Hum Nat (2007) 18:190–208
DOI 10.1007/s12110-007-9017-x

Applying Behavioral Ecology and Behavioral Economics to Conservation and Development Planning: An Example from the Mikea Forest, Madagascar

Bram Tucker

Published online: 9 September 2007

Abstract Governments and non-govermental organizations (NGOs) that plan projects to conserve the environment and alleviate poverty often attempt to modify rural livelihoods by halting activities they judge to be destructive or inefficient and encouraging alternatives. Project planners typically do so without understanding how rural people themselves judge the value of their activities. When the alternatives planners recommend do not replace the value of banned activities, alternatives are unlikely to be adopted, and local people will refuse to participate. Human behavioral ecology and behavioral economics may provide useful tools for generating and evaluating hypotheses for how people value economic activities in their portfolios and potential alternatives. This is demonstrated with a case example from southwestern Madagascar, where plans to create a Mikea Forest National Park began with the elimination of slash-and-burn maize agriculture and the encouragement to plant labor-intensive manioc instead. Future park plans could restrict access to wild tuber patches, hunting small game, and fishing. The value of these activities is considered using observational data informed by optimal foraging theory, and experimental data describing people's time preference and covariation perception. Analyses suggest that manioc is not a suitable replacement for maize for many Mikea because the two crops differ in terms of labor requirements, delay-to-reward, and covariation with rainfall. Park planners should promote wild tuber foraging and stewardship of tuber patches and the anthropogenic landscapes in which they are found. To conserve small game, planners must provide alternative sources of protein and cash. Little effort should be spent protecting lemurs, as they are rarely eaten and never sold.

Keywords Behavioral economics · Conservation and development · Deforestation · Human behavioral ecology · Hunting and gathering · Livelihoods · Madagascar · Slash-and-burn agriculture

B. Tucker (✉)
Department of Anthropology, University of Georgia,
250A Baldwin Hall, Jackson St., Athens, GA 30602, USA
e-mail: bramtuck@uga.edu

Introduction

Practitioners of conservation and international development often seek to modify rural people's livelihoods in pursuit of goals such as biodiversity conservation and poverty reduction. Subsistence activities like slash-and-burn horticulture and foraging for wild foods are often blamed as causes of habitat destruction and species loss, and judged to be inefficient food production strategies that perpetuate rural poverty. A first step in many projects is to stop supposedly destructive and inefficient activities and encourage environmentally friendlier, more profitable alternatives.

This agenda poses many problems. Who decides a project's goals and how they are to be achieved: governments, NGOs, or local communities (Berkes 2004; Tsing et al. 2005; Warner 1997)? Are rural livelihoods the appropriate focus of blame for environmental damage and poverty, or are these symptoms of broader trends in global political economy (Jarosz 1993)? Which activities have negative consequences for the environment and economy? Are horticulture and foraging necessarily destructive and unproductive (Conklin 1961; O'Brien 2002)? How does one evaluate efficiency and profitability of people's current practices and identify alternatives that people are likely to accept?

This paper addresses the latter two questions from a behavioral perspective. In deciding which activities to eliminate and which to encourage, planners operate with an implicit theory of human behavior, a theory about how local people judge the value of current and future courses of action. When planners employ erroneous behavioral theory, grave damage may be done to local livelihoods, and projects may fail as people refuse to participate.

Perhaps the most frequent theories of behavior employed by project planners are variants of rational choice theory and the discourse of social progress. Rational choice assumes that individuals have more-or-less perfect perception of the world and that they make decisions by tallying costs and benefits. Rational choice also assumes that individuals selfishly maximize utility in a social vacuum, which informs Hardin's (1968) infamous pessimism over people's capacity to conserve common property. Social progress assumes that destructive and inefficient practices are primitive and will inevitably be replaced as people modernize. Thus it would seem that rural peoples destroy the environment and underproduce because this is the best that their current stage of social evolution will allow. They are expected to accept higher-yielding (usually more intensive) strategies and technologies once they understand the benefits. Frustrated planners blame local people's apparent inability to act "rationally" on ignorance, superstition, or "culture" (Crewe and Harrison 1998).

Popular alternatives to rational choice and social progress explanations are equally problematic. Redford (1990) criticizes those who suggest that rural reasoning is removed from economistic concerns. "The ecologically noble savage," like Rousseau's noble savage, pursues subsistence out of a tradition that values stewardship of nature over selfish material profits. Redford and Stearman (1993) criticize documents such as the Coordinadora de las Organizaciones Indígenas de la Cuenca Amazónica, which assert that indigenous peoples are natural conservationists allied with conservation biologists. Chapin (2004) documents how large international conservation organizations, having become increasingly frustrated that local people often seek profits from their natural capital in defiance of their noble stereotype, have increasingly excluded indigenous participation from their programs.

I suggest that a theory of behavior derived from a combination of Human Behavioral Ecology (HBE) and Behavioral Economics (BE) supplies a more effective model of behavior for conservation and development planners who wish to understand or modify rural livelihoods. HBE and BE originated from rational choice theory, but they diverge from traditional development economics by taking a descriptive rather than prescriptive approach to rationality. Human behavioral ecologists assume a priori that observable behavior is in some sense rational, meaning that people do what they do for reasons that can be understood by measuring payoffs and constraints in currencies relevant to Darwinian fitness (Smith and Winterhalder 1992). Similarly, BE pioneer Maurice Allais (1953) declared that economists should define “rationality” by the decisions people actually make rather than with calculus models. Practitioners of HBE observe behavior ethnographically, while behavioral economists examine judgment and decision-making using psychological experiments.

HBE attempts to explain observed behavior by testing hypotheses derived from evolutionary and ecological theory (Smith and Winterhalder 1992). Hypotheses are suppositions about what people value, where value relates to survival and reproduction. Optimal foraging theory tests whether people value energetic efficiency (Stephens and Krebs 1986). Rejection of this hypothesis tells us that some other benefit is valued more than energetic efficiency. HBE researchers have argued for non-work time (Smith 1987), a balanced diet (Hill 1988), prestige (Hawkes et al. 1991; Smith et al. 2003), and risk reduction (Winterhalder 1986) in different circumstances.

Although HBE makes minimal assumptions about cognition, this is among the main concerns of BE, which began as an effort to evaluate neoclassical assumptions using cognitive and social psychology (Camerer and Loewenstein 2004). Tversky and Kahneman (1974) tested the assumption that decision-makers have near-perfect information and discovered instead that perception, evaluation, and memory are biased by mental illusions and cognitive shortcuts. Whereas economists have long assumed that decisions result from cost-benefit calculations, much of human cognition seems to be rule-based and influenced by emotion (Gigerenzer and Selten 2001). Decision-makers do not act in a social vacuum; rather, they imitate others, conform to social norms and expectations, and avoid sanction for selfish acts (Henrich et al. 2004). Unlike traditional economics, BE addresses culture, social learning, and social conformity.

