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Traditional Ecological Knowledge and Practice for Edible Wild Plants: Biodiversity Use by the Rarámuri in the Sierra Tarahumara, Mexico

Serge LaRochelle and Fikret Berkes

Natural Resources Institute, University of Manitoba, Winnipeg, Canada

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SUMMARY

The Rarámuri who live in the Sierra Tarahumara of Chihuahua State, Mexico have developed local knowledge and harvesting strategies for edible wild plants that have the effect of conserving the biodiversity of their forest ecosystem. This paper presents the results of ethnobotanical research undertaken in the community of Basíhuare in the Sierra Tarahumara, to provide details on some practical aspects of the Rarámuri worldview regarding interconnections between people and their environment. This traditional philosophy forms the basis for the use of edible wild plants and the harvesting strategies practiced in Basíhuare, such as selective harvesting, environmental modification and domestication. These activities provide the opportunity for harvesters to monitor the landscape and the plant resources that occur on the land, as well as present a setting for the communication and exchange of traditional ecological knowledge. However, Rarámuri harvesting practices are under stress because of increased external pressures from commercial timber extraction and other development. We discuss the state of traditional ecological knowledge and its transmission in the context of development activities in the region. The key to sustainability in the Sierra Tarahumara may be the maintenance of traditional management practices for edible wild plants, and other non-timber forest products, that lead to the conservation of biodiversity by creating patchiness and renewing the plant cover on the land.

INTRODUCTION

> 'Ninety percent of the time we enter a stand, we clear-cut it'
>
> (John Pastor, Third North American Forest Ecology Workshop, Duluth MN, June 2001)

'We' in the quotation refers to the Western industrialized world. However, there is another 'world', that of forest-dwelling indigenous peoples, in which most of the time when people enter a stand, they harvest non-timber forest products such as fruits, nuts, medicinal plants and edible greens. There are sustainability implications in the way forest biodiversity is treated by these two fundamentally different strategies. Some indigenous groups make their livelihoods from non-timber forest products and

Correspondence: S. LaRochelle, Natural Resources Institute, University of Manitoba, 70 Dysart Road, Winnipeg, Manitoba, R3T 2N2, Canada. e-mail: monsieur@mts.net

live in biologically diverse forest regions. It is known that a diversity of local and traditional management practices for forest ecosystem management, including those for succession and for landscape patchiness management, exist (Berkes *et al.*, 2000).

Some indigenous groups are said to possess local and traditional ecological knowledge, developed through generations of interactions with natural forested areas (Brookfield and Padoch, 1994; Turner *et al.*, 2000; Davidson-Hunt and Berkes, 2001). As noted by several authors, including Posey (1999) and Kimmerer (2000), the importance of traditional ecological knowledge in the conservation of biodiversity has been identified by the United Nations Convention on Biological Diversity, which calls for the recognition and protection of traditional knowledge. As outlined in Article 8 of the Convention, member states agree to:

> '. . . respect, preserve and maintain knowledge, innovations and practices of indigenous and local communities embodying traditional lifestyles relevant for the conservation and sustainable use of biological diversity and promote their wider application with the approval and involvement of the holders of such knowledge, innovations and practices and encourage the equitable sharing of the benefits arising from the utilization of such knowledge, innovations and practices' (UNEP, 2000).

Several definitions of traditional ecological knowledge exist, including those by Hunn (1993), Purcell (1998) and Kimmerer (2000). We define traditional ecological knowledge as the cumulative body of knowledge, practice, and belief, evolving by adapting processes and handed down through generations by cultural transmission (Berkes, 1999: 8), and we use the framework of Turner *et al.* (2000) for its analysis. Ethnobotanical research on traditional ecological knowledge relating to non-timber forest products (NTFPs) has made important contributions to the study of biodiversity conservation (Peters, 1994; Turner, 1995). Strategies and practices for harvesting NTFPs, including edible plants, comprise an important aspect of such research because they explore the importance of using a diversity of resources to generate multifunctional landscapes (Gadgil *et al.*, 1993; Anderson, 1996; Posey, 1999). The Rarámuri people, who inhabit the Sierra Tarahumara of northwestern Mexico, are one of the groups whose livelihood activities include the harvesting of edible wild plants (Bye, 1995; Salmon, 2000a). A survey commissioned by the National Public Health Institute of Mexico reported that Rarámuri woman identified wild plants as an important source of nutrition especially for young children (Monarrez Espino and Martinez Salgado, 1996). Also, several cultivated and wild species of *Amaranthus* are used throughout Mexico for their high nutritional value (Wesche-Ebeling *et al.*, 1995).

The present research was undertaken in the predominately Rarámuri community of Basíhuare, in the State of Chihuahua, Mexico. The objective of the research was to analyse traditional ecological knowledge and practices of Rarámuri harvesters, applicable to the sustainable use of edible wild plants and relevant to biodiversity conservation in general.

The paper begins with an explanation of the participatory research methods and provides a description of the study area. Research results pertaining to the Rarámuri knowledge of edible wild plants are then presented and evaluated, following the traditional ecological knowledge framework of Turner *et al.* (2000) which uses the themes, philosophy and worldview; practices and strategies for sustainable living; and communication and exchange of knowledge. Each of these themes is the subject of a section of the paper. The status of traditional ecological knowledge in Basíhuare, in light of relatively recent developments that have occurred in the region, is examined in the discussion section.

RESEARCH METHODS AND STUDY AREA

Partnering with the Basíhuare community in a participatory research paradigm

Traditional ecological knowledge research projects need to be participatory in nature, with the community becoming a partner in the cooperative process of knowledge creation and sharing, rather than merely being the object of research (Martin, 1995; Berkes, 1999; Cunningham, 2001). Thus, to conduct research in the predominantly indigenous community of Basíhuare, we built a research framework that

respected the needs and objectives of the local community.

