordage.

Ladinos also reported a highly positive impact for valuable plants (including *Ceiba pentandra*). For palms they reported a positive impact only for those used for thatch (corozo palm fruits are also sold to a local nongovernmental organization [NGO]). For most plants they reported variable impact. Q'eqchi' reported a positive impact only for thatch palms and a negative impact for Petén's most important cash sources: chicle, tropical cedar (*Cedrela mexicana*), mahogany (*Swietania macrophylla*), and *xate* (decorative *Chamaedorea* dwarf palms collected for export).

In sum, only Itza' had a globally positive view of humans' impact upon the plants judged most necessary for the forest to live. Informant justifications of responses revealed that Itza' provided ecological reasons for protecting economically important plants. Both immigrant groups judged human impact on the largest number of plants to be variable, but only the Q'eqchi' saw the human impact on the economically most important plants as decidedly harmful and costly to the forest. Overall, Q'eqchi' said that they had relatively little impact on plants, a striking observation given that this group exhibited the most destructive agroforestry. This difference did not arise from unfamiliarity, because they mentioned uses for nearly all plants.

Human impact and ecological centrality. Regressions were performed to clarify relations between use, ecological centrality, and reported human impact on plants. We defined ecological centrality for each plant as the proportion of plant-animal associations in a group's consensual ecological model and used two measured of use: (1) wood, shelter, and cash combined and (2) cash alone. For Q'eqchi', none of these variables predicted impact signature, and (nonsignificant) correlations were always negative. For Ladinos, mean number of cash uses was a reliable predictor of reported impact ($r^2 = .34$, $F[2,25] = 6.55$, $p < .01$), but neither plant-animal nor animal-plant associations were reliable. The correlation between cash use and impact was positive, indicating that Ladinos protected plants with cash value. For Itza', the combined r^2 on plant-animal associations was .44 ($F[2,25] = 9.13$, $p < .001$) and both wood, shelter, and cash ($p < .01$) and

18. Itza' gave 577 positive and 14 negative responses, ranging from 41 to 57 responses per informant (modal response of 2 uses per plant). Ladinos gave 562 positive and 2 negative responses, with a range of 40 to 58 per informant (modal response of 2). Q'eqchi' gave 307 positive and 2 negative responses, ranging from 21 to 35 per informant (modal response of 1). Plants not given uses by at least a third of the Q'eqchi' were grasses, the *pukte* tree, and the strangler fig.

ecological centrality ($p < .01$) predicted impact signature. For animal-plant relations the values were $r^2 = .36$, with wood, shelter, and cash ($p = .02$) and centrality ($p < .01$) both reliable. Ecological importance and combined utility—not cash value alone—predicted which plants Itza' sought to protect. Only Itza' saw people as generally benefiting plants that benefit animals.

Finally, regression analysis reveals that, for Itza', weed status (i.e., whether a plant is considered a weed) and ratings of human impact actually predicted (normalized) frequencies of trees observed in informant parcels ($r^2 = .46$, $F[2,20] = 7.58$, $p = .004$; both predictors, $p < .01$). No such relation emerged from Ladinos or Q'eqchi'. Ramon, which is most common to Itza' parcels, exemplifies this tendency (2.6 times more counts than for Ladinos, 4.2 more than for Q'eqchi').

Human-animal relations. Focusing on the role of humans in Itza' and Ladino folkecology, we did a followup study of interactions among animals and people (with 12 new informants for each group). Itza' and Ladinos shared consensus on numbers and kinds of negative animal-human interactions (ratio eigenvalue 1:2 = 3.3, variance = 45%), based mainly on animal damage to milpa crops; however, Itza' reported more positive animal-human interactions ($F[1,112] = 98.38$, $p < .001$), based on use of animals (e.g., in medicine) and their role in forest regeneration (e.g., optimizing seed distributions of valuable trees). This is the same pattern as in the animal-plant interaction study. Correlations ($p < .05$) between the ways animals help plants and the ways humans help animals were also positive for Itza' ($r = .40$) but negative for Ladinos ($r = -.50$).

In summary, Itza' show awareness of ecological complexity and reciprocity between animals, plants, and people, and Itza' agroforestry favors forest regeneration. Q'eqchi' acknowledge few ecological dependencies, and Q'eqchi' agriculture is insensitive to forest survival. Ladino folkecology and practice are intermediate. Itza' agroforestry thought and practice encourage a potentially sustainable balance between human productivity and forest maintenance.

Cultural Epidemiology

To examine how ecological models and practices were learned, we used social network analysis to answer questions about within- and between-group consensus. We began with the informants from the plant-animal study (12 in each group). Previous literature indicated that four to eight intimate ties are readily elicited from people (Wellman 1979, Hammer 1983). We asked each informant to name, in order of priority, the seven persons outside the household "most important to your life" and to justify inclusion of these names in the informant's community of *social network*. Later, we asked each to name by priority seven persons "to whom you would turn to find out something that you do not understand about the forest" and to justify inclusion of names in the informant's *expert network*. For each informant we coded age, gender, occupation, relation to subject (friend, workmate, neighbor, relative, etc.), ethnicity, and frequency of contact with the person named (from the subject's standpoint). We used a "snowball" method to elicit social and expert networks from the first and last persons named in each original informant's social network, as direct ties involving one intermediary often suffice to establish the networks of close and extended ties that regulate information flow within a community (Freeman, White, and Romney 1992).[19]

SOCIAL AND EXPERT NETWORKS

In their social networks, Itza' named no one outside the ethnic community, Q'eqchi' named 1 Ladino, and Ladinos named 1 Itza'. This confirms our sample's ethnic homogeneity. Overall social network density (Dh = ratio of possible to actual names) was substantially greater for Q'eqchi' (4.6) than for Ladinos (2.4) or Itza' (1.94). This was also true for measures of group centrality: Q'eqchi' named 18 people more than 15% of the time, Ladinos 14, and Itza' 2. The same pattern emerged from analyses of interconnectedness, or λ-level (Wasserman and Faust 1994). The λ-level refers to the average person over the group and indicates the number of actual links that have to be severed to disconnect a given person from all other persons in the group. Among the Q'eqchi', actors named in the social networks were connected at $\lambda = 4$, Ladinos at $\lambda = 2$, and Itza' at $\lambda = 1$. Level 5 ($\lambda = 5$) includes 90% of the Q'eqchi', 21% of the Ladinos, and only 10% of the Itza'.