HBE and BE have previously contributed to the conservation literature by critically examining popular notions of individuals’ and communities’ capacity to conserve. Alvard (1995) used optimal foraging theory to demonstrate that prey choice among Piro foragers of Peru maximizes energetic efficiency rather than conserving prey populations, in contrast to the noble savage stereotype. Ruttan and Borgerhoff Mulder (1999) challenged Hardin’s (1968) tragedy of the commons by applying game theory to the transhumance decisions of Barabaig pastoralists in Tanzania. They found that wealthy herders conserve common pasture because self-interest and conservation are not mutually exclusive, whereas poor herders conserve because they are coerced to do so by the wealthy. Behavioral economists have simulated common property problems experimentally using public goods games in which players can either contribute to a pot for shared benefits or defect for higher personal gain (Ledyard 1995; Ostrom 2000). In iterated public goods games, players inevitably relent to the temptation to defect. Yet cooperation is encouraged when any degree of sociality is introduced, for example if players play face-to-face (Ledyard 1995) or if they can punish others for selfish gains (Fehr and Gächter 2000).

This paper pursues a different objective. I use HBE and BE to understand how local people judge the value of the activities they currently practice as well as alternatives recommended by conservation and development programs. I present a case study from southwestern Madagascar, where efforts to create a Mikea Forest National Park began with the elimination of slash-and-burn maize agriculture from rural people's portfolios and the encouragement to cultivate manioc in its place. Future park plans may affect people's ability to forage for wild tubers and small game as well. I explain how Mikea may judge the value of these activities using observational data informed by optimal foraging theory, and experimental data describing time preference and covariation perception. Recommendations for the nascent park are then offered.

In promoting the application of more theory to the problem of livelihood change in conservation and development, I am not trying to offer "better science" with which to reengineer rural economies in a top-down fashion. Rather, what I hope to offer is intermediate between top-down reengineering and bottom-up participatory and community-based approaches. While the latter involves local narrative and opinion, cognitive psychology suggests that people are largely unaware of why they make the decisions they do (Nisbett and Wilson 1977). HBE and BE offer a toolkit by which planners may better understand local people's choices and by which local people may better communicate their unconscious preferences, values, and constraints.

Case Study Background

The Mikea Forest (Alamikea) is a heterogeneous, dry tropical forest in southwestern Madagascar (Fig. 1). Although often labeled a "spiny forest," it consists mostly of deciduous trees (*Dalbergia*, *Cedrelopsis*, *Commiphora*, etc.) choked with vines and punctuated by the occasional dramatic baobab (*Andansonia* sp.). The "spiny" label applies primarily to the coastal edge, where dunes support the distinctive "octopus tree" (*Didiera madagascariensis*). The northern part of the forest contains Lake Ihotre, the second largest lake in Madagascar, as well as the Namonte Basin, a series of pools and grassy pans that flood according to multiyear accumulations of rainfall. Seddon et al. (2000) identify 98 bird species in the Mikea Forest, 40 of which are endemic to Madagascar, and two of which are found only in the Mikea Forest. They identify 48 species of reptiles and a "moderate" diversity of mammals.

The inhabitants of the forest also call themselves Mikea. According to local identity discourse, a Mikea is anyone who lives in the forest and knows how to hunt and gather, just as the neighboring Vezo are coastal fishers and Masikoro are agropastoralists. Yet all three groups share common histories, clan memberships, and customs, and in practice, most households maintain a diversified portfolio of foraging, fishing, farming, herding, and market-oriented activities regardless of purported identity. Mikea oral historians recount that their ancestors were Masikoro and Vezo who sought refuge in the forest to escape the Andrevola kings and their cattle and slave raids, and later, to escape French colonialism (Yount et al. 2001). I

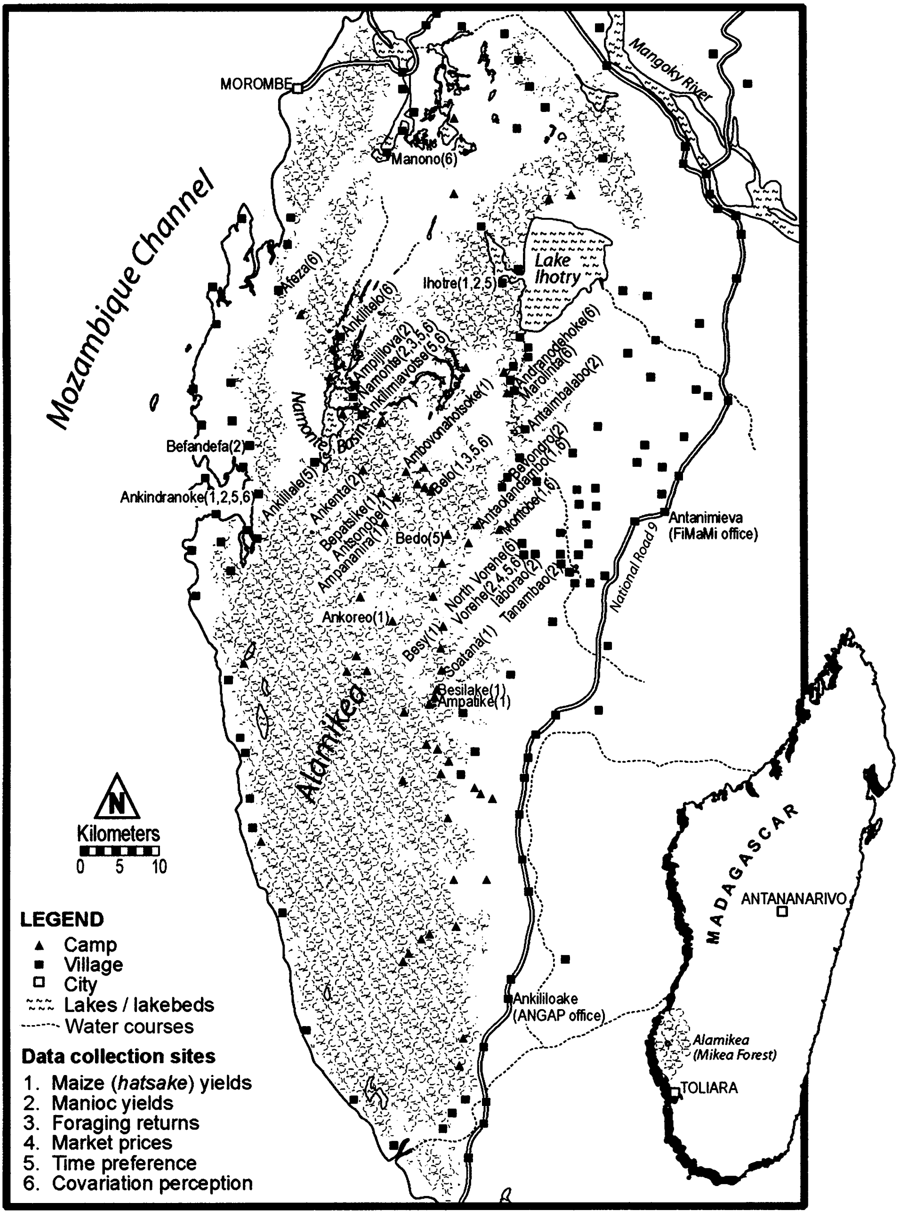

Fig. 1 Map of the Mikea Forest showing data collection sites and place names mentioned in text. ANGAP's current plan would encompass the entire forested area in the Mikea Forest National Park

have argued elsewhere that hunting and gathering is significant to Mikea identity because this symbolizes resistance and self-sufficiency (Tucker 2003).

