Disturbance Pharmacopoeias: Medicine and Myth from the Humid Tropics

Author(s): Robert A. Voeks

Source: *Annals of the Association of American Geographers*, Dec., 2004, Vol. 94, No. 4 (Dec., 2004), pp. 868-888

Published by: Taylor & Francis, Ltd. on behalf of the Association of American Geographers

Stable URL: https://www.jstor.org/stable/3694102

Disturbance Pharmacopoeias: Medicine and Myth from the Humid Tropics

Robert A. Voeks

Department of Geography, California State University, Fullerton

The much-publicized quest for miracle drug plants in tropical rainforests has provided compelling support for the preservationist agenda. This article questions the assumptions that underpin this claim, particularly the myth that pristine forest represents the primary repository of nature's medicinal providence. After tracing colonial European efforts at medicinal plant discovery, intellectual property exploitation, and plant transference and acclimation, I review the recent resurgence of scientific interest in tropical folk pharmacopoeias. In spite of the image marketed by environmental entrepreneurs, the medicinal foraging preference of rural tropical groups is largely successional mosaics of their own creation—trails, kitchen gardens, swiddens, and forest fallows. Focusing on the subsistence transition from hunting and gathering to small-scale cultivation, I propose that disturbance pharmacopoeias are the logical outcome of changing subsistence strategies, ecological processes, and disease patterns. Salient, familiar, accessible, and rich in bioactive compounds, anthropogenic nature represents the ideal tropical medicine chest. Whereas bioprospecting enterprises carried out during the colonial period and at present employ similar rhetoric—deadly disease, miracle cures, and fantastic profits—these endeavors were in the past and continue to be buttressed by fictitious notions of virgin tropical nature and the mysterious healing powers of its "primitives." *Key Words: pharmacopoeia, tropical rainforest, ethnobotany, medicinal plants, human ecology.*

Destructive exploitation of the world's tropical moist forests continues to hold a central position among the ever-growing inventory of global environmental dilemmas. Among the environmental and social casualties of forest conversion—loss of biodiversity, global climate change, cultural genocide, and a host of others—none has provided a more compelling justification for rainforest protection than the impending loss of medicinal drug plants. Fortified by a steady diet of television documentaries, nongovernmental organization (NGO) projects (e.g., the Periwinkle Project), popular books, scientific articles, and Hollywood productions such as "The Medicine Man," the notion that miracle cures for society's most debilitating diseases are harbored in the fading memories of a few elderly forest shamans, the perceived stewards of tropical nature's medicinal providence, has become firmly entrenched in Western everyday wisdom. Rainforest healers, long perceived as misguided purveyors of witchcraft, have been metaphorically resurrected as the earthly embodiments of ancient forest wisdom (see Myers 1984, 210–24; Schultes and Raffauf 1990; Plotkin 1993, 2000; Joyce 1994; Balick and Cox 1996; Cox 1999). By watching passively as native tropical landscapes are converted to timber concessions, monocultural plantations, and cattle ranches, we seem to be mortgaging our pharmacological future for an ignominiously low price. Waxing plaintively in a trade journal, pharmacist and latter day shaman Connie Grauds (1997, 44) notes, "Besides being rich with an overpowering verdant fecundity and colorful wildlife, the rain forest holds secrets that could change the course of medicine as we know it." And from the late botanist Alwyn Gentry, "Is it an impossible dream to hope that through medicinal plants the biodiversity of tropical forests might be able to save the world from cancer or AIDS and at the same time contribute to its own salvation?" (Gentry 1993, 21). Not surprisingly, the rainforest medicine issue has provided persuasive support for preservation of primary forest habitats and has galvanized the often-opposing agendas of natural and social scientists.

This article questions the received wisdom that underpins the rainforest medicine narrative, especially as these claims are deployed by rainforest issue entrepreneurs. My objective is to recast this persuasive narrative within the broader context of ethnolandscape ecology (Zimmerer 2002), informed by the overdue paradigm shift regarding the role of disturbance—natural and cultural—in tropical landscape evolution (Sauer 1963; Balée 1994; Zimmerer and Young 1998; Denevan 2002; Raffles 2002; Heckenberger et al. 2003). No longer conceived as pristine parcels of nature's most ambitious experiment, these protean forests and fields are seen increasingly as the products of millennia of intentional and accidental manipulation by native and diaspora societies, great and small, to secure a living in a difficult environment.

Annals of the Association of American Geographers, 94(4), 2004, pp. 868–888 © 2004 by Association of American Geographers
Initial submission, August 2003; revised submission, January 2004; final acceptance, March 2004
Published by Blackwell Publishing, 350 Main Street, Malden, MA 02148, and 9600 Garsington Road, Oxford OX4 2DQ, U.K.

Medicinally rich tropical habitats, I will suggest, are largely reflections of these humanized landscapes.

I begin by outlining European notions of disease and herbalism during the Age of Exploration, especially the role of medicinal plant discovery, exploitation of indigenous ethnobotanical knowledge, and plant transference to the tropical latitudes. I then trace the recent lines of evidence that have been marshaled in support of this environmental assertion—economic, ecological, biochemical, and geographical—as well as the environmental and cognitive processes that threaten these perceived resources. This is followed by a discussion of the means employed by Western scientists in the process of tropical bioprospecting, in particular, application of the ethnobotanical method. I suggest, however, that the assumptions underlying the rainforest preservation–medical miracle rhetoric are marked by significant defects, the most glaring of which is the assumption that untouched tropical rainforests represent the primary locus of ethnobotanical foraging among traditional healers. The everyday medicinal foraging habitats of rural tropical groups, according to recent studies, are not untouched primary forests, but rather are moderately humanized landscapes—trails, swiddens, kitchen gardens, and recent forest fallows. This habitat preference, I suggest, owes its origin not to local ignorance of primary forests, nor is it an artifact of long-term cultural erosion. On the contrary, disturbance pharmacopoeias combine optimal foraging features with the natural distribution of promising plant-derived compounds. Focusing on the prehistorical transition from a hunting and gathering to a small-scale agricultural mode of subsistence, I propose that disturbance pharmacopoeias are the necessary outcome of changing subsistence strategies, ecological processes, and public health issues.

Medicinal Plants in the Age of Discovery

The knowledge that plants maintain the power to cure what ails us is as ancient as the earliest civilizations. Assyrian, Chinese, and Egyptian medicinal plants and traditions, with pedigrees reaching back at least four millennia, continue to find currency among contemporary healers (Thompson 1908; Manniche 1989; Veith 2002). In Mesoamerica, the Maya maintained extensive plant pharmacopoeias and healing systems, again with elements preserved and administered to the present day (Alcorn 1984; Leonti, Sticher, and Heinrich 2003). The geographical isolation of these and other Old and New World healing floras, as well as the infectious illnesses they sought to remedy, ended abruptly with the arrival of the European Age of Discovery. Oceanic barriers, millions of years in the making, toppled over the course of a single century, allowing unexplainable new diseases to burn across the newfound lands of the Americas and Oceania (Lovell 1992; Crosby 1994). In the course of decimating susceptible indigenous populations, these virgin soil epidemics at the same time inspired among some invading priests and settlers a feverish hunt for nature's healing properties, a medicinal providence that God must surely provide. Over the next few centuries, endemic healing floras and native intellectual property diffused back and forth between Europe and the colonies, transforming forever the geography of tropical plant pharmacopoeias and folk healing traditions.

The quest for exotic spices and medicines, which was a primary catalyst for the European voyages of discovery (Parry 1953; Dalby 2000), owed its momentum in part to a renewed fascination with ancient herbalism. Geographical discoveries in Asia, Africa, and the Americas were coeval with a renaissance of curiosity among Europeans regarding Dioscorides's venerable *Material Medica*, interest in which had languished for generations prior to the sixteenth century.[1] Long-held notions regarding the superiority of tropical pharmacopoeias were reinforced early by the writings of Seville physician Nicholas Monardes, who reported that the Spanish have discovered "new medicines, and new remedies, which if we did lack them, [diseases] would be incurable" (Frampton 1580, fol. 2). These unexplored latitudes, in addition to precious metals, land, and slaves, held promise of a cornucopia of secondary entrepreneurial opportunities, none more intriguing than the search for medicinal herbs and spices.[2]

Bioprospecting in the Colonial Era

As European explorers, settlers, and priests quickly discerned, the particulars of these supposed miracle cures—their identities, their habitats, their mode of preparation, and the relevant illnesses they treated—were held as collective and as specialized knowledge by the native populations. In colonial Brazil, the indigenous shamans were clearly "barbarous," but they were at the same time privy to "herbs and other medicines" that were sorely needed in the colony (Frei Vicente do Salvador 1931, 62). The significance of local informants is illustrated by Monardes', description of guaiacum's (*Guaiacum officinale*) discovery.[3]

> There was a Spaniard that suffered great pain of the pox [syphilis], which he had taken by the company of an Indian woman, but his servant, being one of the physicians of that country, gave unto him the water of guaiacan [guaiacum],

> wherein not only his grievous pains were taken away that he did suffer, but he was healed very well. (Framption 1580, fol. 11)

Although eager to exploit indigenous knowledge of nature, Spanish and Portuguese colonists recognized that shamans were also purveyors of witchcraft and sorcery, and, as such, represented the principal impediments to wholesale catechism of the indigenous population (Hemming 1978, 112–13; Taussig 1987, 142–43; Leite 2000, 21–22). Settlers were sufficiently motivated to mine local ethnobotanical knowledge, but not at the cost of legitimizing heathen beliefs. The strategy employed by the Jesuits to address this dilemma was to thoroughly humiliate the healer in front of his tribe. Padre Nóbrega boasted from his post in colonial Salvador, Brazil, how a famous Tupinambá shaman, after being verbally browbeaten by the good brothers, begged to be baptized into the Christian faith "and now is one of the converted"(Nóbrega 1886, 67). Only after being demoralized by the clergy were tribal healers encouraged to divulge their secretive medicinal recipes.

Eclipsing whatever philanthropic motives that may have existed, Europe's obsession with tropical drug plants was mostly an extension of its ambition to monopolize the lucrative spice trade.[4] So sought after were these exotic flavors and medicines that Columbus felt compelled to report, erroneously, it appears, the existence of several commercially important Asian medicinal plants in his first written description of the New World (Shaw 1992, 15–16; Dalby 2000, 149–51). In the coming centuries, control of these profitable resources waxed and waned as colonial states jockeyed for power and market share. Dramatic price fluctuations were common in Spain and Portugal, as the English and Dutch interrupted their access to medicinal sources in Malacca, Goa, Ceylon, and elsewhere (Almeida 1975). Strategies for dominating the medicinal trade included identifying new species, supplying them to the relevant colonial power, and finally transplanting and acclimating plants in the colonies or in Europe. State control was realized by late eighteenth-century Spain through their requirement that all newly discovered medicinal species be first transported to Spain for approval by the Real Botica in Madrid (Nieto Olarte 2000, 144). The stakes of these actions were high, as the Dutch at least considered unauthorized shipment of its monopolized floral treasures to be "an act of war" (Dean 1995, 86; Dalby 2000).

Efforts to document these curative agents during the early years of colonization were forthcoming from New Spain (Frampton 1580; Acosta 1970), India (Garcia da Orta 1891), and Brazil (Piso 1957; Soares 1966). Healers and healing pharmacopeias of equatorial Africa and their later diaspora appear to have stimulated more fear than fascination among Europeans.[5] These classic inventories provided benchmark descriptions of medicinal species' geography and ecology, as well as their "temperature and wetness"—hot, cool, moist, or dry—thus allowing incorporation into humoral healing.[6] Brazilian planter Soares da Sousa notes that the herbaceous medicinal *capeba* (*Pothomorphe umbellata*) is very hot in nature and good for relief of kidney stones; *pitanga* (*Eugenia uniflora*), another hot taxon, represses nausea and vomiting (Soares da Sousa 1971). Padre José de Acosta reports from Peru that capsicum is a hot species that if taken in excess "provokes to lust" (Acosta 1970, 240). From India, we are informed that the humoral temperament of cannafistula (*Cassia fistola*), a notoriously effective purgative, depends on where it grows; sometimes it is cool, other times it is hot (Garcia da Orta 1891, 193). For European sufferers of disease and ill health, hope appeared on the horizons of newly encountered tropical landscapes.

