Forest cover, use and dietary intake in the East Usambara Mountains, Tanzania

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SUMMARY

Food insecurity and malnutrition in local populations both result from and drive deforestation. This paper examines the relationships between diet of local people and measures of forest cover and use in the East Usambara Mountains, Tanzania. Data on dietary diversity and intake were collected for 270 children and their mothers. Area of tree cover within the vicinity of each household was examined in relation to forest use and diet. Individuals using foods from forest and other non-farm land had higher dietary diversity, consumed more animal source foods and had more nutrient dense diets. They also had more tree cover in a close proximity to the home, suggesting a relationship between tree cover and forest food use. Households reporting trips to the forest had lower area of tree cover within close proximity, suggesting that land close to the home with tree cover such as agroforest and fallow is important for obtaining subsistence products. Although historically there has been little motivation for local people to participate in forest conservation in the East Usambaras, the maintenance of tree cover in the landscape around the home, especially on agricultural and village land, may be important in ensuring continued access to the health benefits potentially available in wild and forest foods.

Keywords: East Usambara Mountains, forest cover, wild food, dietary diversity, nutrition

Couvert forestier, utilisation et alimentation dans les montagnes Usambara de l'Est en Tanzanie

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La nourriture non assurée et la malnutrition chez les populations locales résultent toutes deux de la déforestation, tout en la faisant empirer. Cet article examine les relations entre la nutrition des populations locales et la proportion de couvert forestier et son utilisation dans les montagnes Usambara de l'Est en Tanzanie. Des données sur la diverstité nutritionnelle et la consommation ont été recueillies auprès de 270 enfants et de leurs mères. La zone de couvert forestier autour de chaque foyer a été examinée du point de vue de l'utilisation de la forêt et de la nutrition. Les personnes consommant de la nourriture en provenance de la forêt et d'autres terres non-cultivées connaissaient une diversité nutritionnelle plus importante, mangeaient davantage de nourriture de source animale, et leur régime était plus concentré en substances nutritives. Il existait également une plus grande zone de couvert forestier à close proximité de leur foyer, suggérant une relation entre le couvert forestier et l'utilisation de la nourriture forestière. Les foyers effectuant des déplacements vers la forêt avaient une moindre zone de couvert forestier à proximité, suggérant qu'un terre couverte d'arbres proche du foyer, telle que l'agroforêt et la forêt inexploitée est importante pour l'obtention des produits de subsistance. Bien que les populations locales aient une motivation très limitée, historiquement, pour participer à la conservation forestière dans les Usambaras de l'Est, la gestion du couvert forestier dans le paysage encadrant les foyers, particulièrement sur la terre cultivée et celle des villages, pourrait bien être importante pour assurer un accès non interrompu aux bénéfices sanitaires potentiellement obtenus dans les aliments sauvages et forestiers.

Cubierta forestal, usos, y consumo en la dieta en las Montañas Usambara del Este, Tanzania

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La inseguridad alimenticia y la malnutrición en las comunidades locales son a la vez causa y resultado de la deforestación. Este artículo examina las relaciones existentes entre la dieta de las comunidades locales y la cantidad de cubierta forestal y su uso en las Montañas Usambara del Este, en Tanzania. Se recolectaron datos sobre la diversidad y el consumo en la dieta de 270 niños y sus madres. Se estudió el área de cubierta forestal en los alrededores de cada vivienda en relación con el uso del bosque y la dieta. Los individuos que hicieron uso de alimentos procedentes del bosque, y otras áreas no cultivadas, mostraron dietas más diversas, consumieron más alimentos de origen animal, y sus dietas contuvieron una densidad de nutrientes más alta. También disponían de una mayor cubierta forestal próxima a su hogares, lo cual sugiere que la cubierta forestal y el uso de alimentos del bosque están relacionados. Los hogares que mencionaron caminatas para llegar al bosque disponían de una menor cubierta forestal en las proximidades, sugiriendo que para la obtención de productos de subsistencia es importante la existencia de áreas cercanas al hogar con cubierta forestal, p. ej. agroforestales o en barbecho. Aunque históricamente las comunidades locales apenas han tenido motivación para participar en la conservación del bosque en las Usambara del Este, el mantenimiento de una cubierta forestal en el paisaje alrededor del hogar,especialmente en terrenos agrícolas y comunales, podría ser importante para asegurar el acceso ininterrumpido a los posibles beneficios que los alimentos silvestres y del bosque ofrecen para la salud.