The foraging activities in Mikea portfolios include digging various wild tubers, especially *ovy* and *balo* (varieties of *Dioscorea acuminata*), and the water-laden *babo* (*D. bemandry*) which is consumed to quench thirst. The only large game in the area is the rare bushpig (*Potamocorus larvatus*). Mikea gather wild honey and hunt small game, including three species of tenrec: the large-bodied *tandrake* (*Tenrec ecaudatus*), and the smaller *tambotrike* (*Echinops telfairi*) and *sora* (*Setifer setosus*). Mikea hunt feral cats (*Felis sylvestris*), various birds, and some lemurs, especially the mouse lemur (*Microcebus murinus*) and the fat-tailed dwarf lemur (*Chierogaleus medius*). Tubers, tenrecs, honey, and birds are frequently sold in village markets, but I have never seen lemurs or feral cats sold.

Mikea fish in Lake Ihotre and in the waters of the Namonte Basin. Until recently, the only freshwater fish were four small-bodied (5–20 g) members of the genus *Paratilapia*. Sometime during the years 2000–2003, when the water level in the Namonte Basin was unusually high, local people introduced the large-bodied (1–3 kg) predatory snakehead fish called *vangalopake* (*Channa striata*) into the Namonte waters from the Mangoky River.

Currently, none of the wild resources exploited by Mikea is listed on the World Conservation Union's red list of endangered species (IUCN 2004). Although tenrecs in the genus *Microgale* are endangered, the tenrecs that Mikea exploit are not listed. Of the lemurs, two species of *Microcebus* are endangered (*M. myoxinus* and *M. ravelobensis*), but the more common *M. murinus* is not listed, nor is *C. medius*.

Mikea oral historians claim that maize (*Zea mays*) grown in slash-and-burn fields, a practice called *hatsake*, has been a part of their portfolios for the duration of living memory. Initially hatsake fields were small, often made by burning the forest without chopping any trees in a style called *poakafo*. By the mid 1980s wealthy Gujarati Indian merchants were purchasing maize from Mikea in bulk for export to the Seychelles for use as pig feed. This commercial niche encouraged Mikea to plant increasingly large fields, 3–5 ha. It also attracted neighboring Masikoro and immigrant Tandroy from southern Madagascar to clear 10–40 ha hatsake fields in the southern half of the forest. Because the ethnonym "Mikea" refers to all forest residents, these immigrant farmers call themselves Mikea and are recognized as such by other Mikea. Conservation organizations label the recent immigrants *faux Mikea* (false Mikea), in contrast to the *vrai Mikea* (true Mikea) with centuries of residence in the Alamikea.

Degradation of the forest for hatsake, pasture, and charcoal production were key topics in a 10-year investigation of Masikoro and faux Mikea by the French Institute de Recherche pour le Développement (IRD; Razanaka et al. 1999). By 1997 authorities in the World Wildlife Fund (WWF) and the Service Appui sur la Gestion de l'Environnement (SAGE, a branch of the government's Office National pour l'Environnement or ONE) were holding meetings to discuss the deforestation problem in the Mikea Forest. WWF, SAGE, and ONE, along with Conservation International (CI), sought support from the United Nations Development Programme (UNDP) and the cooperation of the Malagasy military, gendarmerie, and tribunal system, to form a Commission Mixte whose mission was to end hatsake through community "sensibilization" and arrests of offenders. A final player in the commission, said to represent the interests of Mikea people, was the Fikambanana Miaro ny Ala Mikea (FiMaMi), a union of all the elected mayors of the rural townships that include the Mikea Forest—none of whom are themselves vrai Mikea. In 2001 and 2002 the commission conducted village meetings throughout the region to gain local support for the ban on maize. Manioc (*Manihot dulcis*) farming in the savanna and in leftover swidden clearings, which Mikea households were already practicing at small scales, was promoted as a replacement for maize.

Hatsake was nearly eliminated by 2003; in September I saw a UNDP truck containing WWF and CI personnel and armed military heading into the forest to arrest recalcitrants. People were confused. They complained that they did not understand who the various members of the commission were, and that each Landrover delivered different information and promises. Of 81 adults asked how they would cope with the elimination of maize in 2003 and 2004, only about half (N=41) said that they planned to become manioc farmers; the remainder said they planned to specialize on foraging and fishing (N=37) or market activities (N=3). The new manioc farmers complained about the agronomic and legal challenges of growing manioc in forest clearings. They said it takes years to produce manioc that is not excessively bitter. Because manioc fields are farmed continuously, they are permanent assets and require legal title that must be obtained in the provincial capital of Toliara, a task that requires literacy. Some young men lashed out by stealing livestock. Most of all, people complained of food insecurity.

Shortly after the commission succeeded in ending hatsake, the World Bank in partnership with ONE announced that it would fund the Programme Environnemental Phase 3, which calls for the creation of several new national parks with high priority placed on the Mikea Forest. The initial "terms of reference" for the Mikea project sought to discover whether limiting people's access to parts of the forest, effectively limiting or prohibiting some foraging activities, would have negative consequences for livelihoods and cultural identity (World Bank/Office National pour l'Environnement 2003). The document defines vrai Mikea as an indigenous peoples or *peuples autochtones*, to which the World Bank affords special protections.

On 30 April 2007 the first Mikea Forest Protected Area agreement with signed by the Ministers of Environment, Agriculture and Fishing, Energy, and Mines (Arrete Interministeriel No. 5569/2007). This document grants control of the new protected area to the Association Nationale pour la Gestion des Aires Protégées (ANGAP), technically an NGO but with governmental authority to manage protected areas and national parks in Madagascar. The document defines a "Complexe Mikea" of 371,340 ha covering the majority of the forest, of which the inner two-thirds constitutes a "hard core" or noyau dur in which most human activity will be excluded. Surrounding the Noyau Dur is a 0–10 km wide protection zone in which foraging and fishing for non-threatened species, pasturing livestock, and fuel wood collection are permitted. While the document states that one of the goals of the protected area is to preserve the cultural identity and economic stability of Mikea, it does not specify what will happen to Mikea living within the Noyau Dur. ANGAP officials have told me that faux Mikea will be evicted from the Noyau Dur while Vrai Mikea will be permitted to remain, but within a Zone d'Occupation Contrôlé or ZOC around the Namonte Basin in which their resource use would be managed. ANGAP now faces the challenge of determining who qualifies as a vrai Mikea (a difficult task since local people rarely make this distinction), and deciding how activities within the ZOC will be managed.

Data Collection Methods

Observational Data and Net Acquisition Rate

Optimal foraging theory models begin by testing whether people maximize energetic efficiency, usually measured as net acquisition rate (NAR): the energy gained from consuming food minus the energy costs of its acquisition, per unit time (Stephens and Krebs 1986).