Diffusion of Healing Floras

The discovery that many of these tropical botanicals were narrow endemics surprised European explorers and challenged their hegemonic intentions. Domination of the tropical spice and medicine trade would require not only colonial expansion, but just as importantly, intercontinental plant transport and acclimation. Early settlers and priests made noteworthy efforts in this respect, at least in terms of introducing familiar European plants to the Americas. And botanical gardens in Europe and the colonies evolved quickly into globalized gardens of medicinal and other useful species (Grove 1996, 73–94). But tropical plants were likely to be more complicated, since most were wild rather than domesticated, and because tropical seeds are notoriously recalcitrant in regard to storage and germination. Padre Acosta laments, for example, that New World plants transported to Spain "grow little there, and multiply not" (Acosta 1970, 265). There also existed thorny questions regarding the economic and political consequences of acclimation. In the early years of colonization, for example, King Manuel I ordered that all Asian medicinal species that had already been planted in Brazil be uprooted so as to preserve the value of Portuguese conquests in India (Allemão 1856, 565–66). During the first three centuries of colonization, significant attempts were launched at the official and informal levels to introduce curative plants to Europe and to the colonies. These efforts, outlined in various letters of correspondence, constituted requests for living plants and seeds (see

Varnhagen 1843; Xavier 1977), descriptions of the most reliable means of transport (Lapa 1966), shipment of plants (Souza 1787; Almeida 1975), and finally, reports of their successful acclimation (Marques 1999). At the official level, these efforts continued into the early nineteenth century. In the 1770s, Casimiro Gómez Ortega was sent by Spain to study at Europe's major botanical gardens with the objective of learning how to cultivate and, especially, to transport plants from distant colonies. He ultimately wrote a text on the subject, with cinchona (*Cinchona ledgeriana*) topping the priority list (Nieto Olarte 2000, 52–55). In July 1804, a Royal Decree issued by Portuguese King João was intended to stimulate acclimatization of Asian species in all of the Portuguese colonies, especially Indian clove and cinnamon.

Ultimately, these colonial horticultural endeavors were wildly successful. Within two centuries, endemic esculents and medicinals were widely dispersed throughout the tropical and subtropical realm (Crosby 1993). By the mid-sixteenth century, Brazil witnessed the successful cultivation of cinnamon from Ceylon, pepper from Malabar, ginger from China, coconuts from Malaysia, mango from Southeast Asia, jackfruit from India, and, later, cacao from Middle America (Frei Vicente do Salvador 1931, 33; Almeida 1975; Leite 2000, 161). By the end of the sixteenth century, the abundance of naturalized Iberian cultivars moved Padre Fernão Cardim to proclaim "This Brazil is already another Portugal" (Cardim 1939, 91). From Maranhão, Dutch physician Guilherme Piso (1957, 441–45) reported the introduction of "useful herbs" brought by Africans—sesame, eggplant, and okra—and that "the Africans taught the indigenous Americans how to use and prepare them." In Hispaniola, the East Indian medicinal cannafistula (*Cassia fistola*) was reportedly widely naturalized by the sixteenth century (Garcia da Orta 1891, 191). Asian fruits were so thoroughly acclimated in the West Indies that Acosta (1970, 265) encountered "whole woods and forests of orange trees." Within a century of Portuguese colonization, East Indians were cultivating American cashew, pineapples, soursop, squash, capsicums, guava, and cactus (Pina 1946). Jesuit Michael Boym's mid-seventeenth-century illustrations of New World papaya, cashew, pineapple, and avocado being cultivated in Chinese gardens underscored the reciprocal nature of these exchanges (Shaw 1992, 78–81).

Intentional efforts at plant acclimation were often registered in colonial correspondence and early natural histories, but the waves of mostly unnoticed weedy invaders that shadowed their arrival were seldom recorded. Only generations after their appearance did annual or perennial invasives warrant recognition, usually for their pernicious impact on agriculture or livestock. The diffusion of grasses alone, according to James Parsons (1970, 153), "may be one of the most rapid and significant ecological invasions in earth's history." While the alarming ecological impacts of this biogeographical collision become increasingly evident (cf. Cronk and Fuller 2001), the cultural benefits of this pantropical floristic homogenization were nevertheless noteworthy. Particularly for diaspora communities—African, Asian, and European—the competitive displacement of native plant taxa by weedy exotics facilitated the continuation of time-honored healing traditions in alien landscapes. African forced immigrants in the Americas, for example, quickly recognized and incorporated *dandá* (*Cyperus rotundus*), *folha-da-costa* (*Kalanchoe integra*), castor bean (*Ricinus communis*), and other Old World weeds into their healing floras (Voeks 1997). The outcome of these colonial plant movements, intentional and accidental, was nothing less than a wholesale floristic reorganization of the humanized landscapes of the tropical and subtropical zones, one that dramatically enhanced and augmented existing native plant pharmacopoeias.

Over the centuries, with the emergence of germ theory, improved hygiene, and inductive research methods, commercial interest in *material medicas* declined. As superstition surrendered to empiricism, as blind faith yielded to skepticism, and as physicians increasingly invoked the halo of science, faith in the efficacy of folk healing traditions retreated to the domain of alternative medicine (Nuland 2000). In spite of notable pharmaceutical successes, the occult nature of folk herbalism, with its recourse to demonic spirits, arcane rituals, and unsavory elements, drove these traditions into the backwaters of scientific investigation. But not completely, and not forever.

Rainforest Medicine Revisited

The latter twentieth century witnessed a resurgence of interest in traditional botanical medicine (Dufault et al. 2000), particularly from tropical sources (Balick, Elisabetsky, and Laird 1996). Once again, an ailing Western world turned to exploration and exploitation of torrid-zone healers and their mysterious healing floras. Unlike earlier efforts, however, in which the hunt for medicinals justified colonial acquisitions, the newest phase is tied to neocolonial efforts to justify rainforest preservation. Marshalling a host of rhetorical elements, some scientific, others purely emotional, environmentalists turned the search for pharmaceutical drug plants into a persuasive and widely touted environmental claim.

The Geography of Bioactive Plant Compounds

Compared to temperate zone floras, tropical habitats harbor a particularly rich profile of pharmacologically active compounds. This geographical disparity is a function of differing levels of predation and biological complexity. Like other prey, plants are under constant attack from predators—mammals, insects, bacteria, fungi, and the like. Their sessile habit, however, naturally limits their ability to escape via conventional means, that is, they cannot run away. Thus, as an adjunct to mechanical and phenological predator-avoidance methods, many (but not all) plants develop over time a complicated suite of chemical defense mechanisms (Waterman and McKey 1989; Coley and Barone 1996; Sumner 2000, 107–23). These compounds, termed secondary metabolites because they appear to serve no primary metabolic function, include saponins, cyanogenic glucosides, tannins, phenols, alkaloids, and others. Some of these, such as alkaloids, serve as toxicants against herbivory, whereas others act merely as feeding deterrents or pollinator attractants. Alkaloids are particularly relevant to the medical question because they are so frequently bioactive in humans and because they are numerous. A recent census placed the number of identified alkaloids at over 12,000 (Wink 1998). The main evolutionary role of secondary metabolites is to fend off the attacks of predators, but their toxicity often produces marked impacts on biochemical activities inside the human body, particularly neural function (Wink and Schimmer 1999). Some, such as caffeine and ephedra alkaloids, have a lengthy history of recreational and medical use for their stimulating properties. Others, such as atropine from mandrake (*Mandragora officinarum*) and nightshade (*Atropa belladonna*), have more sinister ethnomedical histories (Simoons 1998, 101–34; Mann 2000, 21–27).

Although chemical defense systems occur in all biomes, Levin (1976) uncovered a geographic dimension to the distribution of alkaloids. He noted a statistically significant inverse relationship between the proportion of the flora that tests positive for alkaloids and the average latitude of the country. Mid-latitude countries like the U.S. and New Zealand registered only 13.7 percent and 10.8 percent alkaloid presence, respectively, whereas Kenya and Ethiopia registered 40.0 percent and 37.2 percent, respectively. This gradient in alkaloid content, from temperate to tropical biomes, is highlighted by the dramatic vegetation transitions present on the island of New Guinea. In this case, subalpine forest and alpine grassland each maintained 0 percent alkaloids in their respective floras, whereas lowland and montane rainforest maintained 21.5 percent and 14.6 percent alkaloid presence, respectively. Although other factors may be present, the most likely explanation for this chemical defense gradient is increasing levels of herbivory in species-rich tropical habitats (Coley and Aide 1991).

The significance of this biochemical transition in the search for drug plants is enhanced by the legendary biological diversity exhibited by moist tropical forests. Covering only 7–8 percent of the Earth's surface, tropical forests sustain one-half to two-thirds of its tree species. One-hectare plots in old-growth forest commonly contain over 200 tree species (dbh 10 cm or greater), with a single plot in Brazil's Atlantic coastal forest registering a remarkable 450 tree species (Anon. 1993). This leads to extreme diversity rates (Simpson D_s often greater than 0.95), translating to a mean of one or perhaps two individuals/species/hectare (T. C. Whitmore 1998). And these censuses omit entirely the other life forms—shrubs, treelets, vines, epiphytes, and herbs. Of the estimated 310,000 to 422,000 plant species on Earth, some 125,000 are believed to inhabit the moist tropical realm (Pitman and Jorgensen 2002). Clearly, if mining for alkaloids is the pharmacological objective, then tropical landscapes represent the mother lode.

Drug Discovery in the Rainforest

Bioprospecting in the tropical realm has unearthed several medicinal treasures, many during the colonial era, others quite recently. Pharmaceutical companies have tested and ultimately incorporated an array of plant compounds (Table 1), either as drug components or, more frequently, as templates for synthetic drug development (Heilmann and Bauer 1999). Of the 121 clinically useful prescription drugs developed from plants, 47 were derived from tropical forest species (Soejarto and Farnsworth 1989). Some of the better known examples include quinine, which is derived from the bark of the Peruvian *Cinchona* tree and is used to treat malaria. Pilocarpine from the Brazilian herb (*Pilocarpus jaborandi*) is used to treat glaucoma. Diosgenin from winged yams (*Dioscorea alata*) is used as a female contraceptive. In the most celebrated example, the alkaloids vincristine and vinblastine derived from the Madagascar periwinkle (*Catheranthus roseus*) were developed into chemotherapeutic treatments for Hodgkin's disease and childhood (acute lymphoblastic) leukemia. With the discovery of vincristine (used in combination with other compounds), the survival rate from childhood leukemia climbed from 20 percent to nearly 80 percent (Pui and Evans 1998). An estimated 30,000 American lives are

Table 1. Examples of Pharmaceutical Drugs Derived from Tropical Plant Species

Plant Compound	Therapeutic Category	Species
Arecoline	Anthelminthic	*Areca catechu*
Bromelain	Antiinflammatory	*Ananas comosus*
Cocaine	Anesthetic	*Erythroxylum coca*
Emetine	Emetic	*Cephaelis ipecacuanha*
Glaucarubine	Amoebicide	*Simarouba glauca*
Kawain	Tranquilizer	*Piper methysticum*
Monocrotaline	Antitumor (topical)	*Crotalaria sessiliflora*
Ouabain	Cardiotonic	*Strophanthus gratus*
Physostigmine	Cholinesterase inhibitor	*Physostigma venenosum*
Pilocarpine	Glaucoma treatment	*Pilocarpus jaborandi*
Quinine	Antimalarial	*Cinchona ledgeriana*
Quisqualic acid	Anthelminthic	*Quisqualis indica*
Reserpine	Tranquilizer	*Rauvolfia serpentina*
Rorifone	Antitussive	*Rorippa indica*
Scopolamine	Sedative	*Datura metel*
Strychnine	Central nervous system stimulant	*Strychnos nux-vomica*
Theobromine	Diuretic	*Theobroma cacao*
Vinblastine	Antitumor	*Catharanthus roseus*
Vincristine	Antitumor	*Catharanthus roseus*

Sources: Farnsworth 1988; Soejarto and Farnsworth 1989; Balick and Cox 1996.

saved each year by anticancer drugs derived from plants (Myers 1997, 224).

The economic value of tropical medicinal resources, both to private pharmaceutical corporations and to society, further legitimizes this endeavor (Adger et al. 1995; Myers 1997). According to Soejarto and Farnsworth (1989), 25 percent of all prescription drugs sold in the U.S. in the 1980s contained compounds that were extracted from plants, totaling over US$8 billion in annual retail sales. Principe (1996) placed the value of plant-derived drugs at US$15.5 billion/year.[7] Focusing on the tropical realm, Mendelsohn and Balick (1995) estimated that there were roughly 375 medicinal plant taxa with commercial value yet to be revealed. Each undiscovered drug plant could be worth in the area of US$96 million to a pharmaceutical interest, with gross revenue for all drug plant discoveries yielding a total of US$3.2–4.7 billion.[8] If social benefits are included in this calculation, the potential economic value of plant-derived drugs climbs to between US$200 billion and US$ 1.8 trillion per year (Principe 1991). However speculative these figures may be (Artuso 2002), the impression has at least entered mainstream environmental thought that tropical drug plants represent a hugely lucrative direction for pharmaceutical investigation, if only the forests can be saved.