INTRODUCTION

Human and ecosystem health are integrally linked, in part through the contributions both wild (non-domesticated) and cultivated (domesticated species and crop varieties) biodiversity make to human health by improving food security and nutrition. The role of agricultural biodiversity in improved dietary diversity and human nutrition is increasingly well established (CBD 2006, Johns and Sthapit 2004). Many authors assert the importance of forests and the biodiversity they provide for food security and nutrition (Colfer *et al.* 2006, Johns and Maundu 2006, Vinceti *et al.* 2008), however empirical documentation of these relationships remains scarce. Tree products from forests and agroforests have been suggested to be important in times of food insecurity (Falconer 1990). While the consumption of bush meat is often in conflict with conservation objectives, it is an important part of many local diets (Fa *et al.* 2003, Nasi *et al.* 2008, van Vliet and Nasi 2008). Colfer and colleagues (2006) note that there are likely no contemporary communities in the world which wholly depend on wild gathered food, but that for most communities living in or near forests, these foods make important contributions by supplying micronutrients (e.g. vitamins A or iron) often deficient in food from agricultural and purchased sources, and by providing a safety-net in times of food insecurity. In many settings, the poorest members of the community are also the most dependant on forest resources (Colfer *et al.* 2006, Harris and Mohammed 2003).

Global malnutrition is increasingly attributable to insufficient micronutrients (vitamins and minerals), as opposed to lack of protein and energy. Micronutrient deficiency is associated with growth failure, impaired cognitive development and physical fitness, decreased ability to work, weakened immunity and increased risk of chronic disease (UN-SCN 2004).

Concerns about sustainability of harvesting, even for plant-based forest resources, have in the past often meant that conservation priorities override the importance of forest ecosystems for local nutrition. Over the past two decades, the development of the field of landscape ecology has led the global conservation community to recognize the need to understand the role of humans in landscape level processes, and to approach trade-offs between human and ecosystem health in a more holistic manner (Wiens 2009). Understanding the importance of foods from different land use types (forest, fallow, farm) to the diets of local populations sheds light on the drivers of human actions across landscapes and highlights links between forest conservation, well-being and livelihoods (e.g. Chomitz 2007). Using a landscape ecology approach, incorporating humans as part of the ecosystem (Pfund 2010, Sayer *et al.* 2007), this study seeks to understand the synergies and trade-offs between livelihoods and forests in the East Usambaras by addressing the following three questions: What is the contribution of wild food species (both plant and animal) to the local diet? What is the importance of different land use types in the diets of local people? How does forest use and tree cover in the landscape specifically relate to the local diet and consumption of wild foods?