Net acquisition rates for maize and manioc fields cultivated with differential labor investment are displayed in Table 1. Maize production was measured in 247 hatsake fields in 1998 and 1999 and manioc production was measured in 149 manioc fields in 1999 and 2004. These measurements provided yield in kilograms per hectare, a measure familiar to agricultural scientists. To convert yield into NAR one must consider the time and energy costs of labor (Table 2). Time costs are estimated from focal follow observations of farmers clearing, weeding, planting, and harvesting, matched to caloric expenditure rates from a study of African farming by Fox (1953), cited in Durnin and Passmore (1967:67). The yield (kg/ha) is converted to net calories per hectare by multiplying by the caloric value of maize or manioc and then subtracting energetic costs (kcal/ha). This number is then divided by the labor time (h/ha) to reveal NAR (net kcal/h).

Table 1 Yields and net acquisition rates (NAR) for agriculture

Labor investment strategy	*N* (fields sampled)	Labor per hectare†			Mean yield (kg/ha)	NAR (kcal/h)
		Tasks	Time (person hours)	Energetic cost (kcal)		
Maize						
Poakafo (new burn w/o chop)	1	B, C	22	5,511	228	37,473
Hatsabao (new chop & burn)	87	A, B, C	46.7	16,626	1,045	81,428
Uncleared *monka* (reused field)	18	B, C	22	5,511	498	82,146
Cleared *monka* (reused field)	141	A, B, C	46.7	16,626	911	70,651
Manioc						
Weeded once	3	A, B, C	46.7	16,626	8,267	263,409
Weeded twice	57	A, A, B, C	71.4	27,741	16,928	352,871
Weeded × 3	64	A, A, A, B, C	96.1	38,856	18,354	284,169
Weeded × 4	25	A, A, A, A, B, C	120.8	49,971	19,569	240,959

† See Table 2 for key
A Clearing and weeding, *B* planting, *C* harvesting

Table 2 Key for labor calculation

Task	Person-hours labor/ha	Energetic cost (kcal)[a]
A Clearing, weeding	24.7	7.15/min=450/h
B Planting	11.0	3.85/min=231/h
C Harvesting	11.0	4.50/min=270/h

[a] Values are midpoints in range of comparable activities: *A* clearing scrub and brush, *B* planting ground nuts, *C* grass cutting (Fox 1953, cited in Durnin and Passmore 1967:67).

Net acquisition rates for foraging and fishing activities are displayed in Table 3. The gross acquisition rate data are from a foraging event log (*N*=509) that I maintained in the forest community of Belo during 8 months in 1997–1999 and at Belo and Namonte during 1 month in 2003, in which I recorded the hour and minute I saw foragers leave and return and the number and weight of the wild products they procured. I assume that the energetic cost of all foraging activities is roughly 4.5 kcal/min. This value is near the midpoint for a variety of activities that resemble foraging listed by Durnin and Passmore (1967): chopping firewood, 3.0–4.9; cutting grass, 4.5; weeding, 3.8–7.8; commercial fishing, 5.0; and recreational fishing, 4.0. Although foraging involves exhausting tasks such as felling trees (8.4–8.6 kcal/min) and digging (5.4–10.5), these are balanced by a lot of walking (2.4–3.5 at 4 kph with up to 10 kg load). Some imprecision is excusable because the NAR calculation is insensitive to error in energy costs and the probable range of energy cost values is small.

Because NAR considers only food energy, this measure may fail to explain subsistence choices when a high-energy diet is nutritionally unbalanced (Hill 1988). Nutritional values for cultivated and foraged foods in the Mikea economy are presented in Table 4. The market economy sets value independent of energetic and nutritional concerns. Market values during 33 weekly markets in the village of Vorehe (1997–1999) are also included in Table 4.

Table 3 Net acquisition rates for foraging, assuming an energetic cost of 4.5 kcal/min (270 kcal/h)

Food	*N* (foraging events)	Mean observed gross acquisition rate (kg/h)	NAR (net kcal/h)
Wild tubers			
Ovy and *balo* (*Dioscorea acuminata*)	252	1.350	1,305
Babo (*D. bemandry*)	5	4.921	729
Tenrecs (estivating)			
Tambotrike (*Echinops telfairi*)	12	0.102	−104
Tandrake (*Tenrec ecaudatus*)	8	0.352	303
Lemurs			
Tily (*Microcebus murinus*)	12	0.062	−140
Freshwater fish			
Paratilapia sp.	201	0.189	−22
Vangalopake (*Channa striata*)	19	0.559	421

Table 4 Nutritional and market value

Food	% Fat	% Carbohydrates	% Protein	% Moisture	Energy value (kcal/kg)	Market value† (Malagasy ariary/kg)
Agriculture[a]						
Maize (*Zea mays*)	4.8	73.6	10.0	10.4	3,640	115
Manioc (*Manihot dulcis*)	1.3	86.6	1.3	8.7	1,240	100
Wild tubers[b]						
Ovy (*Dioscorea acuminata*)	0.2	24.9	3.7	70.3	1,167	250
Balo (*D. acuminata*)	0.1	19.8	4.0	75.2	965	250
Babo (*D. bemandry*)	0.1	2.6	2.3	95.0	203	58
Tenrecs						
Tambotrike (*Echinops telfairi*)[b,c]	5.7	1.0	26.8	63.0	1,627	1,000
Tandrake (*Tenrec ecaudatus*)[d]	–	–	–	–	–	1,290
Lemurs						
Tily (*Microcebus* sp.)[e]	6.0	0.0	39.0	12.0	2,098	Never sold
Tihitihy (*Chierogaleus medius*)[c,e]	31.4	0.0	24.2	39.7	3,793	Never sold
Freshwater fish[b]						
Kijonojono (*Paratilapia* sp.)	1.4	1.1	21.6	68.9	1,034	200
Fiambazaha (*Paratilapia* sp.)	2.3	2.4	21.7	59.2	1,581	200
Fiantsako (*Paratilapia polleni*)	3.2	1.6	28.3	60.4	1,320	200
Vangalopake (*Channa striata*)	0.5	0.8	28.9	59.6	1,237	467

† Based on modal prices during 33 weekly markets in the village of Vorehe, 1997–1999; except for vangalopake, which is based on interviews at Ankililale in 2004.
[a] From Wu Leung (1968).
[b] From samples obtained in the Mikea Forest, analyzed at the Centre National de Recherche sur l'Environnement, Antananarivo.
[c] Sample was an estivating animal.
[d] I have no data for tandrake, but this is basically a larger version of tambotrike.
[e] Cadavers of adult lemurs (healthy at time of death but diagnosed with long-term health problems); purchased from the Duke Primate Center; grilled and analyzed at Superior Laboratories, Columbus, Ohio.

Subjective Value Measures: Time Preference and Covariation Perception

Time Preference

Time preference refers to how one judges the value of a smaller reward available immediately versus a larger reward available after a delay (Frederick et al. 2003; Tucker 2006a). I use "preference" in a descriptive manner, as the measurable outcome of the intricate neural processes of cost-benefit calculation, heuristics, biases, and emotions. Time preference is typically described as a discount rate k, where $k=0$ when there is no discounting (5 units now=5 units later), and larger k values mean that future rewards are increasingly devalued.