The pursuit of plant-derived drugs includes the random search and targeted approaches. The former, originally employed by the National Cancer Institute (NCI), uses a broad net to collect and screen as many plants as possible for the presence of bioactivity. This strategy met with limited success.[9] The targeted method, on the other hand, assumes that plant families that are particularly rich in secondary compounds (the phylogenetic approach), or plants with young, expanding leaves (the ecological approach) represent especially strong candidates for investigation (Coley et al. 2003). The strategy that has attracted the most interest, however, is the ethnobotanical method (Bedoya et al. 2001). This approach is based on the observation that many current Western pharmaceuticals originally were employed by tropical folk healers and shamans (Balick and Cox 1994), and, of course, the likelihood that many more remain to be discovered. Unlike indigenous temperate zone societies, which abandoned much of their knowledge of nature long ago, tropical forest groups continue to cultivate many of these material and spiritual relations with the plant kingdom. The ethnobotanical method found particular support following Farnsworth's (1988) much cited work showing that 74 percent of the plant-derived compounds employed in Western drugs maintained in the past a similar medicinal application by traditional healers. The veracity of this plant–people relationship was tested empirically by Balick (1990) in Belize, Cox et al. (1989) in Samoa, and Lewis (2003) in Peru. Balick (1990) discovered that plant extracts from folk medicinals yielded greater antiviral activity in anti-HIV screens than did randomly selected species. Cox et al. (1989) found that 86 percent of species used in traditional herbal medicine exhibited pharmacological activity. Lewis (2003) reported that folk antimalarial plants used by the Aguaruna exhibited significantly greater inhibition of malarial plasmodia than randomly collected plants. Several plant-derived products from other tropical medicinals, including the protein MAP30 from the bitter melon (*Momordica charantia*) and prostratin from the Samoan mamala tree (*Homalanthus nutans*) have shown anti-HIV activity in in vitro studies (Cox 2000; Kell 2001). Thus, in a revival of tactics devised long ago by their European colonial predecessors, modern bioprospectors seek to unearth the nuggets of medicinal wisdom sustained by tropical healers.

Rainforest Medicine as Environmental Narrative

At this juncture, scientific evidence segues into environmental claim, one that resonates deeply among a health- and environmentally conscious public. For just as the cognitive contribution of folk healers and their mysterious pharmacopoeias have recaptured the imagination of the Western world, the combined forces of destructive forest exploitation, species extirpation, and eroding plant knowledge among rural elders undermine their anticipated contribution to Western medicine. Deforestation is linked to decreasing access to traditional plant medicines in Samoa, Kenya, and eastern Brazil (Voeks 1997; Jungerius 1998; Cox 1999). In other locations, such as Sierra Leone, Cameroon, Madagascar, and India, valuable medicinal taxa are declining precipitously due to excessive plant extraction to supply national and international markets (Anyinam 1995; Lebbie and Guries 1995; Pandey and Bisaria 1998; Stewart 2003). In South Africa, an estimated 20,000 tons of plant material from some 700 medicinal species is harvested annually from the wild (Mander 1998). Under these conditions, commercial and biological extinction looms for a growing list of healing plants (Leaman and Schippmann 1998). The most pressing threat to medicinal plants and their knowledge profiles, however, appears to be declining medicinal knowledge among rural tropical communities (Cox 2000). Religious conversion (Caniago and Siebert 1998; Voeks and Sercombe 2000; Steinberg 2002), entrance of Western medicine (Milliken et al. 1992; Ugent 2000), economic improvement (Benz et al. 2000; Voeks and Nyawa 2001), and enhanced access to formal education (Lizarralde 2001; Voeks and Leony forthcoming) have all been linked to declining ethnobotanical knowledge. As reported by Phillips and Gentry (1993, 41), medicinal plant knowledge "is uniquely vulnerable to acculturation."

On the surface, the rainforest medicine narrative provides a persuasive argument in favor of tropical forest preservation. It achieves credibility, on the one hand, through the authority of Western science and the status of its practitioners. Bolstered by contemporary evolutionary theory and ongoing biochemical discoveries, as well as a record of pharmaceutical successes, the long-maligned meta-sciences of herbalism and shamanism have been resurrected from the medical nether reaches of ignorance and occultism. Ecology and history, in turn, fold effortlessly into "green developmentalism," as the prospect of hefty private profits reinforces the notion that nature should be forced to pay its own way (McAfee 1999; Castree 2003). In his review of rainforest bioprospecting, Joyce (1994, 11) contends that "the way to save the rainforest is to prove that it is more valuable standing than cut down and replaced." If the war against rainforest destruction is to be won by open-market commodification, bioprospecting stands as its most instrumental weapon. At the same time, the rainforest medicine issue panders to the developed world's near messianic search for miracle medical cures. Unable to take control of our proximate medical dilemmas—gluttony, stress, and a sedentary lifestyle—we slide effortlessly into archaic beliefs concerning the restorative power of tropical nature, seeking medical absolution in the pharmaceutical bosom of earth's most protean vegetation. Finally, the entire environmental package is bundled together and marketed in popular books and documentaries featuring intrepid young ethnobotanists, slogging through the rainforest primeval, risking life and limb in their mission to bring to light nature's healing mysteries.[10]

In accepting the tenets of the rainforest medicine narrative, environmentalists and the lay public subscribe uncritically to the assumption, clearly inferred but seldom stated, that rainforest medicinals are products of primary tropical habitats. Disturbed landscapes, those messy areas where humans have cut and burned and planted and fallowed, where bovines have displaced the native bestiary, are depicted as part of the problem, not the solution. This assumption follows, in part, from the view that tropical forests constitute virgin landscapes, where human influence (until recently) exerted little more impact than that of other mammals. In spite of mounting evidence to the contrary (Gómez-Pompa and Kaus 1992; Denevan 1992, 2002; Raffles 2002; Heckenberger et al. 2003), the myth of the pristine serves the objectives of the environmental agenda by portraying these highly humanized landscapes as fragile and disappearing vestiges of evolution's most prolific biological experiment. This perception also follows from the sampling bias exhibited by temperate-zone biologists working in the tropics, who focus their taxonomic, ecological, and ethnobotanical investigations on relatively untouched forest areas, nearly to the exclusion of human successional mosaics.[11] Likewise, because the objective of ethnobotanical researchers is often the discovery of commercial drugs, introduced taxa such as weeds, crop plants, and ornamentals are usually ignored (Bennett and Prance 2000). Moreover, although historically associated with the medicinal virtues of nature, weeds over time have assumed in the minds of Westerners a purely pernicious, even evil, influence (Clayton 2003), one unlikely to draw the attention of serious bioprospectors. Finally, the notion that virgin rainforests are the font of potential miracle cures is perpetuated by misleading reporting to the press by some ethnobotanists, who fail to mention that one or another rainforest remedy is in fact derived from a noxious weed or a common garden cultivar. Certainly, if rainforest pharmacopoeias are largely artifacts of human invention, the outcome of anthropogenic disturbance regimes that had gone on for millennia, it seems doubtful that the rainforest medicine issue would have developed into the poster child of tropical rainforest preservation efforts. A comparison of the ethnobotanical knowledge domains maintained by hunter-gatherer societies with small-scale cultivators suggests that this is in fact the case.

Hunter-Gatherer Ethnobotany

For most of the prehistory of our species, the ability to recognize, cognitively categorize, utilize, and manipulate plant species and communities was prerequisite to group subsistence and survival. Ethnobotanical skill was a building block upon which human existence was based. Yet in spite of the profound necessity of this realm of knowledge, significant differences exist in domains of ethnobotanical understanding, including plant pharmacopoeias. Some groups maintain a storehouse of ethnobotanical knowledge; others do not. While these breaks in plant knowledge are responsive to environmental gradients, so that high species richness tends to be associated with large plant lexicons, they also vary among contrasting modes of subsistence—from hunting and gathering to small-scale cultivation. This division is key to understanding the central role of anthropogenic disturbance in the maintenance of tropical plant pharmacopoeias.

The entrance of hunting and gathering societies into permanent occupation of moist tropical forests has been a subject of controversy. Indeed, for some researchers it is an open question as to whether moist forest resource paucity, especially in starch and protein (Piperno and Pearsall 1998, 53–72), would ever have permitted a purely hunting and gathering lifestyle.[12] In this article, I assume that independent foraging in moist tropical forests is (or at least was in the distant past) a viable subsistence choice. In any case, it is likely that regression from horticultural subsistence to foraging has occurred in the Old and New World tropics. The Guajá hunter-gatherers of Amazonian Brazil were likely horticulturalists in the past (Balée 1999), as were the Penan (Punan) of interior Borneo (Rousseau 1990). Furthermore, establishing a clear demarcation between a hunter-gatherer and a horticultural mode of production is rather arbitrary (Ellen 1999; Rival 2002). Foraging groups often engage in incipient horticultural enterprise, and cultivators are frequently skilled hunters and gatherers (Brosius 1991). While I maintain a foraging-cultivating typology in this article, these contrasting livelihoods should be pictured as poles of a subsistence continuum from simple extraction at one extreme to near complete dependence on cultivated crops at the other.

Mode of Subsistence and Ethnobotanical Knowledge

The impact of hunter-gatherer groups on tropical forest vegetation was minimal compared to their cultivating counterparts, but not insignificant. Although forest clearance was neither as extensive nor protracted as that carried out by cultivators, fire and other tools existed and were employed by foraging people for habitat modification and species enhancement. In Paleoindian deposits collected near the Amazon River, for example, abundance of plant fragments from *Attalea* spp. palms, a supremely fire-adapted genus (A. Anderson 1983; Voeks 2002), points to the likelihood of forest manipulation by Pleistocene foragers (Roosevelt et al. 1996). Likewise in Lake Yeguada in Panama, 11,000 B.P. concentrations of charred *Heliconia* and grass phytoliths suggest nearby human-induced successional mosaics (Piperno and Pearsall 1998, 175–79). Whether this degree of anthropogenic vegetation clearance occurred well away from water bodies is unclear. Less obvious human impacts resulting from husbanding and consumption of high-demand, nondomesticated species, including weeding, seed scattering, and replacement planting, were likely more common (Harris 1996). The Semang of Malaysia, for example, burn around bamboo clumps in order to promote new growth (Rambo 1985, 70). The nomadic Penan of interior Borneo protect the younger stems of their principal sago palm (*Eugeissona utilis*), which likely increases seed production and therefore affects abundance and distribution (Brosius 1991; Puri 1997; Voeks 1998). Concentrations of wild fruit trees in the forest serve as indicators of abandoned Penan campsites (Puri forthcoming). For the Amazonian Huaorani, who regularly scatter the seeds of useful species, "distinguishing between 'extraction' and 'management' becomes almost impossible" (Rival 2002, 81).

The limited extent and subtle nature of these forest impacts meant that nonagricultural societies lived in an environment largely created by nature, rather than by themselves. Given their limited material culture and nomadic lifestyle—temporary structures, seasonal migration, and group populations on the order of thirty to fifty people—everyday, encountered nature was of a primary rather than secondary formation. Habitat disturbance of the intensity and duration that favors fast-growing heliophiles, although regularly produced by natural treefall gaps, landslides, and forest trails (Sheil and Burslem 2003), likely represented a fraction of the total forest area occupied by hunting and gathering groups. Unlike the landscapes of present day horticulturalists, which represent, in many respects, cultural artifacts, the habitats within which foraging societies existed can be viewed as products of largely natural ecological processes.

Because tropical forests maintain a near legendary level of plant and animal diversity, it seems intuitive that people who forage for a living in these complex environments would develop a profound understanding of their biotic environment. Subsisting entirely on the endowment of nature, and surrounded by thousands of species, nonagricultural societies would seem to be ideal candidates to maintain vast lexicons of plant names and their uses. But this seems not to be the case. Working with ethnobotanical inventories from various biomes, Brown (1985) and later Berlin (1992) discovered sharp differences in total numbers of labeled plant taxa when subsistence mode was factored into the calculation. Horticulturalists, according to Brown (1985), maintained a magnitude of named plant categories some five times greater on average than that of foragers. Cultivators averaged 890 named plant classes, whereas hunter-gathers exhibited a mean of only 179.[13] Using folk genera rather than named plant taxa, Berlin (1992, 98) calculated that cultivating groups averaged 520 folk generics, compared to 197 for hunter-gathering societies.

Subsequent comparative studies of sympatric tropical forest foragers and cultivators lend support to this quantitative lexical disparity. In Brazil, Balée (1999) determined that the Guajá maintained a total of 28 folk-specific names for plants, whereas the Ka'apor recognized 252 folk specifics, or nearly nine times the number of their neighboring foragers. Likewise, Voeks (1998; forthcoming) compared the ethnobotanical profiles maintained by the Dusun, a hill-rice cultivating group in northern Borneo, with the neighboring Penan, a recently settled foraging society. The Penan, according to their own accounts, never engaged in forest clearance and generally avoided open areas. In the plot census, the Penan identified 63 named species, only two of which were medicinals, whereas the Dusun recognized a total of 241 taxa, twenty-nine of which were medicinals. The Dusun recognized four times as many named taxa, and over fourteen times as many medical plants as the Penan. At least in these two examples, a cultivating lifestyle is associated with a profound quantitative knowledge of nature, whereas hunting and gathering as a subsistence choice is not.