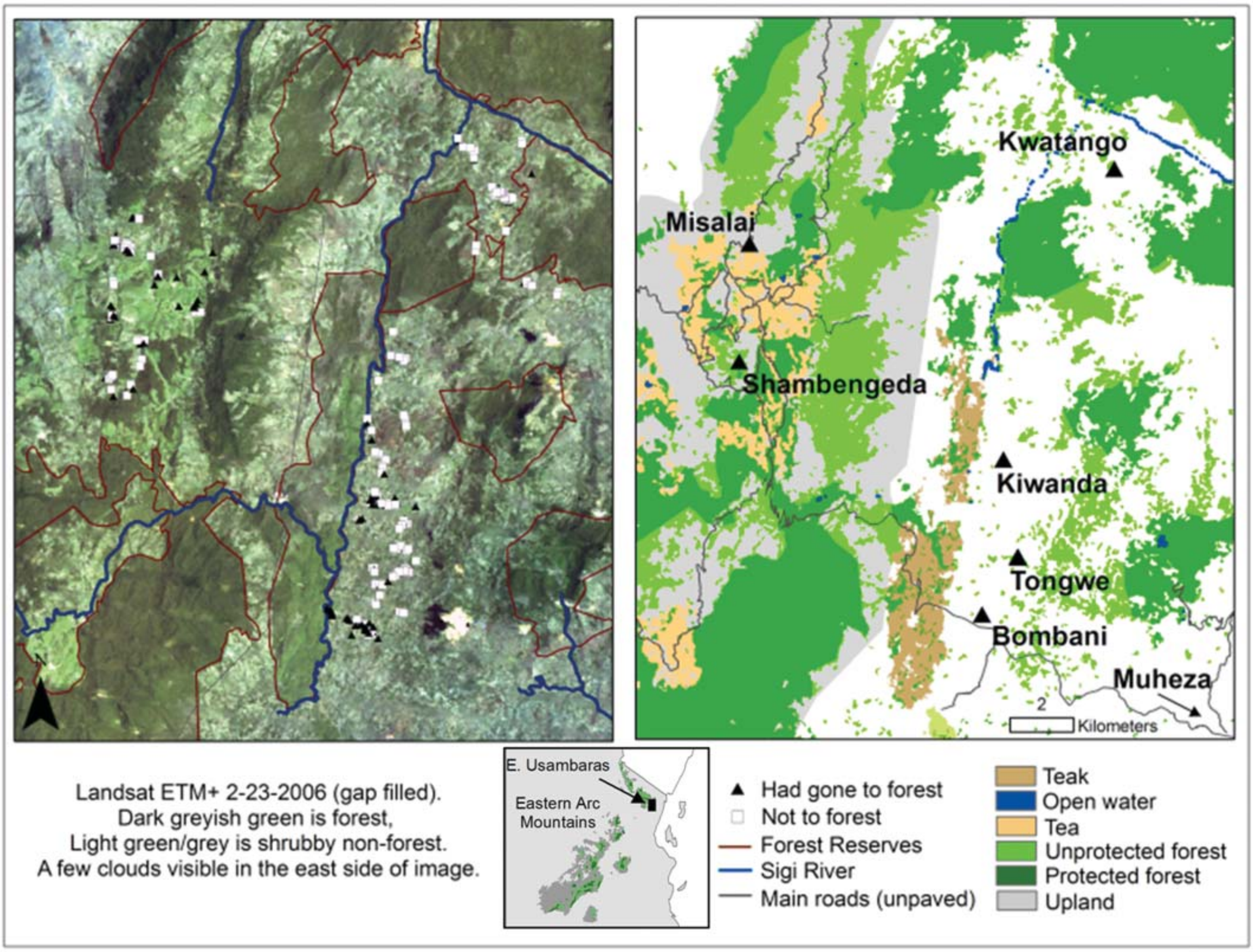
METHODOLOGY

Study site – East Usambara Mountains, Tanzania

In north-eastern Tanzania, the East Usambara Mountains rise from 200m to over 1200m and receive an average of 1500mm of rain annually (data from 2007–2009). Part of the Eastern Arc Mountains, the East Usambaras are renowned for a high concentration of endemic species (Burgess *et al.* 2007), and have been identified as one of the world's most threatened forest ecosystems (Myers *et al.* 2000), with deforestation prevalent throughout the area's unprotected forests (Dewi and Ekadinata 2010, Hall *et al.* 2009). The area contains moist tropical montane forest above ~600m and some of the last remaining but ecologically important lowland montane forest in East Africa (Brooks *et al.* 2002). Forest in the East Usambaras exists under varying degrees of protection, although most lies within government reserves. The East Usambaras encompass some of the oldest protected areas in East Africa; these have historically excluded local people from management and decision making and placed major restrictions on use by local people. Recently there have been significant efforts to decentralize forest management in Tanzania, including in the East Usambaras, where both joint forest management and community-based forest management have been initiated (Rantala 2010, Vihemäki 2005). Despite these efforts aimed "to promote and facilitate active participation of people in sustainable planning, management, use and conservation of forests" (Vihemäki 2005) access to forests under various types of protection for food (and other resources) remains limited (some deadwood collection has long been allowed in even the most highly protected areas) (Rantala 2010).

Although the Usambara Mountains derive their name from the Wasambaa (Shambaa) people who make them their home, the East Usambaras have always been culturally diverse; home to the Zigua, Bondei, and Digo ethnic groups as well (Willis 1992). The ethnic groups of the area have historically inter-married, a tradition which continued as the area experienced significant in-migration of people looking for employment in the tea and timber industries. Ethnic intermixing in the area was further enhanced by nationalistic (and anti-tribal) values promoted by the Tanzanian government under Nyerere (1964–1985) (Yeager 1989). With a population density of 61 people per square kilometre in the East Usambaras, both population density and population growth are higher than most other biodiversity hotspots and the global average (Cincotta *et al.* 2000, Tanzania 2002). Local livelihoods are based primarily on subsistence agriculture, supplemented with cash crops and wage labour (Kessy 1998). Wild or uncultivated foods have long been important in the diets of the Wasambaa (Feierman 1974, Fleuret 1979). People in the area use a high diversity of traditional vegetables and a higher ratio of wild to cultivated vegetables compared to other parts of Tanzania (including Arumeru, Singida and Kongwa) (Keding *et al.* 2007, Weinberger and Swai 2006). Malnutrition, especially vitamin A and iron deficiencies, have been found to be a problem in the area (Mulokozi *et al.* 2003).