By contrast, Q'eqchi' had the lowest agreement on who the forest experts were and Itza' the highest. This is surprising given that the Q'eqchi' community is the smallest; one might expect higher agreement if only for lack of choices. Q'eqchi' named 4 experts at least 15% of the time, Ladinos 8, and Itza' 12. The 2 "experts" cited most by Q'eqchi' (60%) were a Washington-based NGO and the Guatemalan agency responsible for the Maya Biosphere. Itza' named only Itza'. For Ladinos, 3 of the 4 most cited experts were also the 3 named most by Itza'. We elicited expert networks for 6 of the top 10 Ladino experts, and these 6 cited Itza' as *their* experts over Ladinos by a ratio of 6:1. Overlap between social and expert networks was also greatest for Itza' and least for Q'eqchi. For Itza', 14 well-cited (chosen three or more times) social partners were among the 22 well-cited forest experts. For Q'eqchi', only 6 well-cited social partners were among the top 18 experts (all cited much less often than outside institutions). For Ladinos, 11 well-cited social partners were among the top 25 experts, and the 3 top Ladino experts were also among the 6 most socially interconnected Ladinos ($\lambda = 5$). Of 43 named Ladino experts, 42 were men (men were also almost exclusively the experts for the other groups).

For Ladinos, strong overlap between socially connected individuals and Ladino experts (who themselves

19. If the first or last person on a list could not be interviewed, we went to the second or sixth, etc.

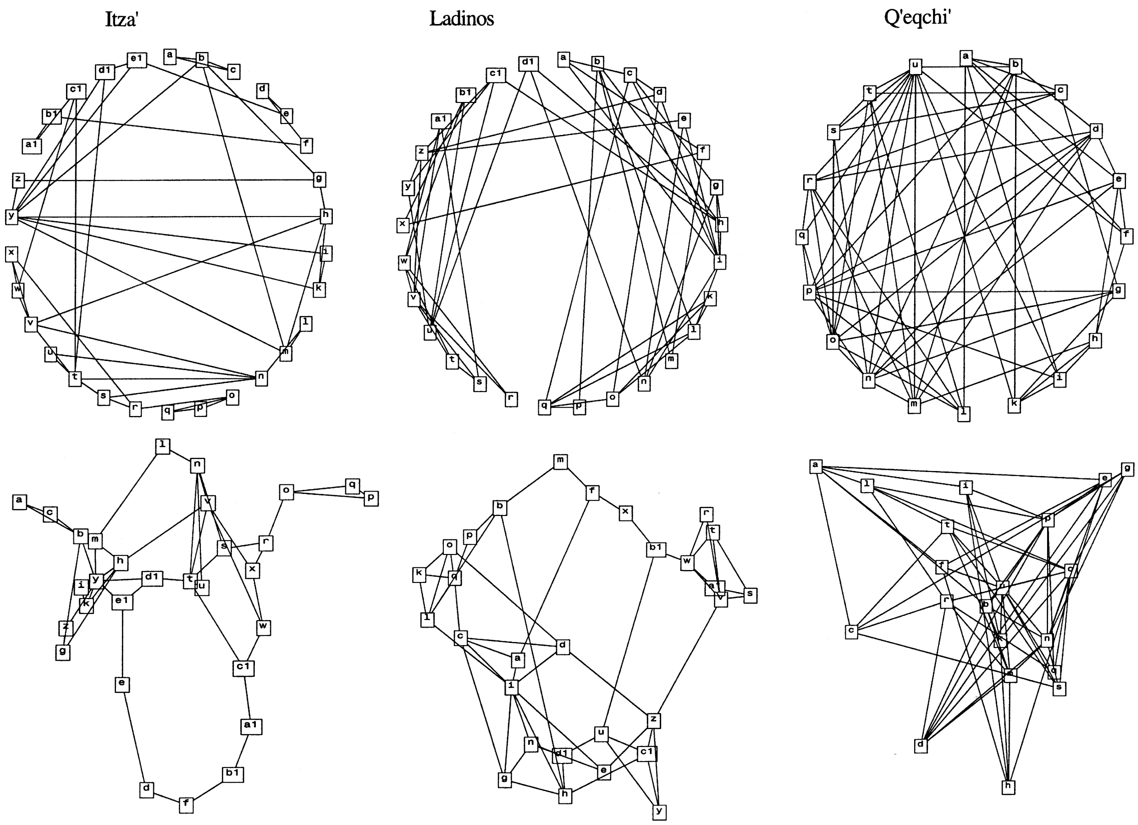

FIG. 5. *Social networks for Itza', Ladinos, and immigrant Q'eqchi'. Circle graph* (top) *and multidimensional scalings* (bottom) *are alternative representations of the same data sets.*

named Itza' as experts) intimates a network of reliable but noninstitutionalized ties for learning about the forest from Itza'. Patterns of residual variance on the plant-animal task further indicate learning. As noted earlier, though Ladinos showed higher within- than between-group agreement vis-à-vis Q'eqchi', they did not share more residual variance with one another than with Itza'. Whatever residual model of plant-animal relations Ladinos shared with one another beyond the overall consensus model they also shared with Itza'.

Thus, the three populations markedly differ in their social and expert network structures, with different consequences for the flow of information about the forest. The Q'eqchi' networks suggest that information pertinent to long-term survival of the forest comes from outside organizations with little long-term experience in Petén. What outside information there is seems unlikely to penetrate deeply into the Q'eqchi' community because it is not conveyed by socially relevant actors (although we need further evidence to show that this is fact). Radical dissociation of the Q'eqchi' expert network from a densely interconnected social network suggests that little outside information pertaining to ecological complexity or forest expertise is being assimilated by the Q'eqchi' community. For Itza', expert information about the forest appears integrally bound to intimate patterns of social life as well as to an experiential history traceable over many generations. For Ladinos, expert information is also likely to be assimilated into the community. But this expert information comes primarily from Itza' experts to Ladino experts, with the Ladino experts, in turn, selectively channeling information to the wider Ladino community.

PATHWAYS OF KNOWLEDGE TRANSMISSION

Visual representations of the social network analyses (fig. 5) show for the Q'eqchi' a dense, highly interconnected network, with no dominant individual or subgroup. This redundant social structure favors communal and ceremonial institutions that organize accountability, and these are manifestly richer among Q'eqchi' than among Itza' or Ladinos. Only Q'eqchi' practice agroforestry in corporate groups: neighbors and kin clear and burn each household's plot, kin groups seed together, and the community sanctions unwarranted access of family stands of copal trees (*Protium copal*), whose resin is ritually burned to ensure the harvest. This implies that institutional monitoring of access to resources, cooperating kin, commensal obligations, a vibrant indigenous language, and knowledge of the land (including recognition of important species) may not suffice to avoid ruin of common-pool resources. For the Q'eqchi' of Corozal, continued corporate and ceremonial ties to the sacred mountain valleys of the Q'eqchi' highlands do not imply a corresponding respect for lowland ecology. A relatively closed corporate structure that channels information focused on internal needs and distant places may function to impede access to ecological information relevant to commons survival.