Health of Hunter-Gatherers

This ethnobotanical unconformity is revealed in the magnitude of healing floras as well; cultivators maintain significantly larger plant pharmacopoeias than their foraging counterparts. Brown (1985) attributes this feature to differences in illness profiles. Cultivating societies, he reasons, suffered from a wider range of illness, especially viral crowd diseases, than their foraging counterparts because of the size and density of their populations. In the past, devastating disease episodes would have driven sedentary cultivators to experiment with, and ultimately assimilate, the medicinal properties of the native vegetation. Small and relatively isolated hunter-gatherer groups, on the other hand, are unlikely to have suffered from similar afflictions. Indeed, several of the most virulent pathogens probably did not appear until the establishment of major agriculture-grazing civilizations; farming was, according to Diamond (1997, 205), a "bonanza for our microbes." Thus, whereas hunter-gatherer groups fell prey to basic parasitic-type infections and a narrow range of bacterial diseases, their plant pharmacopoeias were unlikely to have been influenced by acute pandemics—smallpox, measles, mumps, cholera, diphtheria, whooping cough, and influenza—diseases that could have been sustained only in large and dense human populations (Black 1980; Mascie-Taylor 1993; Waguespack 2002). Interpreting prehistoric foraging health conditions from contemporary groups must be done cautiously. Nevertheless, this healthy forager profile[14] is supported by medical studies among modern-day hunter-gatherers, including Kalahari bushmen (Kent and Dunn 1996), Australian aborigines (Lee 1996; P. Smith and Smith 1999), Philippine foragers (Early and Headland 1998, 98–118), and Malaysian Penan (Zulueta 1956).

Because isolation is a primary determinant in the spread of many infectious diseases, the range of illness experienced by remote forest societies is instructive. The Amazonian Waorani, for example, are hunter-horticulturalists that were only recently contacted by Westerners.

Exhibiting a nearly complete absence of infectious disease, this group reported only six health problems—fungal infections, snakebite, dental problems, fevers, warble fly larvae, and insect stings (Davis and Yost 1983). Similar observations were made among recently contacted groups in New Guinea. The principal illnesses treated by plant medicines were external lesions, magical spells, ear and tooth pain, cough, and eye inflammation. "Highlanders" according to Telban (1988, 152) "in general are poor herbalists." A similarly limited array of ailments is reported by the Penan of Brunei. Prior to settlement, they note that their only health issues were stomach ache, coughs, eye infection, snake bites, superficial wounds, and skin problems (Voeks and Sercombe 2000). Daily life of foraging groups was fraught with physical risks that threatened life and limb, but infectious disease seems not to have been one of them. As a result of low population densities, lack of domesticated animals, nomadic lifestyles, and relative isolation, groups that based their subsistence on hunting and gathering seem to have avoided the panoply of diseases that affected settled groups. Accordingly, hunting and gathering societies failed to develop extensive plant pharmacopoeias for what ailed them, in large measure because not much ailed them.

The transition from foraging to cultivating in the moist tropical realm was accompanied by a host of social, biomedical, and environmental changes. No longer choosing to simply extract nature's products, tropical forest societies increasingly manipulated the forest to meet their subsistence needs. As fire, stone axes, and digging sticks increasingly pushed back the primary forest frontier, human isolation diminished, populations grew, and disease vectors increasingly took hold. The impacts of these changes in terms of depth and breadth of plant pharmacopoeias were considerable.

Anthropogenic Nature and Ethnobotanical Knowledge

Preindustrial cultivating societies dramatically reformulated their tropical forest habitats. Indeed, indigenous and other traditional groups are viewed more and more as complementary, or even necessary, components of landscape-level biodiversity and vegetation patterns (Denevan 1992; Balée 1994, 135–38). Most importantly, forest management, whether of a shifting or more permanent variety, multiplied by orders of magnitude the extent and duration of natural disturbance regimes. The continued discovery of anthropogenic black earth, brown earth, mounds, ridges, canals, fish weirs, orchard-gardens, terraces, and other locally and regionally significant pre-Columbian landscape features testifies to the antiquity and omnipresence of these impacts (N. Smith 1980; Gómez-Pompa, Flores, and Sosa 1987; Woods and McCann 1999; Erickson 2000; Lentz 2000; T. M. Whitmore and Turner 2001; Denevan 2002). The ubiquity of villages, abandoned camps, trails, swiddens, dooryard gardens, and early and old-growth fallows among contemporary groups points to the continuing importance of these actions. Posey (1984), for example, discussed the range of habitat manipulation regimes imposed by Brazil's Kayapó. Recently abandoned fallows produce sweet potatoes, yams, bananas, and other foods for many years, whereas older fallows become sources of medicine, thatch, timber and fruits, the latter both for human consumption and to attract game. Transplanting of useful wild species in swiddens and along trails, sparing valuable trees during clearing, and other forms of encouragement further modify species composition and distribution. Native and exotic ruderals flourish wherever sunlight reaches the soil. Given the pedigree and spatial extent of these human impacts, the distinction between fallow and forest, virgin and disturbed, anthropogenic and natural, in the end seems rather arbitrary (Bennett 1992; Ellen 1998).

The biocultural shift from mostly old-growth forests occupied by foragers to anthropogenic landscapes managed by cultivators caused major changes in disease profiles and the pharmacopoeias used to treat them. Because the daily comings and goings of cultivating folk are concentrated in disturbed habitats, the opportunities for medicinal plant identification and collection were magnified exponentially. This is because, notwithstanding hunting forays and extraction from old-growth forests of highly visible products, such as fruits, nuts, fibers, and timber, tropical forest cultivators are most familiar with the habitats that they have created. In the dooryard gardens, swiddens, short fallow sites, and the network of trails connecting each, people are constantly engaged with the humanized flora—grains, tubers, fruits, nuts, medicinals, ornamentals, spices, and weeds. This familiarity continues during early stages of swidden succession, as annuals and short-lived perennials (grasses, ferns, herbs) yield to shrubs and small trees (e.g., *Cecropia*, *Macaranga*, Melastomataceae, Rubiaceae, Solanaceae). Compared to old-growth forest, these patches maintain relatively low species diversity[15] and emphasize leaf growth and investment over woody biomass accumulation (Guariguata and Ostertag 2001). These are the species and life forms with which forest folk most come in contact. They play among them as children; they toil among them as adults.

It is this anthropogenic nature, the everyday, encountered world of rural cultivating people, that is most salient, most familiar, and most accessible (Brown 1985; Logan and Dixon 1994; Voeks 1996b). It is the subset of the environment that is most likely to be learned and to be codified. It is salient because the disturbed flora enters most into life's daily rituals—weeding, planting, collecting, recreating. Contrary to the bewildering biological diversity encountered in old-growth forests, disturbed areas are floristically simpler and thus easier to apprehend. Disturbance species, cultivated and wild, are encountered many thousands of times, by individuals and by groups, thus permitting repeated opportunities for observation, recognition, lexical codification, and experimentation. Paz y Mino, Baslev, and Valencia (1995) report, for example, that the old-growth forest lianas that are most often used by people are also the most common and conspicuous. Rare lianas with particular high-use value, such as the hallucinogenic yaje (*Banisteriopsis caapi*), are so scarce in the wild that they are cultivated in dooryard gardens. Moreover, because disturbance species are so much a part of the known landscape, they are easy to locate when needed. Gardens and trails and swiddens are close at hand; old-growth forest is less so. And, because recently disturbed areas are usually dominated by low-growing species, such as herbs, shrubs, climbers, and treelets, useful plants are relatively simple to collect. As I have been told by more than one healer, "Why walk off into the forest when so many medicinal options grow immediately at hand?" But do disturbance species actually enter into tropical pharmacopoeias?

Disturbance Pharmacopoeias

Contrary to impressions transmitted by the media and environmental entrepreneurs, tropical pharmacopoeias are largely products of human disturbance regimes, ongoing and ancient. Old-growth tropical forests represent cornucopias of wild foods, fibers, fuels, and other useful primary products, but they are less consequential as sources of healing plants. For these services, traditional forest people turn to crops, weeds, kitchen garden transplants, and other products of their own invention.

The Medicinal Value of Cultigens and Weeds

There is an enduring relationship between tropical food plants and medicinal therapy, one that goes well beyond the understanding that adequate nutrition sustains a person's health. In their review of the importance of edibles in the evolution of traditional medicine, Logan and Dixon (1994, 36) argue that food plants represent the flora with which people are most familiar. And because these species are ingested, their effects can be trusted. "Random experimentation," they assert, "had little to do with the acquisition of plant-based knowledge." Tropical kitchen gardens and swiddens are notoriously rich in crop varieties, and many of these enter into medicinal recipes. Among African Hausa, Etkin and Ross (1991) reported that 49 percent of medicines taken for gastrointestinal disorders are used also as foods. In Vietnam, Ogle et al. (2003) found that one-third of censused wild food plants maintained perceived therapeutic properties. For many traditional societies, now and in the past, food is medicine, and medicine is food (Johns 1996).

This connection between eating and healing is likely as old as the process of plant domestication. For ancient Assyrians, Greeks, and Chinese, cultivated grains, roots, fruits, and spices were employed frequently in the curing arts. In Pharaonic Egypt, for example, lettuce, sesame, onions, leeks, cucumbers, plums, watermelon, and many other edibles were included in the healer's arsenal (Manniche 1989). Accordingly, the purposeful globalization of food plants during the European Age of Exploration must be viewed not only as an exercise in esculent diffusion, but also as an unintentional but highly effective effort to enrich healing habitats throughout the tropical realm. Coeval with and responsive to the viral pandemics that accompanied the spread of Europeans into the Americas, medicinal food crops must have been rapidly assimilated into indigenous healing ceremonies as shamans worked frantically to aid the afflicted. The impact of these colonial plant introductions is plainly evident in present-day tropical pharmacopoeias. Bennett and Prance (2000) report, for example, that 216 plants employed as medicinals in northern South America are exotics, and that 88 of these were originally introduced as food plants.

Outside of crop plants, no life form owes its biogeography more to the actions of humans than weeds. Short-lived, fast-growing, easily dispersed, and usually herbaceous, weeds are almost entirely dependent upon the effects of human disturbance (Baker 1965). A formidable pest for gardeners and farmers, ruderals nevertheless have a history of usefulness to Western pharmacology and to traditional healing practices (see Henkel 1904). They are often abundant, near at hand, easy to harvest, and they are frequently rich in bioactive compounds. Weeds are ideal medicinal plants, and they are amply represented in contemporary tropical healing floras (Stepp and Moerman 2001). Consider the lowly English plantain (*Plantago major*). Millennia before its association with human disturbance, plantain was a tenacious European pioneer that quickly colonized ground laid bare by retreating Pleistocene glaciers. Its application to treat wounds was noted 2,000 years ago in Dioscorides's *Material Medica*, and in medieval Europe plantain was recognized as both a garden pest and a medicinal herb with "extraordinary virtues" (Stannard 1972, 466). Plantain was apparently introduced into North America for its medicinal properties; it shortly became known among New England Native Americans as the "English-man's foot" reflecting its prodigious invasiveness (Crosby 1994, 38). Notwithstanding its propensity for waif dispersal, plantain does not compete well in moist tropical climates. By the early seventeenth century, it had been purposely introduced and was being cultivated for it healing properties in India and Brazil (Sousa 1971, 169–72). Now ranked as one of the world's worst weeds (Holm et al. 1977), this common weed enters into traditional pharmacopoeias throughout the temperate and tropical worlds.

A review of the literature on contemporary tropical pharmacopoeias underscores the primacy of disturbance regimes (Table 2). I include only studies that report the habitat sources of medicinal species, quantitatively test for the significance of successional and cultivated species, or at least refer to their relative importance. Ethnobotanical studies that purposely exclude weeds and cultivars from their census, fail to sample a range of habitats (usually focused on old-growth forest), or do not mention the successional status of medicinal plants are excluded. With few exceptions, these studies highlight the overwhelming importance of "secondary forest," "cultivated plants," "invasives," "successional habitats," "accessible plants," "herbaceous," "managed landscapes,"

Table 2. Habitat and Successional Status of Tropical Medicinal Plants

Borneo (Brunei)	The majority (79%) of medicinal species inhabit disturbed habitats, especially secondary forests.	Voeks and Nyawa 2001.
Borneo (Indonesia)	Healers focused on primary rather than secondary forest. Community medicinal plant knowledge, however, is focused on early successional habitats. Disturbed habitats yield 227 medicinal taxa, compared to 42 (or 103) from primary forest.	Caniago and Siebert 1998.
Brazil (Atlantic Forest)	In quantitative comparison, second-growth forest plots retained 2.7 times more medicinal plant species than old-growth plots.	Voeks 1996b.
Brazil (Atlantic Forest)	Of 227 identified medicinal species, 44% are introduced and 18% are invasives.	Begossi, Hamzaki, and Tamashiro 2002.
Costa Rica	Plot-based census showed that medicinal species richness was significantly higher in the second-growth forest than in old-growth forest.	Chazdon and Coe 1999.
Ecuador	Half of the local medicinal flora inhabited kitchen gardens and successional forest.	Kohn 1993.
Hawaii	Most favored medicinal plants "were ones that were familiar to them, of easy reach among their cultivated food plants . . . and some of those that we would currently label as weeds," p. 213.	Abbott and Shimazu 1985.
India	Medicinal plant census reveals 70% herbaceous, 16% shrubs, 7% climbers, and 6% trees.	Balasingh et al. 2000.
Kenya	Healers report that deforestation is eliminating their "medicinal herbs," p. 55.	Jungerius 1998.
Mexico	Kitchen garden medicinals are most important to the Yucatec Mayans.	Ankli, Sticher, and Heinrich 1999.
Mexico	Most important medicinal species in local pharmacopoeias are "widely distributed ruderal species and [those that are] easily accessible to the local human population," p. 131.	Berlin et al. 1999.
Mexico	Majority of Zapotec and Mixe medicinals from managed habitats; primary and secondary forest relatively unimportant.	Frei, Sticher, and Heinrich 2000.
Mexico	In Mixe community, herbs represent the most prominent medicinal life form.	Heinrich and Barerra 1993.
Mexico	Percentage of weedy medicinal plants is significantly higher than random selection would indicate.	Stepp and Moerman 2001.
Mexico	Medicinals are associated with secondary forest; timber and other extractive products are concentrated in primary forests.	Toledo et al. 1992.
Nicaragua	About 50% of the alkaloid-bearing medicinal plants employed are herbaceous; only 28% are trees.	Coe and Anderson 1996.
Thailand	Majority of medicinal taxa inhabit managed as opposed to wild landscapes.	Kunstadter 1978.
Vietnam	A significant number of medicinals are cultivated or occur in highly disturbed sites, but the most important medicinals are found in species-diverse, undisturbed forest.	On et al. 2001.