FIGURE 1 *Map of the East Usambara Mountains with surveyed households who reported having visiting a forest in the last month (marked with black triangles) and those who did not report a trip to the forest (marked with white dots). Villages marked at location of village office*



A study in the East Usambara lowlands[1] in 1994 found 60% of children between 7–12 years old to be stunted (Height-for-Age Z score ≤–2), 35% wasted (Weight-for-Height Z score≤ –2), and 49% of children to be anaemic (Hb≤110g/L), with high rates of parasite infection (Beasley *et al.* 2000).

Six rural villages in Muheza district (southern East Usambaras) were selected for this study using stratified sampling based on road access and two elevation categories – upland (>500m) and lowland (<500 m) (Figure 1). Villages consists of hamlets or clusters of houses made mostly of poles and mud, mud brick and occasionally cement, with thatched or tin roofs. In the lowlands, Bombani village, 13.5km from the urban centre – Muheza Town – and at a junction of the main road leading into the uplands and a smaller one to the lowlands, has regular public transit and significant opportunity for wage labour (especially in the timber industry due to the near-by Lunguza Teak Plantation). Tongwe, and further Kiwanda, villages are spread-out along the secondary road from Bombani. Only one or two public transit vehicles travel this road per day, less in the rainy season, but because Tongwe is close, markets and wage labour are still quite accessible. Kiwanda is significantly more isolated, with households spread across a large area. Down Sigi River valley from Kiwanda lies Kwatango village. Kwatango has a even lower population density (although still high compared to some other tropical forests at 21 people per square kilometre) (Tanzania 2002) and limited accessibility by a different road coming from the plains to the east (at the time of research this road was in extremely poor condition and frequently impassable during the rains). Public transit leaves Kwatango once or twice a week in good weather; most produce is taken at least part of the way to market on foot. Misalai and Shambangeda, on the Amani plateau (between 800 and 1100m elevation), were surveyed as the two upland villages. Although over 15km up the mountain from Bombani, they benefit from a road which is maintained by the government to ensure access

[1] Villages of Misongeni, Ubembe and Kilometa Saba in Muheza District

to tea estates and the Amani Research Station. Public transit leaves twice a day, in virtually all weather, as well as vehicles carrying crops to markets. Both villages have high population density (Tanzania 2002), with hamlets squeezed between tea estates and protected government forests. Many inhabitants in both villages engage in wage labour on the tea estates as their only source of income, or in addition to agricultural activities.

Data Collection

Dietary assessment: Approximately 45 households from each of 6 villages were selected using systematic sampling from a lists of households with children under 5 provided by village governments (in this case every 2nd or 3rd household was selected, or ~50% of eligible households, total N=270). Dietary intake information was collected for pairs of mothers and children between the ages of 2 and 5 years; the youngest child within the age range in the household was selected with their mother or primary caregiver (henceforth referred to as mothers). Women of childbearing age and young children are the most nutritionally sensitive members of a household both due to higher requirements and inadequate intake (Gibson 2005). The dietary data presented here was collected during the long rainy season from March to May 2009. Dietary data was also collected at the end of the dry season (September to October 2009), in three of the six villages. This paper presents only the data from the wet seasons because it was the period of the year with the highest rates of food insecurity, and highest use of wild and forest foods (Powell *et al.* forthcoming), and because it allowed for larger sample sizes. Mothers responded to a qualitative 7 day food use questionnaire for their own and their child's dietary intake (from memory, with mothers consulting older child during interview). Nutrient intake information was collected for each child using two 24 hour recalls on non-consecutive days. A Mean Adequacy Ratio (MAR) for 11 nutrients (Protein, Thiamine, Riboflavin, Niacin, B12, Vitamin A, Vitamin C, Calcium, Iron, Zinc and Magnesium) and a score of nutrient density across 12 nutrients (above plus fat) was calculated (Dubois *et al.* 2000). Despite the error associated with human memory, most dietary information is collected by recall; for preschool children data is collected from a caregiver (Livingstone and Robson 2000). The source of each food item consumed was recorded and the relative contribution of foods from each source (forest, farm, purchased, etc) to dietary diversity calculated. Dietary diversity is defined here as the number of unique foods consumed in a given period (here 7 days), although it has been measured many different ways (Ruel 2003). Dietary diversity is believed to be a strong marker of diet quality because diversity enhances the likelihood that sufficient quantities of all nutrients are consumed and decreases the likelihood that large quantities of any one potential toxin are consumed (Gibson *et al.* 2000, Johns and Sthapit 2004). Dietary diversity has been linked to higher nutritional status of children and adults, higher micronutrient intake and adequacy and improved food security (Arimond and Ruel 2004, Ruel 2003, Torheim *et al.* 2004).