Both images of the Itza' network indicate that node Y is the best-connected individual. This person is also cited as the top Itza' forest expert. His expertise is independently confirmed. For example, in a study of tropical bird classification involving American birdwatchers and Itza', Y scored highest among Itza' on measures of correspondence with scientific (classical evolutionary) taxonomy (Bailenson et al. n.d.). The multidimensional scaling suggests that the Itza' community is currently divided into two social factions: one dominated by Y and the other by V and W. These factions are also political: Y is founder and chief executive of the Bio-Itza Association, and V is the current mayor of San José. W is V's father, and he is also cited as one of the top three Itza' forest experts. Y and V-W head two families that have continuous genealogical links to preconquest Itza' clans of the same name (although there are also numerous intervening links with Yukatek Maya).[20]

One possibility consistent with this structure is that ecological knowledge is directly transmitted from socially well-connected forest experts such as Y. To evaluate the latter possibility we analyzed patterns of residual agreement in relation to social and expert network structure. We focused on nonempty cells (as determined by our most cited expert Itza' informant, Y), because knowledge transmission should primarily take the form of noting an existing relation, not the absence of relations. Analyses revealed little residual agreement, and this agreement was inconsistent across different tasks (e.g., $r^2 = .02$ between residuals for positive plant-animal and positive animal-plant relations, $r^2 = .15$ for positive plant-animal and negative animal-plant relations, $r^2 = .03$ for positive and negative animal-plant relations). In no case could we discern relationships between residual agreement and social or expert network proximity.

There is an alternative scenario to learning about the forest that is more consistent with independent discovery than direct social transmission of ecological knowledge. When asked how they learn, Itza' acknowledge consulting experts no hard problems but mostly claim to acquire knowledge elicited in our tasks by "walking alone" in the forest they call "the Maya House." For Itza', diffusely interconnected social and expert networks suggest multiple pathways for persons to gain and for the community to assimilate and store information about the forest. Cultural stories, values, and the like bias the interpretation of experience in different ways: for example, a bird or monkey eating fruit is perceived to be harmful by Q'eqchi' and Ladinos but can be inferred by Itza' to be helpful. Although culturally channeled in this way, Itza' knowledge of specific plant-animal interactions is acquired through individual experience and exploration.

The circle graph of the Ladino network shows a clear gender division of the community: C1–R are women, A–Q are men. At the center of the graph is D1, the mayor of San José (i.e., the same person as V in the Itza' network). Both the circle graph and the multidimensional scaling point to I as the best-connected individual. He is also cited most as the top Ladino forest expert. In fact it was I who first received permission for a Ladino settlement in the area from Y in the Itza' network (when Y was mayor of San José).

Because Ladino experts are socially well-connected, information that may come through Itza' experts has access to the greatest number of multiple interaction pathways. To test this learning hypothesis, we regressed gender and frequency of being cited as an expert against Ladino first-factor scores in the combined Itza'-Ladino cultural consensus model. The r^2 on Ladino scores was .63 ($F[2,10] = 6.97$, $p = .02$) with gender ($p = .02$) and expertise ($p = .008$) both reliable. One subgroup (four men, one woman) averaged 5.8 expert citations, 6.0 social network citations, and a first-factor consensus of .73 (versus .75 for Itza'). Averages for the other subgroup (five women, one man) were respectively 0, 1.3, and .59. Male Ladino experts appear to be driving the Ladino population to a convergence of knowledge with Itza'.

Over time, socially well-connected male Ladinos converge toward the consensus of Itza' experts. For example, we found that judgments of plant-animal associations for the most highly rated Ladino expert comprised a proper subset of the pairwise judgments of the most highly rated Itza' expert. It is highly improbable that Ladinos who approximate Itza' response patterns actually observe and copy what Itza' say and think about each of the species pairs in question. Rather, individual Ladinos, in large part, seem to project fragmentary obser-

20. The original mission, or *reducción*, of San Joseph, founded in 1702, was located between present-day Santa Elena and San Benito, opposite the former Itza' island capital of Noj Peten (present-day Flores). In the wake of the chaos and rebellion of the early postconquest years, a new Itza' *reducción* of San Joseph arose at the present site of San José sometime before 1750 (Jones 1998). The earliest marriage record from San José dates from that year (5 mayo 1750, *Libro de Casamientos de la Parochia de los Pueblos de San Andrés, San Joseph y San Geronimo*, Año de 1751, Archivo Apostólica, Flores, Petén). Extant (but partial) records of marriages and baptisms between 1751 and 1788 reveal the surnames mentioned most to be preconquest Itza' (and allied Mopan) patronyms. In descending order of frequency they are (in original spelling) Tun (12), Chayax (11), Canek (9), Tz'in (7), Chabin (7), Kinyocte (7), Cuouh (6), Chata (6), Tut (6), Quixoban (5), Xiquen (5), Citcan (5), Cante (4), Chan (4), Puc (4), Kanchan (4), Tzuntecun (4), and Tesucun (4). Our social network analysis of contemporary Itza' includes 32 surnames: 8 Spanish (Ramos, López, Díaz, Cortéz, Lines, García, Morente, Cinturon), 8 those of families that came from Yucatán between 1750 and 1900 (Huex, Colli, Vitzil, Mex, Panti, Tz'ul, Mis, Yej), and 16 preconquest names from Itza'-ruled territory (Chayax, Cohouj, Chan, Suntecun, Zacal, Tesucun, Zac, Cauich, Ek, Tut, Xiken, Batab, Cante, Chata, Quixchan, Chuc). The genealogies of these families data, in part, to the founding of San José and therefore, very likely, to preconquest Petén Itza'.

vations of Itza′ behavior to a richly textured cognitive model of folkecology *by inference* rather than imitation (Afran 2001*a*).

THE LEARNING LANDSCAPE

In line with evolutionary models of prosocial learning, let us assume that, when in doubt or ignorance about some domain of activity vital to everyday life, people will seek to emulate those with knowledge (Boyd and Richerson 1985, Lansing and Kremer 1993, Henrich and Boyd 1998). Let us also assume that they have direct access not to the deep knowledge they wish to emulate but only to surface signs or "markers" of that knowledge (much as people who wish to be like a famous academician, powerful politician, or celebrity adopt that person's outward trappings in the hope that these will help guide them to success). One reasonable strategy is to seek knowledge from those to whom deference (respect) is shown by others (Henrich and Gil-White 2001). In many small-scale societies, knowledge-bearers tend to be elders, political leaders, economically well-off, and so on.