Once the members of the community had discussed the project at a community meeting and agreed to participate in it, a partnership was struck between the researcher, the community of Basíhuare, the local secondary school (Secundaria Técnica Intercultural Cruz Rarámuri), and Mexico-North Research Network, a regional non-governmental organization. The first task of the partnership was to agree on research objectives and study methods. The project used ethnobotanical research methodology, which is the study of the interactions between people and plants (Martin, 1995). Photographic samples were taken of edible wild plants found in the area, and were used in the identification of local names and uses by research participants. Specimens of edible wild plant species were also collected and identified by botanists from the Universidad Autónoma de Chihuahua in Chihuahua City.

The field research involved a number of activities considered to be part of the participatory rural appraisal approach (Chambers, 1994). With help from the main research facilitator, stories, beliefs and explanations related to edible wild plants were shared by research participants from the community, through semi-structured interviews and transect walks. Focus group discussions (Morgan, 1988) were held with students from the secondary school in Basíhuare, and with other youths from the community. These discussions were designed to explore youth impressions regarding the importance of using and conserving edible wild plants.

The applied component of the project involved working on traditional ecological knowledge communication with students from the Secundaria Técnica Intercultural Cruz Rarámuri, which was a key partner for the project because it is the only secondary school in the State of Chihuahua to offer an intercultural education programme. The project outputs included the preparation of an educational CD-ROM to provide a georeferenced multimedia resource for the secondary school. The CD-ROM integrated digital video images and audio clips recorded by the students for this project, along with those recorded by the researcher. The overall research project was carried out in the context of the Project on Diversity in the Sierra Tarahumara, initiated by Mexico-North, with the goal of documenting and explor-ing the linkages between biological, cultural, and linguistic diversity in the region (Merrill, 2000).

The Sierra Tarahumara: A region of important biological and cultural diversity

The Sierra Tarahumara region of Mexico's northern Sierra Madre Occidental is characterized by a tremendous diversity of tropical, subtropical, and temperate flora and fauna, including a number of species found nowhere else in the world (Merrill, 2000). Some 1900 plant species occur in the Sierra Tarahumara region (Bye, 1995), 350 of which are used for food and medicine (Salmón, 2000a). The World Wildlife Fund designated the Sierra Madre Occidental as a Global 200 Ecoregion, defined as the world's major habitat types chosen for conservation because these regions foster outstanding examples of biodiversity (WWF, 2002). Furthermore, Mexico's National Commission for the Knowledge and Use of Biodiversity has identified six areas within the Sierra Tarahumara as priority terrestrial regions, designated as areas of significant ecological integrity (Arriaga *et al.*, 2000).

The Sierra Tarahumara is also an area of significant cultural diversity. Four aboriginal groups, of which the Rarámuri are most important, call the Sierra Tarahumara their home. The Rarámuri, one of the largest groups of native peoples in Mexico, have a total population of approximately 60 000 members. The Rarámuri people have a particular affinity to the forests and mountains of the Sierra Tarahumara, believing in the interconnectedness and integration of all physical and spiritual life (Salmón, 2000a). Rarámuri harvesters maintain a traditional subsistence relationship with forest resources, including wild plants, with which they view themselves as members of a natural community. The Rarámuri have developed over generations a knowledge base around the harvesting of plant resources, and have used wild plants in a manner that has been described as sustainable (Bye, 1995; Salmón, 2000b).

The recent history of mestizo immigration to the Sierra Tarahumara, begins with the Copper Canyon mineral exploration of the early 1900s (Zingg, 2001). This was followed by commercial forest operations in the mid-twentieth century,

bringing changes regarding land and resource use in the area. A major road through this section of the Sierra runs near the community of Basíhuare. This highway supports the increased flow of traffic from local people and tourists travelling to and from Creel, a commercial centre and a starting point for excursions throughout the Copper Canyon region.

The increased activity has impacted local ecological relations, and contributed to deforestation, soil erosion, and loss of understorey plants (Merrill, 2000). External demand for natural resources in the Sierra Tarahumara and the ensuing increase in trade has resulted in the depletion of some medicinal species (Davidson-Hunt, 2003), the loss of some traditional activities, and in the replacement of wild foods by store-bought foods. There is concern that such changes are threatening traditional ecological knowledge and the cultural integrity of the Rarámuri people (Merrill, 2000).

TRADITIONAL ECOLOGICAL KNOWLEDGE OF EDIBLE WILD PLANTS

Basíhuare is one community in the Sierra Tarahumara where edible plants constitute a portion of the usual dietary regime. Field observations indicated that edible wild plants are commonly harvested and consumed; for example, they were used as a secondary source of food in spring when household stocks of maize are low. Conversations with community members, men, women and youths, confirmed that wild plants are important as a source of regular nutrition. For example, one research participant described that 'it is only logical' to use edible wild plants, and that they are chosen as a food source for practical reasons. The participant explained that *kujubi (Cosmos* sp.*)* is harvested because it grows close to his home and provides nourishment and variety in his family's diet. This plant is also quicker to cook than beans, requiring less wood for the stove.

Research participants identified over 20 wild species of edible plants and described techniques to prepare these plants for consumption. Table 1 lists the edible wild plants that were identified in Basíhuare, and summarizes which parts are consumed and how they are prepared. All of the plants listed in Table 1 were photographed, and the names and preparation methods were identified and verified by research participants. Only those plants for which specimens were collected are identified to the species level.

The traditional ecological knowledge related to these plants was examined according to the framework of Turner *et al.* (2000). The framework categorizes traditional ecological knowledge within three broad themes: philosophy or worldview, practices and strategies for sustainable living, and communication and exchange of knowledge. Figure 1, adapted from Turner *et al.* (2000), illustrates this framework as may be applicable in the study area, and shows how these three themes are linked.