Forest Cover and Biophysical variables: The location of each household was recorded using a hand held GPS 60CSX (Garmin™). Geographic Information Systems (ArcGIS9.2) was used to analyze aspects of the landscape in proximity to each household. Tree cover was determined using a Landsat eTM+ gap filled image (30 m resolution, Row 166, path 064, Feb. 23, 2006) and a SPOT satellite image (10m resolution, Feb. 17, 2007). Classification of the image was performed using a supervised maximum likelihood algorithm using ERDAS imagine software in 2008 by Jaclyn Hall in association with the CIFOR-ICRAF Landscapes Mosaics project (Hall 2009). A Normalized Difference Vegetation Index (NDVI) of photosynthetic activity was created using the Landsat red and near infrared spectral data. NDVI is commonly used to represent productivity and is significantly related to the phosynthetically active leaf area across different land covers (Carlson and Pripley 1997, Jensen 1996). NDVI is a measure of growing season productivity, which is different from forest. Total area of tree cover and average NDVI value (Average Leaf Area) for the area in proximity to each household was determined for circular areas around each household with radii of 1.0, 1.5 and 2.0km.

Forest use and other household variables: Questionnaires conducted with the head of each household covered education, assets, source of income, participation in wage labour, land use, forest use and agricultural practices of the entire household. Household wealth was assessed using community-based ranking in which a group of community leaders were asked to reach consensus on the wealth rank of each of the households in the study (based on their own set of criteria including: livelihood, housing, health and diet, education, clothing, travel, among others). This measure of wealth was chosen over asset based ranking because it was holistic and better able to incorporate more diverse and nuanced factors than the asset based ranking.

Data analysis: Survey data were analyzed using SPSS Student Pack 18. Groups were compared using Chi-squared and Independent t-tests. Multivariate analysis compared groups using logistic regression.

RESULTS

Wild and forest foods in the diet

Sources of food

A total of 202 unique food items were used by all households in the six villages, including 10 staples (including maize, cassava, banana), 38 species of fruit, 53 species of vegetables, 9 mushrooms (identified only by vernacular name), 45 animal sources foods (including fish) and 41 other items (mostly purchased items such as salt, sugar, oil, spices, drinks and snacks). The mean dietary diversity (number of food items consumed within the last 7 days) was 38.4 for mothers and 39.3 for children (with normal distributions and no

FIGURE 2 *Sources of all food items (average of mothers and children)*

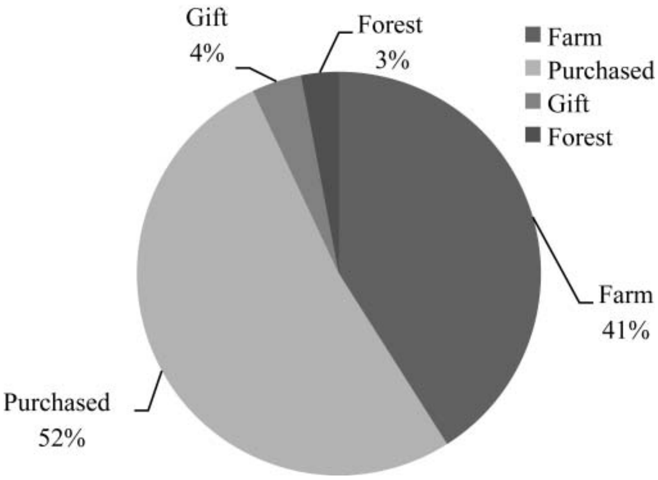
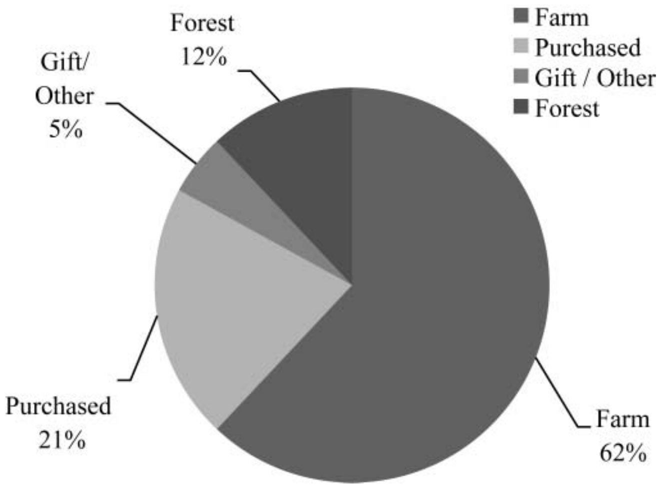