In the Itza′ case, forest experts are experts in a variety of relevant domains (birds, mammals, trees, soils), elder males, and former political town leaders. Ladinos express doubt about forest knowledge and also express a desire to acquire knowledge from Itza′. Apparently, the most respected and socially well-connected Ladinos attend to those Itza′ to whom other Itza′ defer, and these Ladinos, in turn, become subjects of emulation and sources of knowledge for other Ladinos. But how do Ladinos obtain relevant knowledge without initially knowing how it is relevant? Besides patterns of deference, which carry no knowledge content, how and what do Ladinos learn?

Nearly all evolutionary models of prosocial learning assume that the most important information learned is about *norms*, that is, shared rules or principles of knowledge, judgment, or behavior. Norms are supposed to be functional units of cultural selection and evolution (Irons 1996, Sober and Wilson 1998, Boyd and Richerson 2001, Gil-White 2001). Evidence indicates that neither Ladino experts nor the wider Itza′ or Ladino populations are learning norms about the forest from Itza′ experts or from imitating one another. Itza′ express no content-specific normative or prototypical attitudes to the forest other than to "care for the forest as it cares for us." Even the notion of "reciprocity" that we invoke to describe Itza′ patterns is only a gloss for statistically consensual patterns of thought and behavior with considerable variation in content. Ladinos may be acquiring knowledge in part through different isolated examples that trigger preexisting inferential structures to generate convergent patterns and in part through stories and other evocative conduits (on stories, see Atran 2001*b*).[21] Thus, a Ladino may observe or hear about a specific exemplar of ecological knowledge (perhaps embedded in a tale), from a respected Itza′, such as observing that Itza′ elders look for fallen ramon fruits after spider monkeys have passed through trees. Itza′ pick up the fruits that are not chewed through and leave the rest, knowing also that half-chewed fruits are even more likely than unchewed fruits to generate new ramon stands. From such Itza′ behavior a Ladino observer may readily deduce that (1) ramon is desired and useful for people and (2) spider monkeys can negatively affect ramon seeds. But Ladinos don't generally learn that (3) spider monkeys can also positively affect ramon seeds and so help both the forest and people in it. Although Ladino observers seem to lack the Itza′ cultural bias of conceiving species relationships reciprocally, they still spontaneously induce much more from a single instance of experience than simply 1 and 2.

One alternative to normative accounts of cultural formation, transmission and evolution is "cultural epidemiology," which assumes that socially learned information is acquired chiefly through inference rather than imitation (Sperber 1996, Atran 2001*a*). Information is acquired via inference whenever it presents a "content bias." For example, people in every society readily generate richly structured folkbiological taxonomies from fragmentary samples of plants and animals kinds because they have an evolved, task-specific (i.e., "modular") system for folkbiological induction (Atran 1998). This "living-kind module" allows anyone, anywhere, to take isolated plant or animal exemplars (whether observed, reported, seen in a book, on television, etc.) and automatically assign them to one and only one generic species that occupies one and only position within a taxonomic structure (Berlin 1992).

To illustrate: using standard taxonomic sorting experiments, we elicited highly consensual mammal taxonomies (see López et al. 1997). For each population there was a single-factor solution (I = 7.2:1, 61%; L = 5.9:1, 50%; Q = 5.8:1, 48%). First-factor loadings were uniformly positive, and mean first-factor scores reflected highly shared competence for each population (I = 77, L = .71, Q = .68). The aggregated Ladino taxonomy

21. Anthropologists are typically instructed to go out into the field alone for some months or—in exceptional cases—a few years and single-handedly bring back a description of a society. In this situation, there seems to be little alternative to normative description. Normative accounts of society are also closely bound to the doctrine of functionalism. It is not our intention to review the important critiques of functionalism (and allied theories of behaviorism [cf. Murdock 1949]). We would simply point out that from a psychological perspective it is not clear where norms exist: in the brain of an omniscient informant, as an emergent structure partially distributed among individual minds, as a prototypical representation of a statistical pattern, or as a summary account in the analyst's mind. There is scant detail in normative accounts of social structure that allows evaluation of patterns of individual variation, agreement, and disagreement within and between groups (e.g., Human Relations Area Files). Without such detail, normative claims are difficult to verify or falsify.

correlated equally with Itza' and Q'eqchi' taxonomies ($r = .85$), indicating very similar structures and contents.[22]

Thus, we should expect Ladinos to generalize observations much as Itza' do when Itza' and Ladino taxonomies coincide. All that is required is that Ladinos obtain *some* ecologically relevant content from observing Itza' (Q'eqchi' aren't looking to Itza' for ecologically relevant content and so cannot generalize). Much of the difference between the top Ladino and Itza' experts owes to this Ladino's relative lack of knowledge about small palms (P09–P11) and felines (A24–A26). These are well-delimited taxonomic groups for Ladinos and Itza' (Atran 1999). The Itza' expert readily generalizes ecological information from any member of these taxonomic groups to other members; the Ladino expert simply may not have relevant information about plants and animals in these two taxonomic groups to generalize from.

One distinctive aspect of the aggregate Itza' folktaxonomy for animals that emerges is that only Itza' indicate the effect of ecological proclivity on mammal groupings. A notable example is the clustering of arboreal procyonids, monkeys, and tree-dwelling rodents as a taxonomic group (including A02–A06 [López et al. 1997]). Ladinos also generally lack knowledge about bidirectional ecological relations between plants and animals, especially with regard to positive animal-plant relationships (animals helping plants [fig. 3]). These two factors—taxonomic awareness of an arboreal animal association and a culturally salient propensity to appreciate bidirectional ecological relations—favor more consistent generalization of ecological centrality among arboreal animals and plants with which they interact, such as fruit trees (P01–P05). This also applies to ecological appreciation of the Itza' taxonomic cluster of game birds (including A07–A12).

More generally, these data suggest that patterns of undergeneralization and overgeneralization are predictable from the Ladino–Itza' correspondence of taxonomic and ecological groupings. Where Ladino groupings are a subset of Itza' groupings, we expect undergeneralization and where they are a superset overgeneralization. Moreover, Itza' may know better when there are exceptions to an expected generalization. We also have evidence that some Ladinos are making plausible but unwarranted inferences that Itza' do not. For example, in the absence of direct observation of furtive, nocturnal felines, it is plausible to believe that they would hide under the cover of leafy fruit trees to prey upon other animals that feed on the fruit. Female Ladinos who seldom venture into the forest overwhelmingly infer that felines prefer fruit trees (75%). Male Ladinos (17%) and Itza' (16%) know better because they actually witness feline stalking behavior in the forest underbrush.