Figure 1 Themes and components of traditional ecological knowledge as applicable to the Rarámuri. Adapted from Turner *et al.* (2000)

Table 1 Edible wild plants and preparation methods in Basíhuare

Rarámuri name	*Common English and Latin names*	*Plant part and preparation method*
Amáwali	Wild dahlia *Dahlia* sp, Asteraceae	Root: skin is removed and eaten raw or mixed with chillies in a salsa
Basoli	Amaranth *Amaranthus hybridus*, Amaranthaceae	Leaves and shoot: new plant boiled, pounded and fried with onions
Chawi	– *Agave* sp. Agavaceae	Heart: cooked in earth-pit oven and pounded; juice mixed into *Tesguïno* (corn beverage)
Cibóa	Wild onion *Allium rizomatum*, Liliaceae	Stalk: new, steamed or mixed with water Bulb: mature, boiled or fried
Ilá	Prickly pear *Opuntia* sp. Cactaceae	Pads: new, spines removed and boiled, served with onions & tomatoes Fruit: mature, eaten raw
Kóchi'nakara	Milkweed *Asclepia latifolia*, Asclepiadaceae	Leaves and shoots: new, boiled
Kotó	Amaranth *Amaranthus* sp. Amaranthaceae	Leaves and shoots: new, boiled and fried with onions and tomatoes
Kuíchala	Manzanilla *Arctostaphylos* sp. Ericaceae	Fruit: new, raw or mature, mixed with water
Kujúbi	Cosmos *Cosmos* sp. Asteraceae	Leaves and shoots: boiled or mixed with water
Mekwásare	Wild mustard *Brassica* sp. Brassicaceae	Leaves and shoots: new, boiled
Mesagóli	Century plant *Agave* sp. Agavaceae	Heart baked in earth-pit oven and eaten, or pounded and mixed with *Tesguïno.* Stem: new, skin removed and baked
Napá	Oregano *Moranda citrioodora*, Lamiaceae	Leaves and shoot: new, boiled or dried and mixed into soups
Okowí Chupíkare	Mushroom –	All: fried
Okowí Ripomi	White water mushroom –	Cap, minus skin and stem: fried
Okowí Sawaroáme	Yellow mushroom –	Cap, minus stem: fried
Okowí Sitakame	Water mushroom –	Cap, minus stem: fried
Rolokochi	Plantain *Plantago purshii*, Plantaginaceae	Leaves and stem: new, boiled and mixed with onions
Salabí	– *Prionosciadium* sp. Apiaceae	Root: after stem has dried, baked
Sipeke	– *Bidens* sp. Asteraceae	Leaves and shoots: new, boiled
Sowinalí	– *Eryngium heterophyllum*, Apiaceae	Leaves: new, boiled
Tomati	Husk tomato *Physallis wrightii*, Solanaceae	Fruit: mature, raw or boiled and served in salsa
Ulí	Wild grape *Vitis arizonica*, Vitaceae	Fruit: mature, raw
Ulúbisi	Madroño *Arbutus* sp. Ericaceae	Fruit: mature, raw

Given its holistic nature, traditional ecological knowledge is best discussed by considering the interconnections among its various components (Nabhan, 2000). The different elements of traditional knowledge are interrelated regardless of where they appear in the framework. For instance, worldview shapes perception of the landscape and fosters the understanding of ecological processes and the implementation of harvesting strategies. The results of continuous observation of the landscape, or monitoring, are fed into traditions and stories. The organization of the paper follows the three themes, beginning with philosophy and worldview.

PHILOSOPHY AND WORLDVIEW

Philosophy and worldview themes of the Turner *et al.* (2000) model comprise several components that may be applicable in the Sierra Tarahumara. These aspects are discussed using results gathered from participant observation and interviews, and from secondary research of literature held at the 'Escuela Nacional de Antropología y Historia' (ENAH) in Chihuahua City.

Human–nature kinship and traditional ceremonies

The Rarámuri philosophy of humans interconnected with nature seemed to form the underlying principle of resource use. The worldview recognizes a kinship between humans and nature, such that natural resources are respected and cherished as providers of life and energy. As Salmón (2000b: 193) suggests, 'their knowledge of foods and medicinal plants embodies their relationship and, therefore, their model of self-identification with their place and their manner of using what nature has offered.'

The interconnectedness between humans and nature is embodied in customs and ceremonies. An example of how elements of the natural world are linked to humans is seen in a preventative curing ceremony, conducted by a Rarámuri doctor, or *Owiríame,* to promote the growth of livestock and crops and protect them from disease. One Rarámuri doctor in Basíhuare explained that plants did not require a special curing ceremony, but wild plants are used as medicines to 'cure' livestock and crops. During the ceremony, the *Owiríame* motions a sprig of *chuchupate (Ligusticum porteri)* toward crops and livestock and raises the plant to the sky as a way of conveying its protective qualities and recognizing that this plant, along with all other wild plants, were given to benefit the Rarámuri.

Landscape perception and understanding of ecological processes

In the Sierra Tarahumara, many Rarámuri place names relate to the natural environment, often describing physical traits of an area or referring to a natural event that occurred there (Brouzes, 1980). For example, *Basíhuare* is the name of the place where the mountain face resembles a woven belt, and *Rawárachi* is the place where certain birds build their nests among the manzanilla trees. Rarámuri also identified places according to the resources found there, such as where two streams meet and provide a source of water for washing and cooking (*Akíchi*), or an area where oak trees can be found (*Rohwárare*). Places are not named after people or to honour forefathers. As Burgess (1987: 83) recorded in a conversation with a Rarámuri in the Sierra Tarahumara, 'we have no right to name land after ourselves, as if we owned it'. Meaning in place names is drawn from the relationship between humans and the natural environment, and from a keen insight into natural processes on the land.

The Rarámuri worldview and ecological understanding differed from those of government resource managers, leading to a different set of decision-making tools and strategies. In Basíhuare, harvesters did not use maps or calculate maximum yields; nor did they have need for a harvesting schedule for edible plant resources. Local resource management decisions were based on a culturally embedded understanding of ecological processes, including an understanding of relationships in the local ecosystem. For example, members of the Basíhuare community did not need formal meetings to decide when to seed beans. The decision was based in effect on the rainy season and, more specifically, related to when a certain variety of the *ilá* (*Opuntia* sp.) plant began to flower.