I conducted an experiment to examine whether time preference differed among Mikea who planned to specialize in manioc cultivation versus those who planned to specialize in foraging following the ban on hatsake in 2002. Reward amounts and delays were chosen to simulate those of agriculture: rewards were hypothetical gunnysacks of maize, and delays expressed in months. The experiment involved three trials with three sets of binary choices. The first question was always, "Which would you prefer: one sack of maize now, or 12 sacks in six months?" If the participant chose the one sack now, this indicated that it would take more than 12 sacks for her to be indifferent between the immediate and delayed rewards. The next two questions would increase or decrease the value of the delayed option, narrowing the range of indifference values. In the subsequent two trials, the delay was 12 months and 1 month. Indifference values from 27 individuals were solved for the discount rate k. Individual data points were iteratively resampled using bootstrapping to establish 95% confidence intervals. As predicted, results indicated that people who planned to specialize in manioc farming discounted future rewards significantly less (median k=1.4/month) than those who planned to specialize in foraging (3.9/month).

Although differences in experimental designs and incentive sizes make exact comparison problematic, Mikea discount rates are the same order of magnitude as those of Tsimane' forager-horticulturalists of Bolivia (median k=3.65/month; Kirby et al. 2002), whereas peasants in India show greater preference for delayed rewards (k=0.021–0.100/month; Pender 1996).[1]

Covariation Perception

In a previous experiment I explored how Mikea perceive covariation between rainfall and economic payoffs over many years (Tucker 2007). Covariation perception is an important way to learn about causality, yet owing to memory and judgment biases, humans often learn about covariation socially through narrative ethnotheory (Nisbett and Ross 1980). Given that rainfall is highly unpredictable, Mikea portfolios should include a mix of activities that they perceive to be productive in rainy years and those perceived to be productive in dry years. In a historical matrix exercise, a tabular grid was made on the ground in which the rows represented the past 5 years, the first column represented rainfall, and the subsequent columns represented payoffs from various foraging and farming activities. Teams of participants in 14 villages were instructed to place a pile of sand in each cell representing the quantity of rainfall or payoff in each year. People's narrative comments as well as Spearman rank-order correlations among columns indicate that Mikea perceive maize, tandrake tenrecs, and fish to correlate positively with rainfall, whereas manioc and rice are perceived to covary negatively with rainfall. Wild tubers and tambotrike tenrecs are perceived to be interannually invariant.

[1] Kirby et al. (2002) reported median k/day and Pender reported k/year; I convert to k/month for comparison. In experiments of Kirby et al. (2002) with cash rewards, median k=0.12/day, and for candy rewards, median k=0.14/day. Pender (1996) conducted ten different experiments and reported k=0.26–1.19/year.

Analysis

The Value of Agriculture

The value of maize and manioc is distinguished by very high NAR (Table 1) contrasted to foraging (Table 3), negligible nutritional value apart from carbohydrates, and low market value (Table 4). The value of agricultural staples in Mikea portfolios is as cheap food energy, with the surplus being converted to cash.

Interestingly, although manioc yield increases from around 8,000 to 16,000–19,000 kg/ha with increased weeding labor, NAR values for fields weeded once, twice, three times, and four times are statistically similar (one-way ANOVA: $F=1.030$, $df=148$, $p=0.381$). Yield, the conventional measure of agricultural production, assumes that the farmer is economizing production per unit land, whereas NAR assumes economization per unit labor time. If Mikea are more constrained by labor than by land, they are unlikely to cultivate manioc intensively and thus will experience lower yields than planners expect.

There are several reasons to believe that Mikea households face tough labor constraints. The household labor supply is largely endogenous; households rarely share labor (Tucker 2004) or hire labor. I have presented a model that predicts that labor investment in agriculture is constrained by current food needs (Tucker 2006a). Hunger has been shown to increase impulsive behavior in animal subjects (Snyderman 1983), and food insecurity was a significant predictor of time preference in a choice experiment I conducted in 2006 (Tucker 2006b). Because a day spent farming results in sweat, blisters, and hopes, but no actual edible food value, farming increases hunger, which increases discount rates, which diminishes the perceived value of farming relative to foraging. The model predicts that preference will oscillate between foraging and farming because the immediate needs accrued during days spent farming must be paid for through foraging, thus limiting the number of labor days available for agriculture.

Given that Mikea have a greater preference for immediate rewards than some other rural populations, their resistance to manioc may be explained by the longer delay to harvest for manioc versus maize. In my sample, manioc was harvested 7 to 12 months after planting (mean=10.2 months) whereas maize was harvested 3 months after planting. Figure 2 contrasts the value of a 1-ha hatsake field that produces (931 kg/ha × 3,640 kcal/kg) 3,380,840 kcal after 90 days, versus a 1-ha manioc field weeded once that produces (8,267 kg/ha × 1,490 kcal/kg) 12,317,830 kcal after 310 days. The value of these rewards on harvest day is represented with vertical bars. Their discounted value through time is plotted using the hyperbolic discounting model (Mazur 1984) at the discount rates revealed for Mikea in experiment 1 and, for contrast, by the midpoint of the discount rates reported in Pender's (1996) study of peasants in India (converted to *k*/day). This graph indicates that Indian cultivators would clearly prefer the larger rewards of manioc over the smaller gain from maize, despite the dissimilar delays. But for Mikea, during most of the delay to the maize harvest, the discounted value of maize is greater than the discounted value of manioc. For the subsample of respondents who indicated that they would rather forage than plant manioc, discount rates are

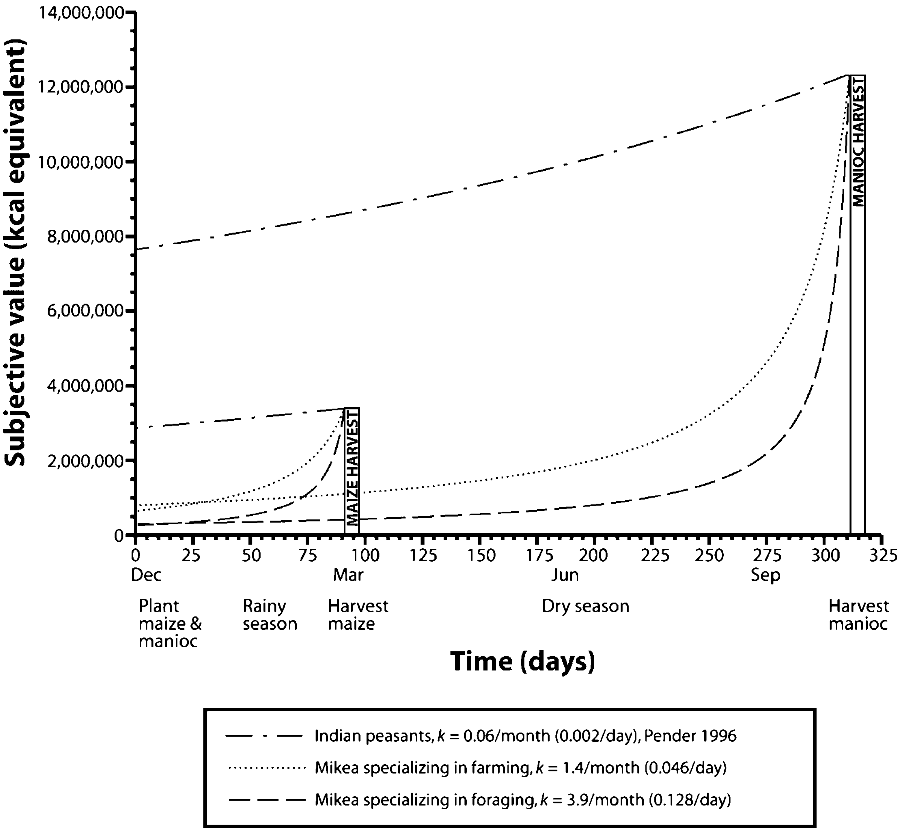

Fig. 2 Comparison of the discounted value of maize and manioc using experimentally measured discount rates

sufficiently high to explain a preference for lower-yielding maize over higher-yielding manioc.