In brief, it appears that preexisting taxonomic structures and lack of culturally prior conceptions of ecological bidirectionality in plant-animal relationships constrain how Ladinos infer knowledge of ecological centrality. Of course, any significant body of social information includes many different kinds of biases toward particular kinds of content, but norms and imitation may have little to do with this learning process. Rather, social learning in the case described arguably involves inferential processes that are mobilized by several factors: (1) domain-specific cognitive devices (e.g., taxonomy for biological kinds), (2) prior cultural sensitivity to certain kinds of knowledge (e.g., species reciprocity in ecological relationships), (3) awareness of lack of knowledge and the motivation to acquire it (doubt), (4) selective attention (e.g., Ladino focus on the patterns of deference to and the behavior of Itza' elders versus Itza' deference and attention to the forest itself), and (5) preexisting values (weighted preferences) regarding a given cognitive domain (e.g., overvaluing economic utility relative to other determiners of interest such as sacredness or role in the economy of nature).

The particular persons observed, actual exemplars targeted, and specific inferences made can vary widely from person to person. Here the culturally specific learning landscape further constrains the canalization process of our specieswide evolutionary landscape. Much as rain falling anywhere in a mountain valley converges into the same natural mountain-valley river basin and is further channeled through the gates of a dam constructed there, so each person's knowledge will converge toward the same cultural basin of thought and action (Sperber 1996).

This "learning landscape" shapes the way in which inferences are generalized from particular instances (experiences, observations, exemplars). It channels the information acquired toward convergence with a general body of knowledge (an emergent structural pattern that achieves a statistical consensus in a population). It produces convergence toward the emergent consensus even though specific inputs vary widely in richness and content (just as many different people, observing many different exemplars of dog under varying conditions of exposure to those exemplars, all still generate more or less the same general concept of *dog*). Other learning factors may be involved, including norms and narratives, but they are not the only or even the primary ones.

In summary, Ladino knowledge is a subclass of Itza' knowledge that underrepresents its ecological complexity. Ladinos look to Itza' for what is important, whereas Itza' look directly to the forest. To be sure, Ladinos use their own taxonomic and ecological knowledge to generalize inferences from Itza' behavior, but they do not appear to have learned quite how "to walk alone in the forest" as Itza' do. From studies of other Ladino communities in Petén, however, it seems that some Peténero Ladino communities have learned to think and act much as Itza' do after three of four generations of the kind of contact described between our Itza' and Ladino samples

22. All three populations grouped taxa according to general-purpose similarity rather than special-purpose concerns (e.g., wild peccary with domestic pig, house cat with margay, etc.). Special-purpose clusters such as domestic versus wild or edible versus nonedible can also be elicited (Lois 1998), but they do not belong to the general consensus of "kinds that go together by nature" (cf. the idiosyncratic version of "Itza' folk taxonomy" in Hofling and Tesucun 1997).

(Schwartz 1990).[23] This may well involve assimilating "spiritual values."

ESTABLISHING A KNOWLEDGE BASELINE: THE HIGHLAND Q'EQCHI'

Social network analysis suggests that one set of factors militating against Q'eqchi' preservation of lowland ecology involves linguistic isolation coupled with a compact social structure that forecloses the intercultural exchanges that might convey appropriate lowland techniques. Moreover, Q'eqchi' immigrants tend to invoke corporate and ceremonial ties with the sacred highland mountain valleys when faced with economic and ecological problems (Schackt 1984). This may serve to deter (not just detour) access to ecological information relevant to lowland commons survival. Studies of other immigrant Q'eqchi' communities also indicate selective use of inappropriate highland techniques (clear-cutting, cash-cropping, continuous cultivation) and failure or inability to transfer highland techniques favoring forest maintenance (intercropping, terracing) (Castellon 1996).

One open issue is whether Q'eqchi' immigrants arrive in Petén with a cognitive model that is already impoverished with respect to knowledge of species relationships or whether they are simple unable to use richer highland models because these are inappropriate to lowland ecology. Accordingly, to understand the cognitive factors responsible for Q'eqchi' immigrant patterns we sought to establish a cognitive baseline for highland Q'eqchi' in their original home area of Alta Vera Paz. We elicited mental models from highland Q'eqchi' in Aldea Paapa near Cobán, employing the same techniques as in Petén. The kinds most frequently mentioned as important to the forest included 27 animals and 20 plants. Nearly half the animals (13) mentioned as important also counted among the most important Petén species. Plants mentioned as most important to the forest included only two of the most important Petén species the pacaya palm and the allspice tree, and also included species primarily associated with orchard (e.g., peach tree, *Prunus persica*) and milpa (e.g., chile pepper, *Capsicum annum*). Although two animal kinds and half the plants must still be identified scientifically, patterns of interaction between plants, animals, and people can be reliably described.

As with the Petén groups, highland Q'eqchi' view plants as positively affecting animals, first by providing food and second by furnishing shelter. Consensus on positive plant-animal relations is marginal (eigenvalue 1:2 = 2.97, variance = 44%). Nearly 20% of all possible plant-animal relations are positive. This figure is about the same for Itza' and Ladinos. Highland Q'eqchi' recognize more negative animal-plant relations (2.3% for all possible animal-plane relations) than immigrant Q'eqchi' (<1%) but less than Itza' (7.8%) or Ladinos (8.2%). Highland Q'eqchi' recognize fewer positive relations of animal affecting plants (<1%) than Ladinos (2.1%) and far less than Itza' (8.2%). Q'eqchi' evince finer appreciation of local ecology in their highland homeland than in their lowland habitat, but this appreciation is significantly less rich than that of Itza' or even immigrant Ladinos. Highlanders also show good consensus on how humans negatively affect plants (eigenvalue 1:2 = 7.68, variance = 75%) but no consensus on how humans positively affect plants. This reinforces the picture of similar cultural notions of how plants affect animals but different models of animals affecting plants, of positive animal-plant relations in particular, and of reciprocity between animals, plants, and humans in general.

Measures of human impact and use confirm this pattern in content-specific ways. For highland Q'eqchi', regression analyses show that food value and ecological centrality predict human impact ($r^2 = .58$, $F[2,12] = 8.20$, $p = .006$, both predictors $p = .06$). Food value and impact are positively correlated ($t = 4.937$, $p = .0001$); highland Q'eqchi' tend to protect food plants. By contrast, ecological centrality and impact are negatively correlated, as are ecological centrality and food value ($t = -2.379$, $p = .0.3$). In other words, highland Q'eqchi' do not consider food plants to be ecologically important and do not protect plants that they consider to be ecologically important. The most important predictor of ecological importance is use of the plant for firewood ($r^2 = .54$, $F[1,18] = 21.457$, $p = .0002$).