Table 2 Food types and harvesting strategies of edible wild plants in Basíhuare. See Table 1 for common English and Latin names of plant species

		Harvesting strategies			
Type of food	*Rarámuri plant names*	*Selective harvesting*	*Pruning*	*Domestication (seeding or transplanting)*	*Environmental modification*
Fruits and berries	*Napó*	✓	✓		
	Kuíchala and Ulúbisi				
	Tomati	✓			✓
	Ulí	✓			
Mushrooms	*Okowi (Sitakame and Sawaroáme)*	✓			
Green leaves and shoots	*Basoli and Mekwásare*	✓		✓	
	Kóchi'nakara	✓			
	Kotó, Kujúbi, Napá Rolokochi and Sowinarí				
	Sipeke and Cibóa	✓			✓
Perennials (heart and stem)	*Ilá and Mesagóli*	✓	✓	✓	
	Chawí	✓			
Perennials (roots)	*Amáwali*	✓		✓	
	Cusalí and Salabí	✓			
	Cibóa	✓			✓

The harvesting practices were often based on detailed natural history and an understanding of when certain wild species were ready to be harvested. For example, the *okowi sawaroáme* mushroom reaches its maximum size in about 24 h and will only survive for approximately 5 days. This species of fungus is best consumed fresh, within 2 to 3 days of sprouting. To benefit from its flavour and nutritional value, harvesters knew when and where the mushroom would appear. The relationship between humans and nature, along with perceptions of the landscape and insight into ecological processes, leads to a number of practices specifically related to the harvest of edible wild plants, as further discussed in the next section.

PRACTICES AND STRATEGIES FOR SUSTAINABLE LIVING

The second theme in the traditional ecological knowledge framework of Turner *et al.* (2000) concerns practices and strategies for sustainable living. Beyond understanding ecological processes, Rarámuri harvesters are aware that human intervention can effect the health of local flora. Thus, strategies and practices have been developed over generations to harvest edible plants in a way that appears to be sustainable (Merrill, 2000). Table 2 lists edible plant harvesting strategies practiced in Basíhuare, under four headings: selective harvesting; pruning; domestication such as seeding and transplanting; and environmental modification.

Selective harvesting

Rarámuri harvesters did not articulate selective harvesting in terms of quantitative goals or harvest allowances. When asked about how much can be harvested, most research participants responded that the optimal quantity relates to what is truly needed. In the case of perennials, *ilá* for example, it was explained that harvesting too many pads would most likely adversely affect the health of the plant. Results of participant

observation indicated that harvesters, in fact, took only what can be consumed. Young pads were the most desirable portion of the plant because of their tenderness and taste; harvesters tended to collect only the pads and left the stock, or the meristem of the plant, intact. It is known that 'as long as plants maintain meristematic tissues and have the capacity to absorb sufficient nutrients and water, they can reproduce vegetatively and maintain individuals and populations even with a certain level of harvesting' (John Zasada, cited in Turner, 2001: 68).

In the case of *amáwali (Dahlia* sp.*)*, it was important to leave the meristem intact for the creation of future bulbs. A research participant likened the replanting of propagules to the practice of harvesting potatoes, where a spud is left in the ground to allow for the development of a new stock of potatoes.

Selective harvesting strategies also apply to annuals. One example is *basoli (Amaranthus* sp.*)*, an edible green that is collected whole before flowering. *Amaranthus* is consumed when it is young, because 'in initial stages, the plant generates large quantities of succulent green matter' (Mapes *et al.*, 1997: 303). Research participants elaborated that for all annuals, it is important to leave some plants intact to allow for future seed generation. The seeds are consumed by livestock or birds and deposited by the passing of faeces in pastureland and along trails and waterways. Seeds that are deposited in riparian areas will be transported to other locations when water levels rise. The wind will also play a factor in propagation by blowing seeds to areas where they will fall and germinate. Harvesters explained that by allowing these natural processes to act on a seed stock left behind, plants would propagate naturally and replenish themselves.

Pruning

The stalk of the flower cluster, or peduncle, of *mesagóli (Agave* sp.*)* is used as a supplementary food source, for instance when stocks of maize are low. Research participants explained that the stalk is harvested before the plant flowers in early spring, so it can be consumed while still tender. Community members harvested the stalk of the century plant for another reason – to extend the life of the plant. It was explained that if the stem were not cut, the juice of the plant would concentrate on producing fruit, denying the heart and roots essential nutrients and effectively killing the plant within one year. If its energies are not focused on reproduction, the plant can live longer.

The practice of pruning such a structure is undertaken to prolong the life of the plant itself. The practice maintains the plant in the developmental state, to grow vegetatively, instead of switching to the mechanism that puts the plant's energy into reproduction. By allowing the plant to survive, the heart expands and provides more substance when it is finally consumed. Thus, pruning the *mesagoli* plant serves a dual purpose – to provide a source of food for immediate consumption, and to extend the life of the plant for future use.

Domestication: Fertilization, seeding and transplanting

The Convention on Biological Diversity includes the domestication and cultivation of wild species in its definition of *in situ* conservation (Melchias, 2001). The Rarámuri in Basíhuare have adopted domestication practices for a number of edible wild plants in naturally fertilized areas, or milpas, grown along with cultivated crops such as maize and beans.

Milpas are maize growing systems used in many parts of Mexico (Alcorn and Toledo, 1998). In Basíhuare, milpas are fertilized by keeping livestock overnight in corrals, positioned on a section of the field and shifted on a rotational system. A research participant explained that corrals are left in one position for approximately two weeks, during which time goats and sheep fertilize the soil, and then the structure is moved to an adjacent location. The droppings are then worked into the soil and the land is prepared for cultivation. This process is repeated until the entire area of the milpa has been fertilized. According to the research participant, the fertilized soil may remain nutrient rich for up to 5 years on flat surfaces and 2 years on slopes or hillsides.