"kitchen gardens," and "weeds" (Toledo et al. 1992; Heinrich and Barerra 1993; Voeks 1996b; Ankli, Sticher, and Heinrich 1999; Berlin et al. 1999; Chazdon and Coe 1999; Stepp and Moreman 2001; Begossi, Hanazaki, and Tamashiro 2002). Compared to humanized tropical landscapes, old-growth forest represents a relatively minor source of folk medicinal plants.

Chemical Defense in Successional Habitats

Tropical folk healers focus their attention on disturbance habitats not only because they are familiar and accessible, but also because they are rich sources of biologically active secondary compounds. A brief review of plant defense theory suggests why this is the case. Returning to Levin's (1976) global alkaloid census, he discerned not only a latitudinal cline in secondary metabolites, but also that plants exhibiting annual life cycles are twice as likely to employ alkaloid defense systems as are perennials. In North America, for example, annuals averaged 32.9 percent alkaloid presence, compared to only 17.1 percent in trees. Moreover, Coley, Bryant, and Chapin (1985) report that fast-growing plants rely more on alkaloid defense systems than primary forest species (see also Coley and Barone 1996). The possible explanation for this phenomenon involves the dynamics of plant-predation interactions. As originally postulated by Feeny (1976) and Rhoades and Cates (1976), plant response to herbivory varies between qualitative (chemical) and quantitative (structural) strategies. Chemical defenses involve metabolically inexpensive tracks (i.e. small toxic molecules), such as alkaloids and phenols, whereas quantitative defenses involve more expensive structural attributes (large molecules), such as tannins, cellulose, and lignin. Because long-lived forest trees are more apparent to predators and are the focus of specialist predation, they should concentrate their avoidance efforts on expensive quantitative strategies. Short-lived successional species are less apparent to predators, so they direct their defense mostly at generalist predators and opt for qualitative defenses (Waterman and McKey 1989; Abe and Higashi 1991). Alkaloids are highly effective against generalist herbivores, but are not particularly successful against specialist feeders. In this vein, Gentry (1993) predicted that rainforest vines focus on chemical rather than structural defense because they are less visible to predators than old-growth trees. Hegarty, Hegarty, and Gentry (1991) further suggested that plants with greater surface-to-volume ratios, such as herbs and shrubs, are likely to maintain the highest concentrations of defensive compounds (see also Hazlett and Sawyer 1998). However, a recent comprehensive study by Coley et al. (2003) indicates that shade tolerant species (canopy) maintain more secondary compounds than disturbance (gap) species, not less, as the previously noted studies predict. Downum et al. (2001), likewise, notes that the number of secondary compounds present in mature rainforest tree leaves is much greater than in sapling's leaves. Coley et al. (2003) also found, however, that young leaves are particularly well defended, chemically rather than structurally, regardless of their successional stage. Thus, although the results of these studies appear to conflict, they suggest, at least, that there is a high probability of encountering pharmacologically active plants in anthropogenic successional mosaics.

Finally, a brief review of tropical medicinals that have successfully transitioned from the field to the pharmacy highlights the prevalence of cultivated and disturbance species. A prime example is provided by the Madagascar periwinkle (*Catharanthus roseus*). The discovery of the efficacy of two of its seventy-six alkaloids—vincristine and vinblastine—in the treatment of acute lymphoblastic leukemia, lymphosarcoma, Hodgkin's disease, and other tumors, was a catalyst for renewed pharmacological interest in plant medicines. The incentive to explore the medicinal properties of this taxon was provided by a native healer, who recommended its use to treat diabetes (Balick and Cox 1996, 33). Often cited by environmentalists as an exemplar of the necessity to preserve old-growth tropical forests, the Madagascar periwinkle is nonetheless never a component of primary habitats. It is a pantropical weed and ornamental, most often encountered growing along a forest trail, eking out an existence from a crack in the sidewalk, or being cultivated for its showy flowers. Reviewing the list of drugs that are derived from tropical plants tells a similar story (Soejarto and Farnsworth 1989). Most are weedy herbs, shrubs, climbers, garden cultigens, or common trees. The glaucoma alkaloid pilocarpine, derived from *Pilocarpus jaborandi*, is a ubiquitous Brazilian herb or shrub. The digestive drug papain, derived from papaya fruits (*Carica papaya*), is a widespread trash-heap cultivar. The anti-Parkinson drug L-Dopa, derived from the *Mucuna deeringiana*, is a common leguminous climber. The antimalarial alkaloid quinine is derived from Andean *Cinchona* spp. trees, which are treefall gap species (K. Young, personal communication, 18 November 2003). The original source of the contraceptive diosgenin is *Dioscorea alata*, an invasive weed of the southern U.S. And in an article titled "From the shaman to the clinic," a virologist reports on the anti-HIV properties exhibited by *Momordica charantia*, the bitter melon (Kell 2001). Widespread as a garden vegetable and escaped weed throughout the tropical world, and universally included in folk pharmacopoeias, this plant exemplifies the medicinal importance of humanized landscapes.

Conclusion

The magnitude of medicinal plant knowledge sustained by tropical forest groups has varied significantly over time in response to social and environmental changes. When foraging for food represented their primary livelihood, forest societies were relatively free of the infectious diseases that would eventually plague their cultivating descendants and later their neighbors. In response, hunting and gathering groups developed neither extensive medicinal plant portfolios nor complex systems of etiology and treatment. The transition from foraging to farming, with consequent community settlement, concentration of waste products, and expanding population numbers, fostered the introduction and spread of acute crowd diseases. Their sporadic eruption and devastating impact likely encouraged an intensified search for healing plants, a pursuit greatly facilitated by the patchwork of successional seres they created and managed. Crops, ornamentals, ruderals, and the assemblage of wild successional species, rich in pharmacologically active secondary metabolites, highly accessible and intimately familiar, presented a cornucopia of prospective medicinal candidates. The result was a florescence in healing plant knowledge—most retained in the collective pharmacopoeia, some ensconced in the memories of specialized healers. Contrary to the rhetorical motif presented by some environmentalists, old-growth tropical forests are not likely to have served as the primary repositories of folk medicinals in the past, and they do not at the present.

Five centuries ago, European settlers and physicians engaged in a classic quest to uncover tropical nature's healing secrets. Encouraged by ancient beliefs regarding the mysteries of the equatorial latitudes, driven by a panoply of pathogens they themselves were scattering, and motivated by the prospect of fantastic profits, they tapped the trees of knowledge sustained by native healers and shamans in these newly encountered worlds. Although their efforts to solve the worst of their medical ills were mostly in vain, they succeeded at least in dispersing a share of their healing plants to distant points of the tropical compass. As a consequence of this floristic homogenization, intentional and accidental, rural tropical societies found their endemic arsenals of medicinal agents enhanced many times over by new medicinal foods, ornamentals, and weeds. European colonists also sustained and transferred to future generations the notion that the torrid zone and its mysterious inhabitants retain remedies for society's pressing medical dilemmas. Bolstered today by the legitimacy of science, a host of largely self-induced medical maladies, and the prospect of formidable financial returns, the descendants of European colonizers accept, almost without criticism, the preconceptions of their medieval ancestors. Once again, we are drawn to the tangled and mysterious forest primeval in search of its hidden medical secrets. It is as if we keep our Middle Ages medical views tucked away in our subconscious, ready to leap to the forefront with the slightest provocation (Nuland 2000). The major distinction between current bioprospecting enterprises and those carried out centuries ago is the presence of environmental issue entrepreneurs and their receptive audience. Employing the rainforest medicine narrative as a linchpin in their preservationist agenda, they have emerged as influential and uncritical advocates of the pristine myth.

For colonial explorers and latter day ethnopharmacologists, traditional rural healers were and continue to be viewed as living conduits of ancient forest wisdom, flesh and blood receptacles of the secrets won of thousands of years of trial and error experimentation. For rural tropical societies, then and now, the perception is quite different. Confronted with countless tropical maladies, some the result of poor hygiene and inadequate nutrition, they apply the orally transmitted ethnomedical traditions inherited from their parents and grandparents. Most therapies minister to everyday medical ills, sometimes of spiritual or magical origin, but others are drawn upon in desperate attempts to treat life-threatening disease. Informal discussions on this topic with elders illustrate not only the richness of their ethnomedical knowledge, but also their consistent inability to cure grave illness episodes. We can romanticize at length about the miraculous cures maintained in the rainforest, but we must also reconcile our enthusiasm with poignant stories of the lives of so many rural children and adults cut short by the ravages of infectious disease. While Westerners increasingly sing the praises of tropical folk medicine, tempered by the galenical notion that nature heals the medical torments it has wrought, they ignore the reality of how often traditional societies are powerless to cope with most diseases.

The rainforest medicine narrative nevertheless achieves its near universal acceptance for reasons that may owe more to psychology than to either biology or pharmacology. As Taussig (1987) notes, there is a considerable pedigree to the belief that marginalized societies are somehow closer to nature, and thus better equipped to reveal its secrets. However backward many of their rituals may be perceived, shamans are also seen as touchstones for the vitalist energy of nature that we in the industrialized world have lost. We seem desperately to "need" to believe that the cures for what ails us, medical and otherwise, are somehow concealed in the occult workings of nature. This ancient theme, portraying a synergistic harmony between man and nature, resonates with regard to the medicinal power of plants, which are envisioned as material channels through which the spiritual forces of nature can be brought to bear. Such archaic notions simmer latently for generations, emerging periodically during medical or spiritual crises, only to be buried again when they fail to fulfill their promises. Fed by science and nurtured by long-dormant concepts, the rainforest medicinal issue has grown for many into an article of pure faith.

The search for rainforest cures has been felt in the developing world as well. The much-publicized charge that lucrative miracle medicines are being pilfered from tropical forests and their indigenous societies is being portrayed as the latest chapter in a lengthy history of neocolonial exploitation. Ethnobotanists have been perhaps too effective in spreading the gospel of rainforest medicine. Bioprospecting narratives are being quickly replaced by biopiracy narratives. Tropical governments pass legislation to assert their sovereign rights over biological resources, while temperate-zone interests race to establish rules of reciprocity and principles of precaution (see Rosenthal et al. 1999; Bannister and Barrett 2001; Artuso 2002). At the same time, the rainforest medicine story is forcing indigenous societies to redefine themselves as the guardians of nature's healing secrets. Brosius (1997) describes how resistance on the part of the Penan to prevent logging in their customary lands was adopted by environmental entities and became part of the international discourse on protection of biodiversity and indigenous rights. The ethnographic texts produced by researchers and temporary visitors rapidly transformed the foundations of Penan indigenous plant knowledge to the point that they now tout the value of medicinal species that were actually taught to them by outsiders. The Penan in the past were familiar with few medicinal plants, and these were employed only to treat a narrow range of illness (Voeks and Sercombe 2000). After continued contact with ethnobotanists and environmentalists, these forest foragers now provide nearly "nonstop commentary on the value of medicinal plants" (Brosius 1997, 62).

This article's arguments for the validity of disturbance pharmacopoeias, and the case against romanticized concepts of pristine nature and culture in the humid tropics, do not diminish the fact that the rainforest medicine narrative has served, at the very least, to publicize the regional and global consequences of destructive forest exploitation and the accompanying rural poverty and injustices faced by tropical peoples. The weedy periwinkle, the miracle drug plant of the 1970s, has come to represent a poster child, however misguided, for conservation and potential sustainability of humid tropical forests. As such, it has dramatically raised awareness among temperate-zone people with little tangible connection to the equatorial latitudes, or interest in tropical ethnobotany or equitable distribution of benefits. Environmental concern for rainforest medicinal plants and folk healers thus may translate somehow to more informed policies with regard to forest management and human rights for equitable development and cultural justice. Recognizing the natural and cultural roles of disturbance pharmacopoeias will be an important foundation of these more informed policies.