FIGURE 3 *Sources of wild food species (average of mothers and children)*



differences between children and mothers). Sources of food recorded included: purchased foods (store, market, vendor, local restaurant); farm, garden and fallow (combined because use of these terms and their definitions were inconsistent across informants); gift (including foods consumed at a friend's house or a funeral); and foods from forest or non-farm land (river, forest, bush).

An average of 51.9% of food items were purchased, 41.1% were obtained on farm and only 2.6% were obtained from forest (and un-cultivated land) (Figure 2). However, wild or uncultivated species (regardless of reported source) accounted for a much higher percentage of the diet (15.4%) than foods that respondents reported were obtained from the forest / non-farm land. Many (61.7%) of these wild species were obtained from areas considered part of farmland, rather than areas considered forest (Table 1, Figure 3). Of the 53 species of vegetables consumed, 41.5% of them were cultivated (domestic) and 58.5% were wild uncultivated species.

Figure 4 presents the differences in wild species foods vs. foods obtained from forest / non-farm land by food type; while the majority of wild bird (83.3%) and mammal (80%) species consumed are obtained from the forest, most of the wild species of vegetables (70%), mushrooms (62.5%) and fruit (50%) were obtained within farm land (including fallow and agroforests). Data for figure 4 was calculated from the list of all food items consumed, by counting the number of wild species and the number of items that respondents reported as obtained from the forest (>10% of the time).

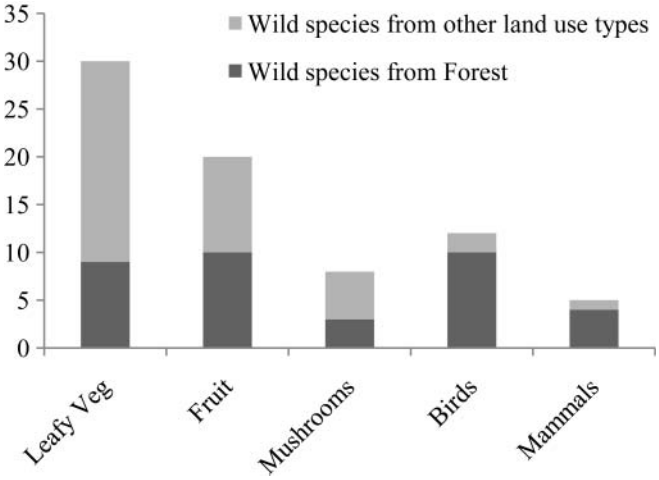
Percent of diversity used

Community level diversity (Table 2) was defined as the total number of food items used by the community as a whole (represented by all individuals included in the survey). The 'primarily source' of each food item was determined as the most common source reported for each food item (used because most food items were obtained from different sources

TABLE 1 *Dietary diversity, mean percent of food items from forest, purchased, gifts, farm and wild species, and sources of wild species food items for mothers and children*