Wild edible plants are either seeded or transplanted into these fertilized areas. The seeds of *mekwásare (Brassica* spp.*)* are collected in the

autumn and sown in fertilized milpas during the rainy season and occasionally in late summer or early autumn. A research participant explained that if seeds are spread during the rainy season, the task is simplified, as the heavy rainfall forces the seeds into the soil. In times of high ground moisture levels, the seeds can begin to germinate in as little as 5 days.

Seeding selected species of edible greens alongside wild varieties provides a condition that fosters genetic exchange and promotes the cross fertilization between domesticated and wild plants (Cotton, 1996). In Basíhuare, those species of the *Brassica* genus that are seeded in milpas cross-fertilize with other varieties of *Brassica* found in the area. Similar findings are reported regarding the cultivation of other wild members of the *Brassica* genus in the Sierra Tarahumara (Bye, 1979). The practice of domesticating wild species locally builds ecologically resilient strains of these species adapted to local environmental conditions (Nabhan, 1997).

Wild plants may also be transplanted in fertilized areas within milpas. Research participants identified *mesagóli (Agave* sp.*)* and *ilá (Opuntia* sp.*)* as two widely used plants that are propagated in this way. The heart and root structure of *mesagóli* is transplanted when it is young, to an area with good quality soil. Rarámuri growers select a location with relatively few submerged rocks, so that the roots can penetrate deeply into the soil and properly anchor the plant.

Environmental modification

Previous research in the Sierra Tarahumara (Bye, 1976; Salmón, 2000a) identified a number of Rarámuri practices of environmental modification that create habitats in which certain types of plant species can prosper. In the Basíhuare region, such agro-ecological practices exist and include selective burning and soil disturbance.

Selective burning practices produce areas that are known locally as *kumérachi* and are used regularly as part of traditional agro-ecological practices (Davidson-Hunt, 2003). Oak trees are selectively cut and burned on mountain plateaus to produce nutrient-rich soil in which mostly beans are cultivated. An area is used only for one year, after which time oak and understorey vegetation are allowed to regenerate naturally. On the Basíhuare landscape, oak forests were in different stages of succession as a result of selective burning, from recently burned patches to those that had not been disturbed for decades. The effect of these practices is to create a mosaic of oak forest patches of different ages, favouring the growth of a diversity of plants, some of them utilized as food sources.

Participant observation research included a visit to a *kumérachi* site that had been burned approximately 7 years earlier, and where little vegetative regeneration was visible, with the exception of a considerable amount of *mesagóli.* Goats had been allowed to graze on the site and had consumed most of the vegetation, except for *mesagóli,* a plant they do not consume. Because oak had not regenerated on this site, the area had become more exposed to sunlight. This provided an adequate habitat for certain species of edible plants, such as *mesagóli,* which thrive in sunny, nutrient-rich environments. The practice of selective burning, combined with livestock grazing on the *kumérachi,* had the effect of increasing the amount of sunlight reaching the soil, and thus produced an area suitable for the growth of edible wild plants.

The other agro-ecological practice observed in Basíhuare was land disturbance on milpas, promoting the growth of certain edible wild species. One such species of edible greens, *sipeke (Bidens* sp.*),* is believed to have originated from the forest. It now prospers on land that has been disturbed by agricultural activity. 'If this land was not cultivated, it is probable that *sipeke* would not flourish here', stated a local agroecologist. The disturbance of landscape also promotes the growth of *tomati (Physallis wrightii),* a husk tomato used to make salsa, which was only found near milpas in Basíhuare.

Disturbance is important in general because it produces a mosaic of patches on the landscape and creates a variety of habitats that are capable of sustaining a diversity of plant species (Cotton, 1996; Altieri, 2000). As such, Rarámuri agro-ecological practices may ensure the regeneration of edible plants, both the semi-domesticated varieties in agricultural fields and the wild ones in forested areas. As the above examples indicate, Rarámuri practices may be undertaken with the practical objective of maintaining and augment-

ing the productivity of the land, but their ultimate effect is the conservation of edible plant stocks and of biodiversity in general.

COMMUNICATION AND EXCHANGE OF KNOWLEDGE

Ruddle and Chesterfield (1977) described the sequences in the transfer of traditional ecological knowledge. First, there is familiarization and observation by the learner. This is followed by putting knowledge into practice, at first with assistance, then on one's own, culminating with sharing of learned experiences with others. As observed with the Rarámuri, the transfer of traditional knowledge is more than a unidirectional flow of information on harvesting practices from elder to youth. The communication of knowledge between generations is executed in a dynamic and interpretive way and involves mutual learning. In Basíhuare, experiencing the landscape by monitoring forest resources plays a role in the communication and exchange of knowledge, which is the third theme in the Turner *et al.* (2000) framework.

Monitoring

In Rarámuri culture, monitoring does not occur in a formal setting, but rather as an element of daily activities, such as gathering livestock, collecting fuelwood, or harvesting plants. Research participants noted that to monitor the state of edible plants, people must harvest and use them. They are likely to lose knowledge and to stop monitoring the landscape of edible plants if they are not using their knowledge. If a certain plant is no longer harvested, then its abundance is not likely to be monitored, and associated knowledge may be lost.

For example, local harvesters knew of several varieties of *ilá* that exist in Basíhuare, four of which were edible. However, the fifth caused headaches if consumed. There was also local knowledge that these plants have rich nutritional value and may prevent diabetes, supported by research findings (González Ferrera, 1998). There were a number of mushroom species in the area, some of which were edible and some poisonous. If the use of these plants was discontinued, local knowledge about the benefits and risks of consuming them may be threatened.