Households may seek to reduce risk by combining activities that covary positively with rainfall with those that covary negatively with rainfall. The most consistent result in the covariation experiment was that maize is perceived to be profitable in years of heavy rainfall whereas manioc is productive in years of light rainfall. Until the ban on maize, most households planted both crops despite the fact that this meant scheduling labor between spatially separate fields in different microenvironments that had to be planted more-or-less simultaneously, before the first rains. One man described his portfolio as a “marriage” between maize and manioc.

The Value of Wild Tubers

The NAR values for foraging activities in Table 3 reveal a somewhat surprising trend. Apart from tuber foraging, most foraging and fishing activities have very low NARs. NARs for small game and fish are typically negative, meaning that foragers spend more energy procuring these resources than they gain from eating them. The high, positive NARs for *ovy* and *balo* (1,305 kcal/h) and even for the water-laden *babo* (729 kcal/h) suggest that these foods join maize and manioc as the major energy sources in the Mikea diet.

However, wild tubers differ from agricultural staples in several ways that further enhance their value. First, all household members dig tubers. Children are avid tuber foragers and experience NARs of 505–537 kcal/h. I have calculated the average daily net caloric production from tubers for male and female children, adolescents, and adults (Tucker and Young 2005:162). A household with six members (one of each age-sex category) averages 6,765 kcal per day, which would accumulate to 2,097,150 kcal over the 10-month dry season (compare with the payoff from 1 ha of maize, 3,280,840 kcal).

Wild tubers provide more protein than manioc (Table 4), and they also fetch a higher price than maize or manioc in the Vorehe market. Wild tuber foraging provides immediate rewards, after a foraging trip lasting an average of 224 min, with very low risk. Whereas maize frequently fails (one third of fields visited in 1998 and 3% of fields in 1999 had zero yield), I have never seen a tuber forager return home empty-handed. To reduce risk with agriculture one must plant both rain-tolerant maize and drought-hardy manioc. In contrast, tubers are perceived to be plentiful in all years regardless of rainfall.

The Value of Small Game and Fish

Table 1 indicates that for many small game and fish species, more energy must be spent to capture them than is gained from their consumption. The only species with positive NARs are the large-bodied tandrake tenrec and the invasive vangalopake. These NAR values are still quite low compared with those for wild tubers, or for other animals that foragers hunt throughout the world (Kelly 1995:81–82). Small game and fish are more than 20% protein, and thus are probably valued for this macronutrient rather than for their energy content (Table 4). With maize, manioc, and wild tubers providing cheap energy, Mikea may be willing to gain protein at an energetic deficit.

The market can transform the value of some game. Although lemurs, feral cat, and other prey were never sold (neighboring Masikoro and Vezo do not generally eat these animals), in 1998 the sale of ready-to-eat tenrecs at the Vorehe market exceeded maize as the primary source of cash for many households. Imagine that a forager spends 6 h pursuing tandrake at an average NAR of 303 kcal/h. This yields around 2,112 g total, or two animals. Instead of eating them, the forager smokes them for preservation and transports them to the market 15 km away, sells them, and buys low-priced maize, which is transported home. In total, 3,616 kcal are spent over 17.75 h.[2] The two tenrecs are sold for 12,000 Malagasy Ariary each, which in turn

[2]A summary of the labor cost and time for each task: 360 min of foraging at 4.5 kcal/min; 15 min searching for firewood at 4.3 kcal/min; 90 min spent resting (1.2 kcal/min) while the tenrecs are being smoked; 240 min spent transporting the tenrecs to the market at 3.5 kcal/min; 120 min spent vending at resting metabolic rate (1.2 kcal/min); and finally, another 4 h at 3.5 kcal/min to transport the purchased manioc home [expenditure rates from Durnin and Passmore: collecting firewood (Durnin and Passmore 1967:51); resting (Durnin and Passmore 1967:39); walking at 4 kph (Durnin and Passmore 1967:42)].

purchases 21 kg of maize worth 76,004 kcal. The NAR for the entire commercial venture is 4,078 kcal/h, assuming no time discounting. NAR for tandrake foraging is increased more than 13-fold through the use of the market.

Recommendations

Many Mikea are unlikely to judge manioc to be an acceptable replacement for maize. Households with constrained labor, a common situation in this diversified economy, will economize labor rather than land, and so are unlikely to experience the high yields that planners expect. Despite manioc's greater harvests, the delay to reward is two to four times greater than that for maize. At discount rates revealed experimentally, the disutility of waiting for manioc will lead many Mikea to prefer maize, even while other peasants faced with a similar decision might judge manioc a superior alternative. Manioc is also an unsuitable replacement for maize because Mikea perceive manioc to produce well in dry years whereas maize produces well in rainy years. Without maize the portfolio is imbalanced.

Maize filled a unique role in the household portfolio; planners will be hard-pressed to find a low-labor, moderate-delay, rain-loving activity to replace it. Perhaps the best course of action would have been not to eliminate maize in the first place, but to stop maize trafficking. It was the commercial incentive rather than the practice of slash-and-burn cultivation itself that caused the deforestation that alarmed conservationists. ANGAP might consider allowing Mikea to plant *poakafo* fields, which are burned without chopping trees.

Wild tubers play a unique role in the Mikea diet, being simultaneously energy-efficient, immediate-return, low-risk, interannually invariant, high-priced, and harvested profitably by all members of the household. Tuber foraging is not environmentally destructive, and the costs of prudent tuber stewardship are quite low. Foragers can harvest them without killing the plant or affecting future productivity as long as the "head" (regenerative portion of the stem) is left in the ground or replanted. Often the head breaks off and remains in the ground or is accidentally replanted in the back dirt. Replanting manually only takes a minute or two (vrai Mikea sometimes complain that faux Mikea rarely replant *ovy* heads).

Any limitations on tuber foraging would have a devastating impact on food supply. The profitability of tuber foraging would be grossly reduced if Mikea are restricted to foraging within a Zone d'Occupation Contrôlé. Because tuber patches are vulnerable to depletion, tuber foraging requires unrestricted access to large expanses of land. Wild tuber production will also be hurt by the gradual replacement of clearings with regenerated forest. Tubers are rare and difficult to locate in the forest. Their best habitat is the old clearings left over from slash-and-burn maize cultivation. ANGAP should consider maintaining some anthropogenic habitats as tuber reserves.