Acknowledgments

I wish to thank my many collaborators in Brazil and Borneo, especially the healers and the healed, who contributed significantly to the ideas I present here. I also thank the three anonymous reviewers, whose suggestions for improvement were insightful and valuable. Funding for field work was provided by grants from the National Geographic Society (7820–02), a National Endowment for the Humanities Summer Stipend, a Fulbright Research Fellowship to Brazil, and several Faculty Research Grants from California State University, Fullerton.

Notes

1. The *Material Medica* saw at least seventy-eight separate European editions during the sixteenth century (Stannard 1999).
2. This quest was fueled in part by ancient determinist beliefs regarding torrid-zone nature and culture. The hot and humid climates of Africa and Asia may have hobbled cultural development, but these same landscapes were also fonts of crucial medicinal imports—aloe, camphor, cinnamon, ginger, clove, and many others (Glacken 1967; J. I. Miller 1969).
3. Guaiacum was the first plant species of New World origin to be reported in Europe (Shaw 1992, 17). Native to the Antilles and southern Florida, this medicinal was being touted by 1510 as the principal weapon against syphilis, which appeared in Europe soon after Columbus's first voyage.
4. For reviews of other important nonmedicinal extractive resources, see Dean 1995; Cleary 2001.
5. This likely reflects long-standing notions regarding the Dark Continent as an intellectual backwater, and African ethnobotanical traditions as too mired in witchcraft and the

occult to be of practical medicinal benefit (Jarosz 1992; Carney and Voeks 2003).

6. The humoral doctrine, which continues to be applied in folk medical systems (E. Anderson 1987; Voeks 1995), holds that health problems are minimized by the individual establishing a state of equilibrium with the principal elements—earth, wind, water, and fire—as well as their states of environmental opposition—hot and cold, or wet and dry (Glacken 1967, 9–12; Jouanna 1998).
7. Because these include all plant-derived compounds, the dollar value of tropical medicinals would be some fraction of these figures.
8. In a subsequent publication, Mendelsohn and Balick (1997) revised the dollar value to drug companies down to zero, noting that "undiscovered drugs have little market value because they are expensive to find" (p. 328). Nevertheless, the value to society of unknown drug plants, they estimate, is still roughly US$109 billion.
9. The random testing of yew bark (*Taxus brevifolia*) in Oregon in the 1960s as part of the National Cancer Institute's plant screening program, and its eventual development into the powerful anticancer treatment taxol in the 1990s, represents a notable exception (Walsh and Goodman 1999).
10. See for example: Paul Cox, *Nafanua: Saving the Samoan rainforest*; Norman Myers, *The primary source: Tropical forests and our future*; and Mark Plotkin, *Tales of a shaman's apprentice*.
11. Ethnobotanists working in the tropical realm often adopt the 1-hectare plot census methodology in order to standardize their results. Because alpha diversity is too high to measure all the plant species, researchers normally include only trees and lianas that are 10 cm in diameter-at-breast-height or greater. Remaining lifeforms—herbs, shrubs, treelets, and most vines—are excluded from their censuses (see Balee 1986; Galeano 2000).
12. Forager subsistence in tropical forests, according to the "wild yam hypothesis," would have been possible only if carbohydrates could be acquired from neighboring sedentary cultivators (Hoffman 1986; Headland 1987; Bailey et al. 1989; Cormier 2003). Purely foraging societies could only have permanently occupied the forest after the entrance of cultivators. Recent research suggests, however, that late Pleistocene/early Holocene foraging predated horticulture by several millennia in most tropical forest biomes (Piperno and Pearsall 1998; Meggers and Miller 2003; Mercader 2003).
13. Among the valid criticisms of Brown's results was that many of the small-scale cultivators in his inventory inhabit speciose tropical regions, but most of the hunter-gatherer records are for groups occupying species-poor temperate zone habitats (Bulmer 1985; Headland 1985).
14. Healthy hunter-gatherer profiles are also attributed to high levels of physical activity, intake of fiber-rich foods, and low triglyceride levels (see M. Miller 1999; Milton 2000). These are not relevant to this discussion, however, because these properties are shared by small-scale cultivators.
15. This is not to suggest that second-growth forest sites are not species rich. As Guariguata and Ostertag (2001) note, overall woody plant richness can approach that of old-growth forest in a few decades (see also Voeks 1996a). However, because the size of individual trees in second-growth forest is usually smaller, their number per unit area is higher than in old-growth sites.

References

Abbot, I. A., and C. Shimazu. 1985. The geographic origin of the plants most commonly used for medicine by Hawaiians. *Journal of Ethnopharmacology* 14:213–22.

Abe, T., and M. Higashi. 1991. Cellulose centered perspective on terrestrial community structure. *Oikos* 60:127–33.

Acosta, José de. [1604] 1970. *The natural & moral history of the Indies* (Trans. E. Grimston). Vol. 61 (2). The Hakluyt Society. New York: Burt Franklin.

Adger, W. N., K. Brown, R. Cervigini, and D. Moran. 1995. Total economic value of forests in Mexico. *Ambio* 24: 286–96.

Alcorn, J. B. 1984. *Huastec Mayan ethnobotany*. Austin: University of Texas Press.

Allemão, Francisco Freire. 1856. Quaes são as principaes plantas que hoje se acham aclimatadas no Brasil? (What are the main plants found today that are acclimated to Brazil?). *Revista do Instituto Histórico e Geográfico Brasileiro* XIX: 539–78.

Almeida, Luis F. de. 1975. Aclimatação de plantas do oriente no Brasil durante os séculos XVII e XVIII (Acclimation of plants from the east in Brazil during the XVII and XVIII centuries.) *Revista Portuguesa da História* 15:339–481.

Anderson, Anthony. 1983. *The biology of Orbignya martiana (Palmae), a tropical dry forest dominant in Brazil.* Ph.D. dissertation, University of Florida, Gainesville.

Anderson, E. 1987. Why is humoral medicine so popular? *Social Science & Medicine* 25:331–37.

Ankli, A., O. Sticher, and M. Heinrich. 1999. Medical ethnobotany of the Yucatec Maya: Healers consensus as a quantitative criterion. *Economic Botany* 53:144–60.

Anon. 1993. New in the botanical book of records: Highest tree diversity in the world. *Field Notes from the New York Botanical Garden* 2:1–2.

Anyinam, C. 1995. Ecology and ethnomedicine: Exploring links between current environmental crisis and indigenous medical practices. *Social Science & Medicine* 40:321–29.

Artuso, A. 2002. Bioprospecting, benefit sharing, and biotechnological capacity building. *World Development* 30:1355–68.

Bailey, Robert C., G. Head, M. Jenike, B. Owen, R. Rechtman, and E. Zechenter. 1989. Hunting and gathering in tropical rain forest: Is it possible? *American Anthropologist* 91:59–82.

Baker, Herbert G. 1965. Characteristics and modes of origin of weeds. In *The genetics of colonizing species*, ed. H. G. Baker and G. L. Stebbins, 147–72. New York: Academic.

Balasingh, J., P. Thiruchelthil, B. Jerlin, A. Samuel, and A. Muthukumar. 2000. Medicinal flora of a tropical scrub jungle. *Journal of Economic and Taxonomic Botany* 24:737–45.

Balée, William. 1994. *Footprints of the forest: Ka'apor ethnobotany—The historical ecology of plant utilization by an Amazonian people*. New York: Columbia University Press.

———. 1999. Mode of production and ethnobotanical vocabulary: A controlled comparison of Guajá and Ka'apor. In *Ethnoecology: Knowledge, resources, and rights*, ed. T. L. Gragson and B. G. Blount, 24–40. Athens: University of Georgia Press.

Balick, Michael J. 1990. Ethnobotany and the identification of therapeutic agents from the rainforest. In *Bioactive compounds from plants*, ed. D. J. Chadwick and J. Marsh, 21–31. Chichester, U.K.: Wiley.

Balick, Michael J., and Paul A. Cox. 1994. The ethnobotanical approach to drug discovery. *Scientific American* 270:82–7.

———. 1996. *Plants, people, and culture: The science of ethnobotany*. New York: Scientific Publications.

Balick, Michael J., E. Elisabetsky, and S. Laird, eds. 1996. *Medicinal resources of the tropical rainforest: Biodiversity and its importance to human health*. New York: Columbia University Press.

Bannister, K., and K. Barrett. 2001. Changing the status quo in ethnobotany. *Cultural Survival Quarterly* 24:10–13.

Bedoya, L., S. Sanchez-Palomino, M. Abad, P. Bermejo, and J. Alcami. 2001. Anti-HIV activity of medicinal plant extracts. *Journal of Ethnopharmacology* 77:113–6.

Begossi, A., N. Hanazaki, and J. Tamashiro. 2002. Medicinal plants in the Atlantic Forest (Brazil): Knowledge, use, and conservation. *Human Ecology* 30:281–99.

Bennett, B. C. 1992. Plants and people of the Amazonian rainforests. *BioScience* 42:599–607.

Bennett, B. C., and G. Prance. 2000. Introduced plants in the indigenous pharmacopoeias of northern South America. *Economic Botany* 54:90–102.

Benz, F. F., E. Cevallos, M. F. Santana, A. Rosales, and M. Graf. 2000. Losing knowledge about plant use in the Sierra de Manantlan Biosphere Reserve, Mexico. *Economic Botany* 54:183–91.

Berlin, Brent. 1992. *Ethnobiological classification: Principles of categorization of plants and animals in traditional societies*. Princeton, NJ: Princeton University Press.

Berlin, Brent, E. A. Berlin, J. Ugalde, L. G. Barrios, D. Puett, R. Nash, and R. González-Espinoza. 1999. The Maya ICBG: Drug discovery, medical ethnobotany, and alternative forms of economic development in the highland Maya region in Chiapas, Mexico. *Pharmaceutical Biology* 37:127–44.

Black, R. L. 1980. Modern isolated pre-agricultural populations as a source of information on prehistoric patterns. In *Changing disease patterns and human behaviour*, ed. N. F. Stanley and R. A. Joske, 37–54. London: Academic.

Brosius, J. Peter. 1991. Foraging in tropical rain forests: The case of the Penan of Sarawak, East Malaysia. *Human Ecology* 19:123–50.

———. 1997. Endangered forest, endangered people: Environmental representations of indigenous knowledge. *Human Ecology* 25:47–69.

Brown, Cecil H. 1985. Mode of subsistence and folk biological taxonomy. *Current Anthropology* 26:43–53.

Bulmer, R. 1985. Comments. *Current Anthropology* 26:54–55.

Caniago, I., and S. F. Siebert. 1998. Medicinal plant ecology, knowledge and conservation in Kalimantan, Indonesia. *Economic Botany* 52:229–50.

Cardim, F. [1584] 1939. *Tratados da terra e gente do Brasil*, (Treatise on the land and people of Brazil). São Paulo: np.

Carney, Judith, and Robert Voeks. 2003. Landscape legacies of the African diaspora. *Progress in Human Geography* 27: 68–81.

Castree, N. 2003. Bioprospecting: From theory to practice (and back again). *Transactions of the Institute of British Geographers* 28:35–55.

Chazdon, Robin, and F. G. Coe. 1999. Ethnobotany of woody species in second-growth, old-growth, and selectively logged forests of northeastern Costa Rica. *Conservation Biology* 13:1312–22.

Clayton, N. 2003. Weeds, people, and contested places. *Environment and History* 9:301–31.

Cleary, D. 2001. Towards an environmental history of the Amazon: From prehistory to the nineteenth century. *Latin American Research Review* 36:65–96.

Coley, Phyllis D., and T. M. Aide. 1991. Comparison of herbivory and plant defenses in temperate and tropical broadleaved forests. In *Plant-animal interactions: Evolutionary ecology in tropical and temperate regions*, ed. P. W. Price, T. M. Lewinsohn, G. W. Fernandes, and W. W. Benson, 25–49. New York: Wiley.

Coley, Phyllis D., and J. A. Barone. 1996. Herbivory and plant defenses in tropical forests. *Annual Review of Ecology and Systematics* 27:305–35.

Coley, Phyllis D., J. P. Bryant, and F. S. Chapin. 1985. Resource availability and plant anti-herbivore defense. *Science* 230:895–99.

Coley, Phyllis D., M. Heller, R. Aizprua, B. Araúz, N. Flores, M. Correa, M. Gupta, P. Solis, E. Ortega-Barría, L. Romero, B. Gómez, M. Ramos, L. Cubilla-Rios, T. Capson, and T. Kursar. 2003. Using ecological criteria to design plant collection strategies for drug discovery. *Frontiers in Ecology and the Environment* 1:421–28.

Cormier, Loretta A. 2003. *Kinship with monkeys: The Guajá foragers of Eastern Amazonia*. New York: Columbia University Press.

Cox, Paul A. 1999. *Nafanua: Saving the Samoan rain forest*. New York: W. H. Freeman.

———. 2000. Will tribal knowledge survive the millennium? *Science* 287:44–45.

Cox, Paul A., L. R. Sperry, M. Tuominen, and L. Bohlin. 1989. Pharmacological activity of the Samoan ethnopharmacopoeia. *Economic Botany* 43:487–97.

Cronk, Q., and J. Fuller. 2001. *Plant invaders: The threat to natural ecosystems*. London: Earthscan.