Traditions and stories

The knowledge of edible wild plants in the Sierra Tarahumara has developed through generations of sharing traditions and stories, manifested by the passing of knowledge from elders to youths. A person's knowledge begins to grow from an early stage in a child's development and expands through time. As explained by an elder: 'the knowledge required to recognize and prepare wild plants is learned little by little over a lifetime'.

One research participant, a man in his late 30s, acknowledged that he does not yet hold complete knowledge of edible plants available in the area. As such, the harvester was expanding his own personal knowledge base throughout research activities with community elders, discovering locations or new ways of using already known plant species, and finding out about entirely new species of plants. A local research participant compared the process of gaining knowledge of edible plants to learning a language: 'Learning begins when you are a baby, when it progresses from mumbling a few words to being able to read and write, and becoming familiar with the language. In fact, learning continues until the day you die.'

Experiences on the land

Young community members gain an understanding of edible plants and their habitat by experiencing life on the landscape. The exchange of knowledge was achieved by youths accompanying siblings, parents or grandparents into the forest on harvesting journeys or to collect firewood. These activities provided youths with the opportunity to watch an adult gathering edible plants, to learn how and where to collect them, and to eventually undertake these harvesting activities on their own. A female elder of the community explained the process of acquiring knowledge related to edible wild plants in the following way: 'Children will first learn by watching their parents and hearing them speak of the plants. They will then watch them search and harvest the plants. The parents will also

teach them which can or cannot be used, and show them how to prepare the foods. Finally they will begin identifying and collecting their own.'

Youths learn from their experiences on the land, and rely on those living there to understand the landscape and range of harvesting areas. During field research, the facilitator harvested *okowí sawaroáme,* a commonly used supplementary food item from an area he first encountered as a child where he had often herded goats. The facilitator explained that he now collects mushrooms from this area with his son, who is learning the proper time and place to find them. Knowledge about conditions and locations of a specific habitat was gained and preserved by experiencing the landscape and exchanging ecological knowledge over a lifetime.

Evaluating the status of traditional ecological knowledge

Traditional knowledge associated with edible wild plants seems to live on because of the continued importance of using them. As expressed by a research participant, 'edible plants still form an important part of our diet, so our children are learning which are and which are not edible, how and when to collect them, and how to prepare them'. Another research participant related that it was important for his children to learn about plants, as he did from his parents when he was young; if his children were in need of nourishment, knowing about edible plants would allow them to simply walk through the forest and harvest them.

Discussions with the local secondary school students participating in the project confirmed that they learned how to identify, collect and prepare edible plants from their parents or grandparents. One youth indicated that his children would also know which plants to harvest because they will observe him and their mother preparing edible plants. When asked which edible plants they preferred, students were able to identify a variety of greens, along with their habitat and preparation techniques for consumption. Knowledge exists among the youths in terms of conservation practices for edible greens, such as seeding and transplanting. It was considered important to differentiate edible plants from the poisonous ones. The students found it important to continue harvesting, preparing, and consuming edible plants because they are nutritious and available naturally, while store bought food can be expensive.

However, there have been changes in the extent of wild plant harvesting and the transfer of traditional knowledge. Increasing development in Basíhuare has enhanced trade, resulting in wild foods being replaced by store bought foods and those from drought assistance programmes. Some plants were rarely harvested, and parents were no longer teaching their children about those plants that required relatively more time and effort to harvest. An example is *salabí* (*Prionosciadium* sp.), which is used less frequently today than it was a generation ago when almost everyone in the community knew how to use it. During this research, the resource availability of *salabí* was unknown because it was rarely harvested and no longer monitored. As people were no longer consuming some edible wild plants, they were losing the knowledge of how to manage them.

DISCUSSION AND CONCLUSIONS

Communication and exchange of local knowledge about edible wild plants is important for the maintenance of the local philosophy and worldview in which humans and nature are interconnected, and the relations are guided by ethical and ecological principles. For instance, the naming of places by Rarámuri is a product of culturally transmitted knowledge of the landscape. The understanding of the land, and place names derived from knowledge of the land, are important components of knowing where to find and how to maintain the habitat for edible wild plants. Furthermore, the Rarámuri who live in Basíhuare rely on their ecological understanding and insight to make harvesting decisions. Ecosystem dynamics, not only in regard to seasonal variations, but also of interactions between system elements, are key to making decisions, as noted in the section on environmental modification.

The exchange of knowledge is important for the maintenance of practices and strategies for the sustainable use of resources, specifically as they relate to the harvesting and management of edible wild plants. Strategies for managing edible

plants, such as selective harvesting, domestication and environmental modification, provide an array of management options necessary for the conservation of biodiversity. For instance, traditional use of fire renews the plant cover and creates a mosaic of landscape patches. This probably leads to biological diversity at the species and landscape levels, through the creation of patches of habitat at different stages of succession (Berkes *et al.*, 2000).

In terms of livelihood strategies, not putting all their dietary eggs in one basket by harvesting edible wild plants ensures a variety of food sources, and provides a back-up resource when stocks of maize are low. As pointed out by Cronon (1983) in the historical ecology of New England, this strategy is not unlike the financial practice of investing in a diversified portfolio, which involves a number of holdings to provide a safer, more stable return. In agricultural terms, this may lead to missing out on quick cash incomes from commodities, but ensures against devastation of disease or drought. As such, the harvesting and management of edible wild plant species practiced by Rarámuri people in Basíhuare plays a role in supporting a resilient social-ecological system able to absorb perturbations, such as those brought on by environmental variability (Berkes *et al.*, 2000).

Rarámuri culture and traditional education have a number of characteristics that support the acquisition and exchange of environmental knowledge. Youths are provided with the freedom to act at a very early age, with the assurance that their independent thought and experiences will provide the knowledge they need to survive. In this way, youths begin to understand their surroundings and develop techniques for monitoring the landscape. Monitoring begins with watching over the state of individual species and extends to understanding habitat and landscape. While searching for wild plants, harvesters not only watch for the health of individual plant species, they also monitor the state of the forest. Monitoring thus plays a principal part in the Rarámuri role as stewards of the land.