Only Itza' seem to have a positive vision of the role of plants, animals, and humans in helping the forest to survive that is based on species reciprocity. For example, an analysis of variance involving all Petén groups together with highland Q'eqchi' shows that only Itza' differ reliably from each of the other groups in appreciating positive animal-plant relations; the other groups do not reliably differ from one another ($F[3,44] = 21.24$, $p <$ 0001). Both immigrant and highland Q'eqchi' report that animals have little impact on plants. Immigrant Q'eqchi' view humans as having a markedly negative impact on economically important plants, especially those with cash value. Highland Q'eqchi' tend to destroy plants that they consider ecologically important—especially plants that can be used for firewood—and to protect only plants that have high food value.

Cash sale and firewood are arguably the least productive categories in terms of forest regeneration. Cash sale of important plants is not part of a local system of production; it is driven by an extractive economy that depends almost entirely on demand from outside markets and even outside the region. For example, extraction of "nontimber forest products" such as *xate* has been touted as a prime source of "sustainable development" of the Petén forest (Reining and Heinzman 1992), but *xate* extraction (or even latex tapped from the chicle tree) traditionally had little value in the subsistence economy.

Organization of labor and production for extraction of such products has little to do with local subsistence requirements—including the requirement that the local people and the environment they live in be mutually sustaining—but everything to do with outside markets.

23. Some Peténeros perform Maya rain ceremonies that Itza' no longer do (Schwartz 1990).

When those markets shift or collapse, no provisions are made for the consequent shift or collapse of the social organization and ecology necessary to maintain production. Moreover, in contrast to the situation in advanced market economies, alternative outlets for labor and production are scarce. A return to premarket conditions is liable to be just as difficult. In short, the more divorced the money item is from local subsistence needs or a system of local production, the less likely in the long run it is to sustain the local economy and the environment supporting that economy.

It would take us too far afield to explore here the historical reasons for the relatively impoverished Q'eqchi' models. Nevertheless, a few summary observations are in order. There is scant evidence that the trauma of recent civil war is a key factor in immigrant Q'eqchi' attitudes toward Petén. Highland Q'eqchi' models of species relations were likely already impoverished, perhaps in part because the highland environment is relatively deforested (compared with Petén), and earlier and ongoing Q'eqchi' migrations into the lowlands show little concern with maintaining forest biodiversity. Under the protection of the Dominican clergy for centuries, highland Q'eqchi' institutionally managed their own highly commensalist and intense forms of cultivation. When land was scarce, they migrated into the Petén lowlands, often for the short term.

Other Q'eqchi' communities that immigrated into Petén and adjacent areas of Belize both before and after the civil war behave similarly to our study group (Carter 1969, Fagan 2000). When environmentally related economic difficulties arise (e.g., banana blight, hurricanes, etc.), immigrant leaders may send delegations to sacred places in the Q'eqchi' highlands to seek aid and redress from highland spirits (cf. Schackt 1984), but our immigrant Q'eqchi' do no concern themselves with lowland spirits or consult Itza'. When we asked why they failed to consult Itza' about the forest, the Q'eqchi' often remarked that they did not feel the need to seek our or placate lowland spirits as long as they remained true to their ancestral deities.

The Spirit of the Commons

Anthropologists and sociologists target norms as functional building blocks of cultures and societies. Economists and political scientists see norms as institutional means for solving public goods problems such as "the tragedy of the commons" (Hardin 1968, Fukuyama 1995). The general idea is that to solve the problems of rational choice inherent in balancing individual with collective needs, individuals must be made to forsake a measure of self-interest and to sacrifice resources in accordance with institutional norms that function to maintain the public good(s).

The tragedy of the commons and similar social dilemmas are basically variants of a fundamental problem in decision theory and game theory known as "the prisoner's dilemma." Consider a group of n persons who share a common territory of fixed size on which they hunt animals. Each hunter has one of two choices: he can cooperate with the others by not overhunting on the commons, or he can hunt in a way that is advantageous to him but ultimately results in the overuse and destruction of the common resource. The second option, it appears, is more rational in the short term. This is because the short-term advantage to one who overhunts (e.g., 1) always outweighs the short-term disadvantage to him when that disadvantage is equally distributed among the other hunters ($1/n$). If all cooperate, the common resource is preserved, but if the rationale of self-interest pervades the camp, no one will have an incentive to cooperate and all will defect.

Field and laboratory studies indicate that individual calculations of rational self-interest collectively lead to a breakdown of a society's common resource base unless institutional or other normative mechanisms are established to restrict access to cooperators (Berkes et al. 1989, Atran 1986). This is so even when people's "basic needs" are satisfied, no matter how small the group or how well-informed of the looming tragedy (White 1994; but see Ostrom 1998 on strangers' cooperating, at least for low-cost items). Yet, evidence from our "garden experiment" indicates neither the primacy of norms in explaining cultural differences with regard to the tragedy of the commons nor the exclusivity or primacy of institutional mechanisms as means for preserving common resources. Immigrant Q'eqchi' form the most socially interconnected and institutionalized community but are the least likely to preserve the resource base (perhaps because the community is so culturally hermetic). The Itza' community is the most socially atomized and least institutionalized (at least in terms of coordinated agricultural schedules), but its individuals most clearly act to maintain the common environment. If neither institutionalized learning nor institutional control mechanisms are responsible for commons maintenance among Itza', what is?

VALUES

More generally, the puzzle for decision theory is: How do people sustainably manage limited resources without apparent institutional or other obvious normative constraints to encourage and monitor cooperation? Our tentative line of reasoning is that Itza', and perhaps other native peoples with a long history of ecological maintenance, may not treat resources as traditional decision and game theory suggests, that is, as objects of a payoff matrix (extensional items substitutable along some metric, such as one that assigns monetary value to every object). Instead, they may treat resources such as species as intensional, relational entities that are subjectively defined, like friends or enemies (cf. Rappaport 1979, Ingold 1996).

Our next study explored this possibility. We asked people from each of the three Petén groups to rank-order 21 plant species in terms of their importance according to (1) members of their own community, (2) and (3) members of each of the other two communities, (4) God, and (5) the forest spirits. The average age for Itza', Ladino, and Q'eqchi' informants, respectively, was 63.4, 59.8, and 55.9 years. An analysis of variance yielded no significant age differences across populations.