Crosby, Alfred W. 1993. *Ecological imperialism: The biological expansion of Europe, 900–1900*. Cambridge, U.K.: Cambridge University Press.

———. 1994. *Germs, seeds, and animals: Studies in ecological history*. Armonk, NY: Sharpe.

Dalby, Andrew. 2000. *Dangerous tastes: The story of spices*. Berkeley, CA: University of California Press.

Davis, E. Wade, and J. A. Yost. 1983. The ethnomedicine of the Waorani of Amazonian Ecuador. *Journal of Ethnopharmacology* 9:273–97.

Dean, Warren. 1995. *With broadax and firebrand: The destruction of the Brazilian Atlantic forest*. Berkeley: University of California Press.

Denevan, William M. 1992. The pristine myth: The landscape of the Americas in 1492. *Annals of the Association of American Geographers* 82:369–85.

———. 2002. *Cultivated landscapes of native Amazonia and the Andes*. Oxford, U.K.: Oxford University Press.

Diamond, Jared. 1997. *Guns, germs, and steel: The fate of human societies*. New York: W. W. Norton.

Downum, K., D. Lee, F. Hallé, M. Quirke, and N. Towers. 2001. Plant secondary compounds in the canopy and understory of a tropical rain forest in Gabon. *Journal of Tropical Ecology* 17:477–81.

Dufault, R., R. Hassell, J. Rushing, G. McCutcheon, M. Shepard, and A. Keinath. 2000. Revival of herbalism and its roots in medicine. *Journal of Agromedicine* 7:21–29.

Early, J., and T. Headland. 1998. *Population dynamics of a Philippine rain forest people: The San Ildefonso Agta*. Gainesville: University of Florida Press.

Ellen, Roy F. 1998. Indigenous knowledge of the rainforest: Perception, extraction, and conservation. In *Human activities and the tropical rainforest: Past, present, and possible future*, ed. B. Maloney, 87–99. Dordrech: Kluwer.

———. 1999. Modes of subsistence and ethnobotanical knowledge: Between extraction and cultivation in Southeast Asia. In *Folkbiology*, ed. D. L. Medin and S. Atran, 91–117. Cambridge, MA: MIT Press.

Erickson, Clark L. 2000. An artificial landscape-scale fishery in the Bolivian Amazon. *Nature* 408:190–93.

Etkin, Nina, and P. Ross. 1991. Should we set a place for diet in ethnopharmacology? *Journal of Ethnopharmacology* 32: 25–36.

Farnsworth, Norman. 1988. Screening plants for new medicines. In *Biodiversity*, ed. E. O. Wilson, 83–97. Washington, DC: National Academy Press.

Feeny, P. 1976. Plant apparency and chemical defense. *Recent Advances in Phytochemistry* 10:1–40.

Frampton, John. 1580. *Joyfull newes out of the new found world* (Translation of N. Monardes). London: William Norton.

Frei, B., O. Sticher, and M. Heinrich. 2000. Zapotec and Mixe use of tropical habitats for securing medicinal plants in Mexico. *Economic Botany* 54:73–81.

Frei Vicente do Salvador. [1627] 1931. *Historia do Brasil*, 1500–1627. São Paulo: Melhoramentos.

Galeano, G. 2000. Forest use at the Pacific Coast of Chocó, Colombia: A quantitative approach. *Economic Botany* 54:358–76.

Garcia da, Orta. [1563] 1891. *Coloquis dos simples, drogas e coisas medicinais da India* (Conversations on Indian simples, drugs, and medicinal items), ed. Conde de Ficalho. Lisbon: Imprensa Nacional.

Gentry, Alwyn H. 1993. Tropical forest biodiversity and the potential for new medicinal plants. In *Human medicinal agents from plants*, ed. A. D. Kinghorn and M. F. Balandrin, 13–24. Washington, DC: American Chemical Society.

Glacken, Clarence. 1967. *Traces on the Rhodian shore: Nature and culture in western thought from ancient times to the end of the eighteenth century*. Berkeley: University of California Press.

Gómez-Pompa, Arturo, J. Salvador Flores, and V. Sosa. 1987. The "pet kot": A man-made forest of the Maya. *Interciencia* 12:10–15.

Gómez-Pompa, Arturo, and A. Kaus. 1992. Taming the wilderness myth. *BioScience* 42:271–79.

Grauds, C. 1997. Jungle medicine. *Pharmacy Times* 63:44–48.

Grove, Richard H. 1996. *Green imperialism: Colonial expansion, tropical island Edens and the origins of environmentalism, 1600–1860*. Cambridge, U.K.: Cambridge University Press.

Guariguata, M. R., and R. Ostertag. 2001. Neotropical secondary forest succession: Changes in structural and functional characteristics. *Forest Ecology and Management* 148:185–206.

Harris, David R. 1996. Domesticatory relationships of people, plants and animals. In *Redefining nature: Ecology, culture and domestication*, ed. R. Ellen and K. Fukui, 437–63. Oxford, U.K.: Berg.

Hazlett, D. L., and N. W. Sawyer. 1998. Distribution of alkaloid-rich plant species in shortgrass steppe vegetation. *Conservation Biology* 12:1260–68.

Headland, Thomas N. 1985. Comments. *Current Anthropology* 26:57–58.

———. 1987. The wild yam question: How well could independent hunter-gatherers live in a tropical rain forest ecosystem? *Human Ecology* 15:463–91.

Heckenberger, Michael, A. Kuikuro, U. T. Kuikuro, C. Russell, M. Schmidt, C. Fausto, and B. Franchetto. 2003. Amazonia 1492: Pristine forest or cultural parkland? *Science* 301:1710–14.

Hegarty, M. P., E. E. Hegarty, and A. H. Gentry. 1991. Secondary compounds in vines with emphasis on those with defensive functions. In *The biology of vines*, ed. F. E. Putz and H. A. Mooney, 287–310. Cambridge, U.K.: Cambridge University Press.

Heilmann, J., and R. Bauer. 1999. New medical applications of plant secondary metabilites. In *Functions of plant secondary metabolites and their exploitation in biotechnology*, ed. M. Wink, 274–310. Sheffield, U.K.: Academic Press.

Heinrich, M., and N. A. Barerra. 1993. Medicinal plants in a lowland Mixe Indian Community (Oaxaca, Mexico): Management of important resources. *Angewandte Botanik* 67:141–44.

Hemming, John. 1978. *Red gold: The conquest of the Brazilian Indians, 1500–1760*. Cambridge, MA: Harvard University Press.

Henkel, A. 1904. Weeds used in medicine. *USDA Farmers Bulletin* No. 188, Washington, DC: Government Printing Office.

Hoffman, Carl. 1986. *The Punan: Hunters and gatherers of Borneo*. Ames: Iowa State University Press.

Holm, L. G., D. L. Plucknett, J. V. Pancho, and J. P. Herberger. 1977. *The world's worst weeds: Distribution and biology*. Honolulu: University Press of Hawaii.

Jarosz, Lucy. 1992. Constructing the dark continent: Metaphor as geographic representation in Africa. *Geografiska Annaler* 74:105–15.

Johns, Timothy. 1996. *The origins of human diet and medicine*. Tucson: University of Arizona Press.

Jouanna, J. 1998. The birth of Western medical art. In *Western medical thoughts from antiquity to the Middle Ages*, ed. M. Grmek, 22–71. Cambridge, MA: Harvard University Press.

Joyce, Christopher. 1994. *Earthly goods: Medicine hunting in the rainforest*. Boston: Little, Brown, and Co.

Jungerius, P. D. 1998. Indigenous knowledge of landscape-ecological zones among traditional herbalists: A case study in Keiyo District, Kenya. *GeoJournal* 44:51–60.

Kell, B. 2001. From the shamen to the clinic: The role of ethnobotany in antiviral research. *International Antiviral News* 9:123–24.

Kent, S., and D. Dunn. 1996. Anemia and the transition of nomadic hunter-gatherers to a sedentary life-style: Follow-up study of a Kalahari community. *American Journal of Physical Anthropology* 99:455–72.

Kohn, E. O. 1993. Some observations on the use of medicinal plants from primary and secondary growth by the Runa of eastern lowland Ecuador. *Journal of Ethnobiology* 12:141–52.

Kunstadter, Peter. 1978. Ecological modification and adaptation: An ethnobotanical view of Lua' swiddeners in northwestern Thailand. In *The nature and status of ethnobotany*, ed. R. I. Ford, 168–200. Ann Arbor: University of Michigan Museum of Anthropology.

Lapa, José Roberto do Amaral. 1966. O Brasil e as drogas do oriente (Brazil and the eastern drugs). *Studia* 18:7–40.

Leaman, D., and U. Schippmann. 1998. Medicinal plants: An unhealthy outlook. *World Conservation* 29:16–17.

Lebbie, A., and R. Guries. 1995. Ethnobotanical value and conservation of sacred groves of the Kpaa Mende in Sierra Leone. *Economic Botany* 49:297–308.

Lee, A. 1996. The transition of Australian aboriginal diet and nutritional health. *World Review of Nutrition and Diet* 79: 1–52.

Leite, Serafim. [1945] 2000. *História da companhia de Jesus no Brasil* (History of the Jesuits in Brazil). Vol. 5. Belo Horizonte: Editora Itatiaia.

Lentz, David L. ed. 2000. *Imperfect balance: Landscape transformations in the Precolumbian Americas*. New York: Columbia University Press.

Leonti, M., O. Sticher, and M. Heinrich. 2003. Antiquity of medicinal plant usage in two Macro-Mayan ethnic groups (Mexico). *Journal of Ethnopharmacology* 88:119–24.

Levin, Donald A. 1976. Alkaloid-bearing plants: An ecogeographic perspective. *The American Naturalist* 110:261–84.

Lewis, W. H. 2003. Pharmaceutical discoveries based on ethnomedicinal plants: 1985 to 2000 and beyond. *Economic Botany* 57:126–34.

Lizarralde, M. 2001. Biodiversity and loss of indigenous languages and knowledge in South America. In *On biocultural diversity: Linking language, knowledge and the environment*, ed. L. Maffi, 265–81. Washington, DC: Smithsonian Institute Press.

Logan, M. H., and A. R. Dixon. 1994. Agriculture and the acquisition of medicinal plant knowledge. In *Eating on the wild side: The pharmacologic, ecologic, and social implications of using noncultigens*, ed. N. L. Etkin, 25–45. Tucson: University of Arizona Press.

Lovell, W. George. 1992. Heavy shadows and black night: Disease and depopulation in colonial Spanish America. *Annals of the Association of American Geographers* 82:426–43.

Mander, M. 1998. *Marketing of indigenous medicinal plants in South Africa: A case study in Kwazulu-Natal*. Rome: FAO.

Mann, John. 2000. *Murder, magic and medicine*. Oxford, U.K.: Oxford University Press.

Manniche, Lise. 1989. *An ancient Egyptian herbal*. Austin: University of Texas Press.

Marques, V. R. B. 1999. *Natureza em boiões: Medicinais e boticários no Brasil setecentista* (Nature in Jars: Medicines and Pharmacies of 18th century Brazil). Campinas, Brazil: Unicamp.

Mascie-Taylor, C. 1993. The biological anthropology of disease. In *The anthropology of disease*, ed. C. Mascie-Taylor, 1–72. Oxford, U.K.: Oxford University Press.

McAfee, Kathleen. 1999. Selling nature to save it? Biodiversity and green development. *Society & Space* 17:133–54.

Meggers, Betty, and E. T. Miller. 2003. Hunter-gatherers in Amazonia during the Pleistocene-Holocene transition. In *Under the canopy: The archaeology of tropical rain forests*, ed. J. Mercader, 291–316. New Brunswick, NJ: Rutgers University Press.

Mendelsohn, Robert, and Michael Balick. 1995. The value of undiscovered pharmaceuticals in tropical forests. *Economic Botany* 49:223–28.

———. 1997. Valuing undiscovered pharmaceuticals in tropical forests. *Economic Botany* 51:328.

Mercader, J. 2003. Introduction: The paleolithic settlement of rain forests. In *Under the canopy: The archaeology of tropical rain forests*, ed. J. Mercader, 1–31. New Brunswick, NJ: Rutgers University Press.

Miller, J. I. 1969. *The spice trade of the Roman Empire: 29 B.C. to A.D. 641*. Oxford, U.K.: Clarendon.

Miller, M. 1999. The epidemiology of triglyceride as a coronary artery disease factor. *Clinical Cardiology* 22 (Suppl): 1–6.

Milliken, W., R. P. Miller, S. R. Pollard, and E. V. Wandelli. 1992. *The ethnobotany of the Waimiri Atroari Indians of Brazil*. Kew, U.K.: Royal Botanical Gardens.

Milton, K. 2000. Hunter-gatherer diets—A different perspective. *American Journal of Clinical Nutrition* 71:665–67.

Myers, Norman. 1984. *The primary source: Tropical forests and our future*. New York: W. W. Morton.

———. 1997. Biodiversity's genetic library. In *Nature's Services*, ed. G. C. Daily, 255–73. Washington, DC: Island Press.

Nieto Olarte, M. 2000. *Remedios para el imperio: Historia natural y la apropiación del nuevo mundo* (Medicine for the empire: Natural history and exploitation of the New World). Bogata: La Imprensa Nacional de Colombia.