Exchanging knowledge requires accompanying youths on the land so they too can begin harvesting. When an elder was asked directly about the key to caring for the forest environment, his response was to teach children about the importance of using natural resources properly and in a way that provides for future generations. As a youth from the local school confirmed, there are three ways to maintain knowledge about which plants can be harvested and how to prepare them: by living on the land; by continuing to search and collect wild plants; and by teaching their own children the knowledge related to edible wild plants.

What makes knowledge traditional, as described by Berkes (1999), is the fact that it has been handed down over the generations, based on interactions with the environment. Traditional knowledge develops by personal observation along with teachings from elders and community members. It requires a forum in which the exchange of knowledge can continue. For example, the sharing of stories by elders is important not only in the information that is being delivered but also in the cultural context that it provides. Traditional knowledge offers a means for youth to appreciate the cultural and ecological value of the forest. Communication with elders and the *Owirúame* lead to learning about the importance of maintaining an interactive and interconnected relationship with the land and its resources.

Such communication and exchange can be fostered by the school system, through field excursions and research activities with community members. These activities provide the opportunity to consult with harvesters, to remain in contact with nature, and to observe and incorporate experiences into the school. Traditional knowledge of edible wild plants can thus be incorporated into a formal setting. But if harvesting practices are not sustained on the land, the application and integration of this knowledge is undermined, along with the culture. In order for the exchange of knowledge to continue, harvesting of edible wild plants must also continue as part of local subsistence activities.

Perhaps the major threat to the use of non-timber forest products by the Rarámuri is the loss of control over the forest commons. According to Mexican Forest Law, the community has control over forest resources, but it must first develop a forest management plan, and have it accepted by a majority of community members. However, the final approval and implementation

of these plans remain in the hands of state representatives of the Federal Ministry of Natural Resources.

Indigenous groups such as the Rarámuri have difficulty maintaining control over their forest resources because they often do not have the technical capacity to develop management plans, and because government forest technicians develop plans that emphasize timber production. These plans pay lip service to sustainable forestry, and often do not incorporate traditional land-use practices, such as selective burning and use of non-timber forest products (Davidson-Hunt, 2003).

Can the current system of decision-making in the Mexican forest be restructured to integrate traditional land-use practices into sustainable forestry management plans? The experience from various parts of the world, including Latin America, indicates that there is an issue of environmental injustice that complicates planning for sustainability (Zerner, 2000). Indigenous peoples are perceived to be unconnected to global markets, but in fact, in the present case, they are greatly affected by the globalization of timber markets. The situation is further complicated by tourism development, land-use restrictions, and an increasing number of mestizo residents in the Sierra Tarahumara.

Zerner (2000) concludes that, in keeping with environmental justice and equity, biodiversity conservation must include a concern for local uses of the landscape and human issues such as food security. The conservation of biodiversity in the Sierra Tarahumara would thus imply continued access to land and resources by the Rarámuri, so as to maintain a worldview in which people monitor and harvest a portfolio of forest resources, and not just clear-cut for timber.

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REFERENCES

Alcorn, J.B. and Toledo, V.M. (1998). Resilient resource management in Mexico's forest ecosystems: the contribution of property rights. In Berkes, F., Folke, C. and Colding, J. (eds), *Linking Social and Ecological Systems*, pp. 216–49. (Cambridge: Cambridge University Press)

Altieri, M.A. (2000). Multifunctional dimensions of ecologically-based agriculture in Latin America. *International Journal of Sustainable Development and World Ecology*, **7**, 62–75

Anderson, M.K. (1996). Tending the wilderness. *Restoration & Management Notes*, **14**, 154–66

Arriaga, L., Espinoza, J.M., Aguilar, C., Martinez, E., Gómez, L. and Loa, E. (2000). *Regiones terrestres prioritarias de México*. Comisión Nacional Para el Conocimiento y Uso de la Biodiversidad, México (at: http://www.conabio.gob.mx)

Berkes, F. (1999). *Sacred Ecology: Traditional Ecological Knowledge and Resource Management*. (Philadelphia: Taylor and Francis)

Berkes, F., Colding, J. and Folke, C. (2000). Rediscovery of traditional ecological knowledge as adaptive management. *Ecological Applications* **10**, 1251–62

Brookfield, H. and Padoch, C. (1994). Appreciating agrodiversity: a look at the dynamism and diversity of indigenous farming practices. *Environment*, **36**(5), 7–11; 37–44

Brouzes, F. (1980). *La Nourriture Partagée: Introduction à l'étude de la 'Korima' chez les Tarahumaras (Mexique)*. Post-graduate research report. Université de Bordeaux, Bordeaux

Burgess, D. (1987). *Western Tarahumara Place Names*. (Paper held at the Universidad Autónoma de Chihuahua (UACH), Chihuahua City, Mexico)

Bye, R. (1976). *Ethnoecology of the Tarahumara of Chihuahua, Mexico.* Dissertation. (Cambridge, MA: Harvard University)

Bye, R. (1979). Incipient domestication of mustards in northwest Mexico. *Kiva,* **44**, 237–56

Bye, R. (1995). Ethnobotany of the Mexican tropical dry forests. In Bullock, S.H., Mooney, H.A. and Medina, E. (eds). *Seasonally Dry Tropical Forests,* pp. 423–37 (Cambridge: Cambridge University Press)

Chambers, R. (1994). Participatory rural appraisal (PRA): analysis of experience. *World Development,* **2**, 1253–68

Cotton, C.M. (1996). *Ethnobotany Principles and Applications.* (Baffins Lane, England: John Wiley and Sons Ltd)

Cronon, W. (1983). *Changes in the Land: Indians, Colonists, and the Ecology of New England.* (New York: Hill and Wang)