Although the small game that Mikea typically pursue are not currently on the IUCN red list, it seems likely that some tenrecs and lemurs may be added in the foreseeable future. Populations of tambotrike and trandrake tenrecs have diminished drastically during the period of my fieldwork, certainly as a result of overharvesting. Data presented here suggest that many game species have low dietary value; protein gain is achieved at energetic deficit. People may be quite happy to accept alternative, immediate-return protein sources. What makes tenrecs worth pursing is their high sales price, in contrast to lemurs, which are never sold for consumption. ANGAP should not spend much effort preventing Mikea from killing lemurs, given their negligible food value and zero sale value.

ANGAP may wish to remove the invasive, predatory snakehead fish from the Namonte Basin. Yet it is clear why Mikea purposefully introduced this fish. They were essentially adding a new immediate-return, high-protein, high-NAR prey to their foraging menu. Indeed, vangalopake are now the largest local game animal excluding bushpig. To prevent locals from continually reintroducing this fish, a suitable high-NAR replacement should be offered.

Conclusions and Future Directions

Among the traditional missions of anthropology is to explain the behavior of poorly understood peoples to the Western world so as to defend the logic of peoples otherwise prejudicially categorized as primitive, backward, or other. This mission is increasingly important as conservation and development become increasingly global, leading simultaneously to a greater impact on rural people's daily lives and livelihood strategies, and decreased intimacy and attention to local voices. "Bottom-up" participatory approaches have been championed as a remedy (Berkes 2004; Tsing et al. 2005; Warner 1997). But problems arise because planners and locals speak different languages, literally and figuratively, and because speech is an imperfect way to communicate unconscious values, preferences, and constraints. Behavioral science and its observational and experimental field methods can help planners understand rural people and their decisions.

In this paper I have evaluated Mikea activities using NAR, nutrition, market value, time preference, and perceived covariation with rainfall. The HBE and BE literatures suggest other measures that could be useful in planning projects. For example, HBE researchers have used sexual selection theory to argue that men practice energetically inefficient food production activities for fitness-enhancing prestige benefits. A conservation planner who tries to prevent Hadza men from hunting large ungulates (Hawkes et al. 1991) or Torres Straits Islanders from hunting sea turtles (Smith et al. 2003) may be benefited from understanding the role these activities play in choice of marital and sexual partners. The elimination of such activities would erode gender identity, a significant component of social structure.

Additional measures from BE include risk preference (Kuznar 2001; Henrich and McElreath 2002) and social preferences (Henrich et al. 2004). The latter, which refers to how people judge fairness, may be particularly useful for understanding how communities will redistribute incentives and perceive income inequality.

In exploring how Mikea judge the value of foraging and farming activities, I am not suggesting that their values are representative of all rural people, nor of all foragers, horticulturalists, Malagasy, or members of any other category. Researchers and planners should assume that people's preferences and values vary among populations. Although Binswanger and Sillers (1983) found that peasants in India, Thailand, the Philippines, and El Salvador are similarly risk-averse, Henrich and

McElreath (2002) found that Mapuche of Chile and Sangu of Tanzania are risk-prone whereas other Chilean peasants and UCLA students are moderately risk-averse. I recently compared risk and time preferences of 69 Mikea, 71 Masikoro, and 129 Vezo using a one-shot choice among four real-reward options. Preliminary results suggest that Mikea have a stronger preference for immediate rewards and are more risk-averse than their neighbors (Tucker 2006b). The scientific goal of such comparison is to understand why human judgment varies, whether because judgments are adaptations to needs relative to wealth status (Kuznar 2001) or because they represent socially learned norms (Henrich and McElreath 2002). Exploring such theoretical questions and their application to significant world issues are mutually consistent goals.

Acknowledgements This paper has benefited greatly from comments by Pete Brosius, Flora Lu, Dan Steck, Sarah Hitchner, Dave Himmelfarb, Amber Huff, Elaina Lill, James Yount, Keri Goodman, and Ted Maclin. Research described in this paper was funded by Fulbright IIE (1997–1998), the National Science Foundation (1999), and travel grants from the University of North Carolina at Chapel Hill (1996), Ohio State University (2003, 2004), and the University of Georgia (2006). Thanks to the many research participants in the Mikea Forest and to Gervais Tantely, and to my colleagues at the Université de Toliara, Tsiazonera, Jaovola Tombo, and Tsimitamby.

References

Allais, M. (1953). Le comportement de l'homme rationnel devant le risque: Critique des postulats et axiomes de l'ecole americaine. *Econometrica, 21*, 503–546.

Alvard, M. (1995). Intraspecific prey choice by amazonian hunters. *Current Anthropology, 36*, 789–818.

Berkes, F. (2004). Rethinking community-based conservation. *Conservation Biology, 18*, 621–630.

Binswanger, H. P., & Sillers, D. A. (1983). Risk aversion and credit constraints in farmers' decision-making: A reinterpretation. *Journal of Development Studies, 20*, 5–21.

Camerer, C. F., & Loewenstein, G. (2004). Behavioral economics: Past, present, and future. In C. F. Camerer, G. Loewenstein, & M. Rabin (Eds.), *Advances in behavioral economics* (pp. 3–51). Princeton: Russell Sage Foundation.

Chapin, M. (2004). A challenge to conservationists. *World Watch, 17*(6), 17–31. Nov–Dec.

Conklin, H. C. (1961). The study of shifting cultivation. *Current Anthropology, 2*, 27–61.

Crewe, E., & Harrison, E. (1998). *Whose development? An ethnography of aid*. London: Zed Books.

Durnin, J. V. G. A., & Passmore, R. (1967). *Energy, work, and leisure*. London: Heinemann Educational Books.

Fehr, E., & Gächter, S. (2000). Fairness and retaliation: The economics of reciprocity. *Journal of Economic Perspectives, 14*, 159–181.

Fox, R. H. (1953). *Energy expenditure of Africans engaged in various rural activities*. Ph.D. thesis, London University.

Frederick, S., Loewenstein, G., Reed, D., & Baumeister, R. F. (2003). Time discounting and time preference: A critical review. In G. Loewenstein, D. Read, & R. F. Baumeister (Eds.), *Time and decision: Economic and psychological perspectives on intertemporal choice* (pp. 13–86). New York: Russell Sage Foundation.

Gigerenzer, G., & Selten, R. (Eds.) (2001). *Bounded rationality: The adaptive toolbox*. Cambridge, MA: MIT.

Hardin, G. (1968). The tragedy of the commons. *Science, 162*, 1243–1248.

Hawkes, K., O'Connell, J. F., & Blurton Jones, N. G. (1991). Hunting income patterns among the Hadza: Big game, common goods, foraging goals and the evolution of the human diet. *Philosophical Transactions of the Royal Society of London B, 334*, 243–251.

Henrich, J., & McElreath, R. (2002). Are peasants risk-averse decision makers? *Current Anthropology, 43*, 172–181.