Itza' showed consensus regarding their own individual values (ratio eigenvalue 1:2 = 4.73, eigenvalue 1 = 59% of variance), imagined Ladino (4.97, 50%) and Q'eqchi' (4.33, 56%) values, and God's imagined values (5.16, 56%). Overall, Itza' did not show consensus on the imagined values of spirits, but male Itza' did not show such consensus (3.49, 52%; $p < .05$ given mean competence = .72 for $N = 7$ informants [see Romney, Weller, and Batchelder 1986:326]). Male Itza' stay much longer in the forest than women and report many more encounters with forest spirits (*arux* = *uyumil k'aax*, "masters of the forest"). To be a successful hunter (*aj b'äk saj*, "the meat getter"), chiclero (*aj men cha'*, "the chicle latex collector"), or farmer (*aj men kol*, "the milpero") requires that a man resist the constant teasing, tricks, and traps of the forest spirits without cursing the spirits for his misfortune. He must also show the spirits that he knows how to protect the animals and plants under their care, and he must do so with "valor" (*muk'*). Only then will the forest spirits, in turn, protect him and his activity (Atran 2001*b*).

Ladinos also showed consensus on Ladinos (4.34, 58%), Itza' (3.38, 47%) and God (3.19, 50%). They showed marginal consensus on Q'eqchi' (2.80, 49%) but no consensus on spirits. By contrast, Q'eqchi' showed no consensus on Q'eqchi', Itza', Ladinos, God, or spirits. A followup study of younger Q'eqchi' men (average age 42.5 years) and women (average age 41 years) indicated some consensus on Q'eqchi' (3.27, 47%). These younger men and women, who have spent nearly their entire adult life in Petén, may be establishing their own information network about the Petén forest, although they are still largely impervious to outside knowledge sources.

Itza' overestimated the agreement between their responses and those of the Q'eqchi' but underestimated agreement with Ladinos (Q'eqchi' also overestimated agreement with Itza'). For example, the correlation between Itza' beliefs about Q'eqchi' preferences and their own preferences (i.e., [Iq, Ii], $r = .94$) differed appreciably from the correlation between Itza' beliefs about Q'eqchi' preferences and actual Q'eqchi' preferences ([Iq, Qq], $r = .74$). By contrast, the correlation between Itza' beliefs about Ladino preferences and Itza' preferences ([Il, Ii], $r = .90$) did not differ appreciably from the correlation between Itza' beliefs about Ladino preferences and actual Ladino preferences ([Il, Ll], $r = .93$). Similarly, ([Qi, Qq], $r = .84$) − ([Qi, Ii], $r = .62$) = .22, whereas ([Lq, Ll], $r = .92$) − ([Lq, Qq], $r = .84$) = .08. Ladino beliefs about Itza' preferences correlated almost perfectly with Ladino beliefs about God's preferences ($r^2 = .96$).

Only Itza' saw the forest spirits as actively protecting the forest: Itza' rankings from the point of view of the forest spirits were significantly related to Itza' models of human impact as well as ecological centrality. For example, multiple regressions showed that male Itza' consensus on spirits together with the overall Itza' consensus on combined use (wood + shelter + cash) accounted for most of the variance in human impact ($r^2 = .70$, $F[2,18] = 20.71$, $p = .0001$, with spirits and use equally reliable predictors [p's < .01]). The most reliable combination predictors for what (male Itza' believe) the spirits think is ecological centrality and God (both p's < .01) ($r^2 = .65$, $F[2,18] = 17.0$, $p = .0001$). Ladinos and Q'eqchi' asserted belief in forest spirits and even provided normative accounts of spirit life similar to those of Itza', but in these two groups there was no consensus about spirit preferences, nor was belief in spirits reliably linked to forestry practice.[24]

Finally, we asked 17 members of several NGOs at a workshop on the Maya Biosphere Reserve (November-December 1999) to rank the same trees in terms of importance to forest life. For the NGOs, there was marginal consensus, with one slightly negative first-factor score (−.076) (ratio eigenvalue 1:2 = 2.73, variance = 45.6%). The most valued species for the NGOs were, in rank order, mahogany, tropical cedar, allspice, and chicle. These are the most important trees for the extractive economy and export market. NGO preferences partially predict the consensus on preferences expressed by Ladinos ($r^2 = .72$) and Itza' ($r^2 = .44$),[25] but the worst predictors of NGO rankings are Itza' male rankings of spirit preferences ($r^2 = .06$, n.s.) and Itza' ratings of ecological centrality ($r = -.229$).

SPIRITUAL GAMES

To data, rational-decision and game-theoretic accounts involving human use of nonhuman resources have not considered the possibility of resources' (e.g., species') having their own measures of "utility" or resources' and humans' being "players" in the same game. Prima facie, this idea is implausible, because species are assumed not to have motives, desires, beliefs, or strategies for cooperation or deception that would be sensitive and systematically responsive to corresponding aspects of human intention. Nevertheless, both in increasingly globally oriented ecological movements in the industrial world and in the religious practices of small-scale societies there are public pronouncements of respect for species. Indeed, one claim for "animistic" and "anthropomor-

24. In one of the few studies to replicate findings on theories of mind in a small-scale society (cf. Wimmer and Perner 1983), Knight et al. (2001) showed monolingual Yukatek children a tortilla container and told them, "Usually tortillas are inside this box, but I ate them and put these shorts inside." Then they asked each child in random order what a person, God, the sun (*k'in*), the principal forest spirits (*yumil k'ax'ob*, "Masters of the Forest"), and other minor spirits (*chiichi'*) would think was in the box. Children over 5 attributed true beliefs according to a hierarchy with God at the top and people at the bottom. As do Itza', these Yukatek Maya consider the masters of the forest powerful and knowledgeable spirits that punish people who try to overexploit forest species. Yukatek children tend to believe that the forest spirits, like God and the sun, "live" (*kukuxtal*) but do not "die" (*kukumil*) (see Atran et al. 2001).

25. Recall that for the Q'eqchi' there was no consensus.

phic" interpretations of species in many small-scale societies is that the "intention gap" between humans and species is thus bridged (at least to human satisfaction) with outcomes beneficial to the survival of species and of the human groups that depend on them (cf. Bird-David 1999).[26]

When asked, Itza' men and women express the belief that they will be punished if they violate spirit preferences, although women are less clear about what such preferences are likely to be. Especially for men, it appears, the spirits are intermediaries or "spokesmen" for the forest species, although there is wide individual variation in response to what the spirits say about any given species. This has intriguing implications for ecological decision and game theory in that individual Itza' may be basing cognitive and behavioral strategies for sustaining the forest more on playing a game with spirits than on playing a game with other people (on the wide role of spirits in Itza' life and religion, see Atran 2001*b*). Evolution itself provides mechanisms for interactive "games" that make commensurate the incommensurable (e.g., "strategies" of bacteria and their hosts), and so may human minds (semantically rather than biologically) in ways consistent with maintaining respect for sacred or "taboo" values basic to long-term survival and quality of life (Fiske and Tetlock 1997, Medin et al. 1999).