Cunningham, A.B. (2001). *Applied Ethnobotany: People, Wild Plant Use and Conservation.* (London: Earthscan Publications Ltd)

Davidson-Hunt, I.J. (2003). *Journeys, Plants and Dreams: Social–Ecological Resilience, Memory and Adaptive Learning.* PhD Thesis (Winnipeg, Canada: University of Manitoba)

Davidson-Hunt, I.J. and Berkes, F. (2001). Changing resource management paradigms, traditional ecological knowledge, and non-timber forest products. In Davidson-Hunt, I.J., Duchesne, L.C. and Zasada, J.C. (eds), *Forest Communities in the Third Millennium,* pp. 78–92. (St. Paul, MN: USDA Forest Service, North Central Research Station)

Gadgil, M., Berkes, F. and Folke, C. (1993). Indigenous knowledge for biodiversity conservation. *Ambio,* **22**, 151–6

González Ferrera, M.M. (1998). *Plantas Medicinales del Noreste de Mexico.* (Monterrey, Mexico: Editora El Sol)

Hunn, E. (1993). What is traditional ecological knowledge? In Williams, N.W. and Baines, G. (eds), *Traditional Ecological Knowledge: Wisdom for Sustainable Development,* pp. 13–15. (Canberra, Australia: Centre for Resource and Environmental Studies)

Kimmerer, R.W. (2000). Native knowledge for native ecosystems. *Journal of Forestry,* August 2000, 4–9

Mapes, C., Basurto, F. and Bye, R. (1997). Ethnobotany of quintonil: knowledge and management of edible greens *Amaranthus* spp. (Amaranthaceae) in the Sierra Norte de Puebla, Mexico. *Economic Botany,* **51**, 293–306

Martin, G.J. (1995). *Ethnobotany: A Methods Manual.* (London: Chapman & Hall)

Melchias G. (2001). *Biodiversity and Conservation.* (Enfield, USA: Science Publishers Inc.)

Merrill, W.L. (1988). *Rarámuri Souls: Knowledge and Social Process in Northern Mexico.* (Washington, DC: Smithsonian Institution Press)

Merrill, W.L. (2000). Concept Paper on the Sierra Tarahumara Diversity Project. Mexico-North Research Network. (at: http://mexnor.org/stdpaug.htm)

Monárrez Espino, J. and Martínez Salgado, H. (1996). *Diseño de una despensa de ayuda alimentaria para la población Rarámuri menor de tres años en el Municipio de Guachochi. Chihuahua.* Report presented to the Instituto Nacional de Salud Pública, Mexico

Morgan, D.L., 1988). *Focus Groups as Qualitative Research.* (London: Sage Publications)

Nabhan, G.P. (1997). *Cultures of Habitat: On Nature, Culture and Story.* (Washington, DC: Counterpoint)

Nabhan, G.P. (2000). Interspecific relationships affecting endangered species recognized by O'odham and Comcáac cultures. *Ecological Applications,* **10**, 1288–95

Peters, C.M. (1994). *Sustainable Harvest of Non-timber Plant Resources in Tropical Moist Forests: An Ecological Primer.* (Landover, MD: Corporate Press Inc.)

Posey, D.A. (ed.) (1999). *Cultural and Spiritual Values of Biodiversity: A Complementary Contribution to the Global Biodiversity Assessment.* (Nairobi, Kenya: UNEP)

Purcell, T.W. (1998). Indigenous knowledge and applied anthropology: questions of definition and direction. *Human Organization,* **57**, 258–72

Ruddle, K. and Chesterfield, R. (1977). *Education for Traditional Food Procurement in the Orinoco Delta.* Ibero-Americana 53. Berkeley: University of California Press

Salmón, E. (2000a). Kincentric ecology: Indigenous perceptions of the human-nature relationship. *Ecological Applications,* **10**, 1327–32

Salmón, E. (2000b). Iwigara: a Rarámuri cognitive model of biodiversity and its effect on land management. In Minnis, P.E. and Elisens, W.J. (eds), *Biodiversity and Native America.* (Norman: University of Oklahoma Press)

Turner, N.J. (1995). Ethnobotany today in northwestern North America. In Schultes, R.E. and von Reis, S (eds), *Ethnobotany: Evolution of a Discipline,* pp. 264–83. (Portland: Dioscorides Press)

Turner, N.J. (2001). 'Keeping it Living': applications and relevance of traditional plant management in British Columbia to sustainable harvesting of non-timber forest products. In Davidson-Hunt, I.J., Duchesne, L.C. and Zasada, J.C. (eds), *Forest Communities in the Third Millennium,* pp. 78–92. (St. Paul, MN: USDA Forest Service, North Central Research Station)

Turner, N.J., Boelscher Ignace, M. and Ignace, R.

(2000). Traditional ecological knowledge and wisdom of aboriginal peoples in British Columbia. *Ecological Applications*, **10**, 1275–87

United Nations Environment Programme (2000). *Traditional Knowledge: Indigenous and Local Communities Knowledge, Innovations and Practices.* UNEP, Secretariat of the Convention on Biological Diversity, Montreal. At http://www.biodiv.org/doc/publications/guide.asp

Wesche-Ebeling, P., Maiti, R., Garcia-Diaz, G., Gonzalez, D.I. and Sosa-Alvarado, F. (1995). Contribution to the botany and nutritional value of some wild *Amaranthus* species (Amaranthaceae) of Nuevo Leon, Mexico. *Economic Botany*, **49**, 423–30

WWF (2002). *WWF's Global Conservation Programme: Global 200 Ecoregions.* World Wildlife Fund. (at: www.panda.org/resources/publications/sustainability/global/global.html)

Zerner, C. (ed.) (2000). *People, Plants and Justice: The Politics of Nature Conservation.* (New York: Columbia University Press)

Zingg, R. (2001). *Behind the Mexican Mountains.* Campbell, H., Peterson, J. and Carmichael, D. (eds). (Austin: University of Texas Press)