Nóbrega, Padre Manuel da. 1886. Cartas do Brasil do Padre Manuel da Nóbrega (1549–1560). *Materiais e achêgas para a história e geografia do Brasil* (Materials and supplements to the history and geography of Brazil), No.1. Rio de Janeiro: Imprensa Nacional.

Nuland, Sherwin. W. 2000. *The mysteries within: A surgeon reflects on medical myths*. New York: Simon and Schuster.

Ogle, B. M., H. T. Tuyet, H. N. Duyet, and N. Dung. 2003. Food, feed or medicine: The multiple functions of edible wild plants in Vietnam. *Economic Botany* 57:103–17.

On, T. V., D. Quyen, L. D. Bich, B. Jones, J. Wunder, and J. Russell-Smith. 2001. A survey of medicinal plants in BaVi National Park, Vietnam: Methodology and implications for conservation and sustainable use. *Biological Conservation* 97:295–304.

Pandey, A., and A. Bisaria. 1998. Rational utilization of important medicinal plants: A tool for conservation. *The Indian Forester* 124:197–202.

Parry, J. W. 1953. *The story of spices*. New York: Chemical Publishing.

Parsons, James J. 1970. The "Africanization" of the New World tropical grasslands. *Tübinger Geographische Studien* 34: 141–53.

Paz y Mino, C., H. Balslev, and R. Valencia. 1995. Useful lianas of the Siona-Secoya Indians from Amazonian Ecuador. *Economic Botany* 49:269–75.

Phillips, O., and A. H. Gentry. 1993. The useful plants of Tambopata, Peru: II. Additional hypothesis testing in quantitative ethnobotany. *Economic Botany* 47:33–43.

Pina, Luis de. 1946. Flora e fauna Brasílicas nos antigos livros médicos portugueses (Brazilian flora and fauna in old Portuguese medical books). *Brasília* 3:149–340.

Piperno, Delores, and Deborah Pearsall. 1998. *The origins of agriculture in the lowland neotropics*. San Diego, CA: Academic.

Piso, Guilherme. [1648] 1957. (Translation by Mario Lobo Leal) *História natural e médica da Índia Occidental* (Natural and medical history of the West Indies). São Paulo: Editora Nacional.

Pitman, N., and P. Jorgensen. 2002. Estimating the size of the world's threatened flora. *Science* 298:989.

Plotkin, Mark. 1993. *Tales of a shaman's apprentice: An ethnobotanist searches for new medicines in the Amazon rainforest*. New York: Viking.

———. 2000. *Medicine quest: In search of nature's healing secrets*. New York: Viking.

Posey, Darrell. 1984. A preliminary report on diversified management of tropical forests by Kyapó Indians of the Brazilian Amazon. *Advances in Economic Botany* 1:112–26.

Principe, P. P. 1991. Valuing the biodiversity of medicinal plants. In *Conservation of medicinal plants*, ed. O. Akerele,

V. Heywood, and H. Synge, 79–124. Cambridge, U.K.: Cambridge University Press.

———. 1996. Monetizing the pharmacological benefits of plants. In *Medicinal resources of the tropical forest: Biodiversity and its importance to human health*, ed. M. J. Balick, E. Elisabetsky, and S. Laird, 191–218. New York: Columbia University Press.

Pui, C., and W. Evans. 1998. Acute lymphoblastic leukemia. *New England Journal of Medicine* 339:605–15.

Puri, Raj K. 1997. Penan Benalui knowledge and use of tree palms. In *People and plants of Kayan Mentarang*, 195–226. Jakarta: WWF Indonesia/UNESCO.

———. Forthcoming. Post-abandonment ecology of Penan forest camps: Anthropological and ethnobotanical approaches to the history of a rainforested valley in East Kalimantan. In *Biodiversity and society in Southeast Asia*, ed. M. R. Dove, P. Sajise, and A. Doolittle. New Haven, CT: Yale University Press.

Raffles, Hugh. 2002. *In Amazonia: A natural history*. Princeton, NJ: Princeton University Press.

Rambo, A. T. 1985. *Primitive polluters: Semang impact on the Malaysian tropical rain forest ecosystem*, Anthropological Papers, Museum of Anthropology 76, Ann Arbor: University of Michigan.

Rhoades, D., and R. Cates.. 1976. Toward a general theory of plant antiherbivore chemistry. In *Biochemical interactions between plants and insects*, ed. J. W. Wallace and R. L. Mansell, 168–213. New York: Plenum Press.

Rival, Laura M. 2002. *Trekking through history: The Huaorani of Amazonian Ecuador*. New York: Columbia University Press.

Roosevelt, Anna M., C. Lima da Costa, Lopes Machado, M. Michab, N. Mercier, H. Valladas, J. Feathers, W. Barnett, M. Imazio da Silveira, A. Henderson, J. Sliva, B. Chernoff, D. Reese, J. Holman, N. Toth, and K. Schick. 1996. Paleoindian cave dwellers in the Amazon: The peopling of the Americas. *Science* 272:373–84.

Rosenthal, J. P., et al. (22 authors). 1999. Combining high risk science with ambitious social and economic goals. *Pharmaceutical Biology* 37:6–21.

Rousseau, Jerome. 1990. *Central Borneo: Ethnic identity and social life in a stratified society*. Oxford, U.K.: Clarendon Press.

Sauer, Carl O. 1963. Man in the ecology of tropical America. In *Land and life: A selection from the writings of Carl Ortwin Sauer*, ed. John Leighly, 182–93. Berkeley: University of California Press.

Schultes, Richard E., and Robert F. Raffauf. 1990. *The healing forest: Medicinal and toxic plants of the Northwest Amazonia*. Portland, OR: Dioscorides Press.

Shaw, Elizabeth. 1992. *Plants of the New World: The first 150 years*. Cambridge, MA: Harvard College Library.

Sheil, D., and D. Burslem. 2003. Disturbing hypotheses in tropical forests. *Trends in Ecology and Evolution* 18:18–26.

Simoons, Frederick J. 1998. *Plants of life: Plants of death*. Madison, I: University of Wisconsin Press.

Smith, Nigel. 1980. Anthrosols and human carrying capacity in Amazonia. *Annals of the Association of American Geographers* 70:553–66.

Smith, P., and R. Smith. 1999. Diets in transition: Hunter-gatherers to station diet to the self-select store diet. *Human Ecology* 27:115–34.

Soares, F. [1594?] 1966. *Coisas notáveis do Brasil*. (Noteworthy things from Brazil), Vol. 1 (prepared by A. G. Cunha). Rio de Janeiro: Instituto Nacional do Livro.

Soejarto, D. D., and N. R. Farnsworth. 1989. Tropical rain forests: Potential source of new drugs? *Perspectives in Biology and Medicine* 32:244–56.

Sousa, Gabriel S. de [1587] 1971. *Tratado descritivo do Brasil em 1587* (Treatise on Brazil in 1587). 4th edition. São Paulo: Editora Nacional.

Souza, Custódio Dias de. 24 October, 1787. Letter. Brazilian National Library Archives (Rio): ms, I-32, 34, 046.

Stannard, Jerry. 1972. Greco-Roman materia medica in medieval Germany. *Bulletin of the History of Medicine* 46:455–68.

———. 1999. Dioscorides and renaissance materia medica. In *Herbs and herbalism in the Middle Ages and Renaissance*, ed. K. Stannard and R. Kay, 1–21. Brookfield, VT: Ashgate.

Steinberg, Michael. 2002. The second conquest: Religious conversion and the erosion of the cultural ecological core among the Mopan Maya. *Journal of Cultural Geography* 20:91–105.

Stepp, J. R., and D. E. Moerman. 2001. The importance of weeds in ethnopharmacology. *Journal of Ethnopharmacology* 75:19–23.

Stewart, K. M. 2003. The African cherry (*Prunus africana*): Can lessons be learned from an over-exploited medicinal tree? *Journal of Ethnopharmacology* 89:3–13.

Sumner, Judith. 2000. *The natural history of medicinal plants*. Portland, OR: Timber Press.

Taussig, Michael. 1987. *Shamanism, colonialism, and the wild man: A study in terror and healing*. Chicago: University of Chicago Press.

Telban, B. 1988. The role of medical ethnobotany in ethnomedicine: A New Guinea example. *Journal of Ethnobiology* 8:149–69.

Thompson, R. Campbell. 1908. *Semitic magic: Its origins and development*. London: Luzac.

Toledo, V. M., A. I. Batis, R. Becerra, M. Esteban, and C. H. Ramos. 1992. Products from the tropical rain forests of Mexico: An ethnoecological approach. In *Sustainable harvest and marketing of rain forest products*, ed. M. Plotkin and L. Famolare, 99–109. Washington, DC: Island Press.

Ugent, Donald. 2000. Medicine, myths and magic: The folk healers of a Mexican market. *Economic Botany* 54: 427–38.

Varnhagen, F. A. de. 1843. Martim Affonso de Souza. *Instituto Histórico e Geográfico Brasileiro* 5:248–56.

Veith, Ilza. 2002. *Huang Ti Nei Ching Su Wên: The yellow emperor's classic of internal medicine*. Berkeley: University of California Press.

Voeks, Robert A. 1995. Candomblé ethnobotany: African medicinal plant classification in Brazil. *Journal of Ethnobiology* 15:257–80.

———. 1996a. Extraction and tropical rain forest conservation in eastern Brazil. In *Tropical rainforest research–current issues*, ed. D. Edwards, W. Booth, and S. Choy, 477–87. Netherlands: Kluwer.

———. 1996b. Tropical forest healers and habitat preference. *Economic Botany* 50:354–73.

———. 1997. *Sacred leaves of Candomblé: African magic, medicine, and religion in Brazil*. Austin: University of Texas Press.

———. 1998. Environmental risk and ethnobotanical knowledge: Foragers and farmers in northern Borneo. In *Nature's geography: New lessons for conservation in developing countries*, ed. K. Zimmerer and K. Young, 307–26. Madison: University of Wisconsin Press.

———. 2002. Reproductive ecology of the piassava palm (*Attalea funifera* Mart.) of Bahia, Brazil. *Journal of Tropical Ecology* 18:121–36.

———. Forthcoming. Subsistence strategy and breadth of ethnobotanical knowledge. In *Borneo's hunter-gatherers in the 21st century: Peering from the shadows.*, ed. P. Sercombe and B. Sellato. Copenhagen: Nordic Institute of Asian Studies.

Voeks, Robert A., and Angela Leony. Forthcoming. Forgetting the forest: Assessing medicinal plant erosion in eastern Brazil. *Economic Botany.*

Voeks, Robert A., and Samhan Nyawa. 2001. Healing flora of the Brunei Dusun. *Borneo Research Bulletin* 32:178–95.

Voeks, Robert A., and Peter Sercombe. 2000. The scope of hunter-gatherer ethnomedicine. *Social Science & Medicine* 50:1–12.

Waguespack, N. 2002. Colonization of the Americas: Disease ecology and the Paleoindian lifestyle. *Human Ecology* 30:227–43.

Walsh, V., and J. Goodman. 1999. Cancer chemotherapy, biodiversity, public and private property: The case of the anticancer drug taxol. *Social Science & Medicine* 49:1215–25.

Waterman, P. G., and D. McKey. 1989. Herbivory and secondary compounds in rain-forest. In *Ecosystems of the world: Tropical rain forest ecosystems*, ed. H. Lieth and M. J. A. Werger, 513–36. Amsterdam: Elsevier.

Whitmore, Timothy C. 1998. *An introduction to tropical rain forests.* 2nd ed. Oxford, U.K.: Oxford University Press.

Whitmore, Thomas M., and B. L. Turner II. 2001. *Cultivated landscapes of Middle America on the eve of conquest.* Oxford, U.K.: Oxford University Press.

Wink, Michael. 1998. A short history of alkaloids. In *Alkaloids: Biochemistry, ecology, and medicinal applications*, ed. M. Roberts and M. Wink, 11–44. New York: Plenum.

Wink, Michael, and O. Schimmer. 1999. Modes of action of defensive secondary metabolites. In *Functions of plant secondary metabolites and their exploitation in biotechnology*, ed. M. Wink, 17–133. Sheffield, U.K.: Academic Press.

Woods, W., and J. McCann. 1999. The anthropogenic origin and persistence of Amazonian dark earths. *Yearbook, Conference of Latin Americanist Geographers* 25:7–14.

Xavier, Carlos. 1977. Plantas indiáticas no Brasil (East Indian plants in Brazil). *Instituto Histórico e Geográfico Brasileiro* 314:45–50.

Zimmerer, Karl S. 2002. Report on geography and the new ethnobiology. *Geographical Review* 91:725–34.

Zimmerer, Karl S., and Ken Young. 1998. *Nature's geography: New lessons for conservation in developing countries.* Madison: University of Wisconsin Press.

Zulueta, J. 1956. Malaria in Sarawak and Brunei. *Bulletin, World Health Organization* 15:651–71.

Correspondence: Department of Geography, California State University, Fullerton, CA 92831, e-mail: rvoeks@exchange.fullerton.edu.