Henrich, J., Boyd, R., Bowles, S., Camerer, C., Fehr, E., & Gintis, H. (Eds.) (2004). *Foundations of human sociality: Economic experiments and ethnographic evidence from fifteen small-scale societies*. Oxford: Oxford University Press.

Hill, K. (1988). Macronutrient modifications of optimal foraging theory: An approach using indifference curves applied to some modern foragers. *Human Ecology, 16*, 157–197.

IUCN (International Union for Conservation of Nature) (2004). IUCN Red List of Threatened Species. www.iucnredlist.org.

Jarosz, L. (1993). Defining and explaining tropical deforestation: Shifting cultivation and population growth in Madagascar (1896–1940). *Economic Geography, 69*, 366–379.

Kelly, R. L. (1995). *The foraging spectrum: Diversity in hunter-gatherer lifeways*. Washington, DC: Smithsonian Institution Press.

Kirby, K. N., Godoy, R., Reyes-García, V., Byron, E., Apaza, L., Leonard, W., et al. (2002). Correlates of delay-discount rates: Evidence from Tsimane' Amerindians of the Bolivian rain forest. *Journal of Economic Psychology, 23*, 291–316.

Kuznar, L. A. (2001). Risk sensitivity and value among Andean Pastoralists: Measures, models, and empirical tests. *Current Anthropology, 42*, 432–440.

Ledyard, J. O. (1995). Public goods: A survey of experimental research. In J. H. Kagel, & A. E. Roth (Eds.), *The handbook of experimental economics* (pp. 111–181). Princeton: Princeton University Press.

Mazur, J. E. (1984). Test of an equivalence rule for fixed and variable reinforcer delays. *Journal of Experimental Psychology: Animal Behavior Processes, 10*, 426–436.

Nisbett, R., & Ross, L. (1980). *Human inference: Strategies and shortcomings of social judgment*. Englewood Cliffs, NJ: Prentice-Hall.

Nisbett, R. E., & Wilson, T. D. (1977). Telling more than we can know: Verbal reports on mental processes. *Psychological Review, 84*, 231–259.

O'Brien, W. E. (2002). The nature of shifting cultivation: Stories of harmony, degradation, and redemption. *Human Ecology, 30*, 483–502.

Ostrom, E. (2000). Collective action and the evolution of social norms. *Journal of Economic Perspectives, 14*, 137–158.

Pender, J. L. (1996). Discount rates and credit markets: Theory and evidence from rural India. *Journal of Developmeny Economics*, *50*, 257–296.

Razanaka, S., Grouzis, M., Milleville, P., Moizo, B., & Aubry, C. (Eds.) (1999). *Sociétés paysannes*, *transitions agraires*, *et dynamiques ecologiques dans le sud-ouest de Madagascar*. Antananarivo: CNRE-IRD.

Redford, K. H. (1990). The ecologically noble savage. *Orion Nature Quarterly, 9*, 25–29.

Redford, K. H., & Stearman, A. M. (1993). Forest-dwelling native amazonians and the conservation of biodiversity: Interests in common or in collision? *Conservation Biology, 7*, 248–255.

Ruttan, L. M., & Borgerhoff Mulder, M. (1999). Are east African Pastoralists truly conservationists? *Current Anthropology, 40*, 621–652.

Seddon, N., Tobias, J., Yount, J. W., Ramanampamonjy, J. R., Butchart, S., & Randrianizahana, H. (2000). Conservation issues and priorities in the Mikea Forest of South-west Madagascar. *Oryx, 34*, 287–304.

Smith, E. A. (1987). On fitness maximization, limited needs, and hunter-gatherer time allocation. *Ethology and Sociobiology, 8*, 73–85.

Smith, E. A., & Winterhalder, B. (1992). Natural selection and decision-making: Some fundamental principles. In E. A. Smith, & B. Winterhalder (Eds.), *Evolutionary ecology and human behavior* (pp. 25–60). New York: Aldine de Gruyter.

Smith, E. A., Bliege Bird, R., & Bird, D. W. (2003). The benefits of costly signaling: Meriam turtle hunters. *Behavioural Ecology, 14*, 116–126.

Snyderman, M. (1983). Optimal prey selection: The effects of food deprivation. *Behaviour Analysis Letters, 3*, 359–369.

Stephens, D. W., & Krebs, J. R. (1986). *Foraging theory*. Princeton, NJ: Princeton University Press.

Tsing, A. L., Brosius, J. P., & Zerner, C. (Eds.) (2005). *Communities and conservation: Histories and politics of community-based natural resource management*. Walnut Creek, CA: AltaMira.

Tucker, B. (2003). Mikea origins: Relicts or refugees? *Michigan Discussions in Anthropology, 14*, 193–215.

Tucker, B. (2004). Giving, scrounging, hiding, and selling: Minimal food sharing among Mikea of Madagascar. *Research in Economic Anthropology, 23*, 45–68.

Tucker, B. (2006a). A future discounting explanation for the persistence of a mixed foraging-horticulture strategy among the Mikea of Madagascar. In D. J. Kennett & B. Winterhalder (Eds.), *Behavioral ecology and the transition to agriculture* (pp. 22–40). Berkeley: University of California Press.

Tucker, B. (2006b). Testing the effects of wealth versus identity on risk and time preferences among Mikea, Vezo, and Masikoro of Madagascar. Paper presented at the American Anthropological Association annual meeting, San Jose, CA.
Tucker, B. (2007). Perception of interannual covariation and strategies for risk reduction among Mikea of Madagascar: Individual and social learning. *Human Nature,* doi:10.1007/s12110-007-9007-z.
Tucker, B., & Young, A. G. (2005). Growing up Mikea: Children's time allocation and tuber foraging in southwestern Madagascar. In B. Hewlett & M. Lamb (Eds.), *Hunter-gatherer childhoods* (pp. 147–171). Piscataway, NJ: Transaction.
Tversky, A., & Kahneman, D. (1974). Judgment under uncertainty: Heuristics and biases. *Science, 185*, 1124–1131.
Warner, M. (1997). "Consensus" participation: An example for protected areas planning. *Public Administration and Development, 17*, 413–432.
Winterhalder, B. (1986). Diet choice, risk, and food sharing in a stochastic environment. *Journal of Anthropological Archaeology, 5*, 369–392.
World Bank/Office National pour l'Environnement (2003). *Plan pour le developpement des Mikea (PDM)*. Antananarivo, Madagascar.
Wu Leung, W.-T. (1968). *Food composition table for use in Africa*. Rome: Food and Agriculture Organization of the United Nations.
Yount, J. W., Tsiazonera, & Tucker, B. (2001). Constructing Mikea identity: Past or present links to forest and foraging. *Ethnohistory, 48*, 257–291.

Bram Tucker currently an assistant professor in the Department of Anthropology at the University of Georgia, received his Ph.D. from the University of North Carolina at Chapel Hill in 2001. He has been investigating subsistence behavior in southwestern Madagascar since 1996 with a focus on two scales: at the cognitive level of judgment and decision-making and at the individual and household level of livelihood strategies.