Highland Q'eqchi' also religiously taboo unbridled exploitation of forest species or, more accurately, certain forested places. The taboo on exploitation of the forested areas near certain highland caves and mountain streams and worship of these sites (tzuultaq'a) are akin to our society's protection of and reverence for wilderness areas, but they imply a set of attitudes and understandings that differs fundamentally from Itza' values with regard to forest species. For Itza', the forest is a mental and ecological landscape that people—the most savvy of whom follow spiritual guides—create and manage by living with it in cooperative exchange. For the Q'eqchi', as for many conservation organizations, the forest can be used and exploited or preserved and worshipped but seldom exploited and worshipped simultaneously.

Conclusion

Different cultural groups subject to equal pressures on common resources respond with strikingly different behaviors and cognitions. These culturally distinctive actions and folk models are systematically related to one another and to distinct prospects of maintenance or destruction of the common environment. Native Itza' Maya, who have few cooperative institutions,[27] show awareness of ecological complexity and reciprocity among animals, plants, and people; Itza' agroforestry favors forest regeneration. Immigrant Q'eqchi' Maya, who have highly cooperative institutions, acknowledge few ecological dependencies; Q'eqchi' agriculture is insensitive to forest survival. The folkecological models and agroforestry practices of Spanish-speaking immigrant Ladinos fall between. There is no overriding "local" or "indigenous" relation to the environment.

The area that these groups reside in is not completely open to access by outsiders, but all of the actors are keenly aware that their commons is highly vulnerable to uncontrolled immigration, depredation, and lawless deforestation. Theories of rational action predict that increases in the number of noncooperative players in the environment and their apparent disregard for the future should lead even native cooperators to abandon long-term interest for short-term gain unless institutional restraints can compel individual action toward the common good. In other words, it is irrational to continue an act to sustain a diminishing resource that others increasingly deplete. No doubt economic rationality and institutional constraints are important in determining actions upon common-pool resources, but they may not suffice. There also appears to be an important cognitive dimension to the way people learn to manage environmental resources. Valuation studies suggest that, at least for some small-scale societies like the Itza', cognition of supernatural agents may serve not only to guarantee trust and foster cooperation between nonkin, as standard commitment theories assume (Frank 1988, Irons 1996), but also to foster human interaction with nonhuman resources in relations of "indirect reciprocity" (Alexander 1987) to monitor and accommodate to nature's requirements for obtaining its support.

It is no surprise that native Maya with centuries-old dependence on a particular habitat better resist actions that lead to its degradation than immigrants, although the underlying models for behavior and modes of learning are not predictable on a priori grounds. What is surprising is that Ladino immigrants who share no evident tradition with native Maya come to resemble them in thought and action. Network analyses reveal reliable though noninstitutionalized channels that allow socially well-connected Ladinos access to Itza' forest expertise. The highest overlap, or "fidelity," among individual patterns stems from subtle forms of inference based on individual exposure to role models, not instruction or imitation. No identifiable "rules, "norms," or other discrete bits of cultural information of behavior function as plau-

26. There is nothing in principle to prevent rational-choice theory from assigning extensional values to relational entities (e.g., people may be willing to choose to save their pet over a favorite tree, their child over their dog, their nation over their children). Do sacred values form a special class of "protected choices" that are internally negotiable but off-limits to more mundane, monetary exchanges? It is not clear how current approaches could model such choices except as ad hoc "externalized contingencies."

27. Faced with the rapid and relentless demise of their language and forest, in 1997 an association of Itza' successfully petitioned Guatemala's National Assembly to grant them self-management of a small portion of former Itza' territory as the Bio-Itza' reserve. Here Itza' hope to teach the value of the forest before it disappears. Some Itza' elders have adopted Q'eqchi' prayer ceremonies to help create this new institutional identity. The Q'eqchi' are appreciative and paying attention.

sible candidates for cultural transmission and selection.[28] Our results call into question an assumption of agent-based norm models (Axelrod 1997, Rogers 1998), namely, that societies that do not share normative values (e.g., Itza' and Ladinos) are less likely to interact and converge than societies that do (e.g., Itza' and Q'eqchi').

This bears on the problem of extending the lessons of local commons to mobile and multicultural societies: Even in a relatively open-access environment (e.g., with uncontrolled immigration), if there is ready access to relevant information, then ecologically sound behaviors may be learned by relative newcomers who have no social institutions, cognitive predispositions, or cultural traditions favoring commons survival. But having time to learn is critical. Rates of environmental and cultural degradation in neotropical areas are awesome by any standard because of global economic and political processes that function similarly across such areas. The massive demographic, economic, and political upheavals of recent years may no longer allow sufficient lag time for immigrants to contact, learn, and implement Itza' techniques.

Although an examination of the cultural values and causal processes that mediate the relationship between cognition and behavior lie beyond our scope, we think that the studies reported here are important to (1) establish a methodology for assessing a first approximation of ecological cognition across cultures, (2) set up a framework for further exploration of the relationship between the structure and the flow of ecological information across cultures, (3) provide operational criteria for assessing "spiritual" values that may help human societies to resolve "the tragedy of the commons" and other ecologically pertinent forms of "the prisoner's dilemma," and (4) offer a model for empirical research into cultural effects on deforestation and land change.

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28. We used the same techniques to monitor ecological cognition and social networks for Yukatek Maya (Xk'opchen) and Ladinos (Xkomha) in Quintana Roo (Mexico), among Lacandón Maya (Metzäb'äk) and Tzeltal and Tzotzil immigrants in the Selva Lacandona (Chiapas, Mexico), and among Native American Menominee and majority-culture rural groups along the Wolf River in Wisconsin (Medin, Ross, and Atran 2001). Preliminary studies in the Lacandón forest (interrupted by civil strife) suggest that the patterns of knowledge and behavior among Lacandón (Lakantun) Maya versus Tzeltal and Tzoltil Maya born to families that immigrated into the Selva Lacandona from the Chiapas highlands resembles that of Itza' to Q'eqchi' immigrants (Ross n.d.; cf. Nigh 2002). The fact that these descendants of immigrants have lived all their lives in the Selva Lacandona suggests that mere personal exposure to the local ecology is not a deciding factor. The Wisconsin studies concern fish and fishing rather than agroforestry. Results show that differences between Menominee and rural majority-culture on relations between fish-fish and human-fish relations resemble more the patterned differences between Itza' and Ladinos. This underscores the generalizability of our methods.

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