	Mother (N=269)		**Child (N=269)**	
	Mean±SD	**Min-Max**	**Mean±SD**	**Min-Max**
Dietary Diversity (number of items)	38.4±11.6	14-81	39.3±11.7	15-80
Percent- Reporting ≥1 items from the **FOREST** (%)	44.6	-	45.4	-
Percent of Food Items **PURCHASED** (%)	51.4±12.9	25.8-91.7	52.4±12.5	25.8-91.7
Percent of Food Items from **GIFTS** (%)	4.6±6.3	0-45.0	4.9±6.8	0-50.0
Percent of Food Items from **FARM** (%)	41.6±12.2	5.0-68.3	40.5±12.2	5.0-66.7
Percent of Food Items from **FOREST** (%)	2.6±4.0	0-23.9	2.5±3.7	0-22.8
Percent of Food Items from **WILD SPECIES** (%)	15.4±5.4	-	15.3±5.2	-
Percent of **WILD SPECIES**: **PURCHASED** (%)	22.1±22.5	0-100	20.7±21.2	0-100
Percent of **WILD SPECIES**: **from GIFTS** (%)	2.5±7.8	0-50	3.8±10.4	0-80
Percent of **WILD SPECIES**: **from FARM** (%)	61.6±24.7	0-100	61.9±25.2	0-100
Percent of **WILD SPECIES: from FOREST** (%)	12.5±16.8	0-61.5	12.0±16.3	0-63.6

FIGURE 4 *Total number of wild species from the forest and other land use types used by all surveyed households, by different food types*



by different households and wild species came from many sources). The *percent of diversity used* for food from each source was calculated as the mean individual dietary diversity from that source divided by the community level diversity of foods primarily obtained from that source, and is assumed to be approximately equal to the percent of available diversity used.

The higher the *percent of diversity used*, the more similar individuals were to each other in terms of food items consumed from that source. Table 2 shows that the *percent of diversity used* was 30% for purchased foods and 15% for food from the farm, indicating that individuals used many of the same purchased foods, but were less similar in their use of foods from the farm. *Percentage of diversity used* was very low for wild species (6.7%) and foods from forests (3.8%) indicating large variation from one individual to the next in terms of species used from these sources (few food items in common).

Diet, Forest Use and Forest Cover

Forest food use

Only 44.6% of mothers and 45.6% of children were reported to have consumed one or more foods obtained from the forest in the past 7 days (Table 1). Compared to those not reporting

TABLE 2 *Community level diversity, mean individual dietary diversity and percent of (available) diversity used for all foods and different types of foods*

Source	Community level diversity	Mean individual dietary diversity	Percent of diversity used
TOTAL (All sources)	202	39	19.3%
Purchased	69	20	29.0%
From Farm	106	16	15.1%
From Forest	26	1	3.8%
Wild Species	91	6	6.7%

TABLE 3 *Differences in characteristics for mothers and children using and not using foods from the forest for lowland villages*

Characteristics	Mothers		Children	
	Using Forest Foods (N=93)	Not using Forest Foods (N=91)	Using Forest Foods (N=92)	Not using Forest Foods (N=92)
Dietary Diversity (Count)	39.5±11.6	36.0±11.3*	40.2±11.5	37.1±11.0(1)
Number of Animal Foods Used	6.3±2.7	5.2±2.6*	6.3±2.6	5.3±2.6*
Percent of diet from Animal Foods	15.7±4.4	14.1±4.9*	15.5±4.5	13.8±4.4*
Percent of diet from Purchased Food	44.5±10.1	54.3±12.3**	46.2±9.6	54.8±11.6**
Percent of diet from Wild Species	18.6±6.0	13.3±5.1**	19.0±5.4	13.4±4.8**
Leaf Area 200m (Average)	3.09±0.35	2.82±0.46**	3.07±0.35	2.79±0.47**
Tree cover 1.0km (ha)	236.7±169.3	158.6±123.1**	233.0±169.1	163.1±126.5*
Tree cover 1.5km (ha)	793.7±527.3	527.3±304.7**	788.7±515.3	535.3±308.0**
Tree cover 2.0km (ha)	1785.8±1044.0	1343.4±595.6**	1768.9±1045.1	1365.1±614.0*

* statistically significant in an independent t-test p<0.05

** statistically significant in an independent t-test p<0.001

(1) p=0.061. When both upland and lowland villages are included in the analysis, children reported to have used forest foods had significantly higher dietary diversity than those not using forest foods

use of forest foods, those reporting use of foods from forest / non-farm land had higher tree cover within 1km, 1.5km and 2km radii around their homes. The percent of mothers and children reporting use of foods from the forest was significantly higher in the lower elevations[2]. Table 3 displays only results for the four lowland villages.

Mothers and children who used foods from the forest had significantly higher dietary diversity, consumed a greater number of animal source food items, obtained a lower percentage of their food by purchasing and a higher percentage of their food from wild species (Table 3). Children who consumed forest foods had a higher nutrient density score (Student's t-test p=0.045, 39.0 vs. 36.2 for those not using forest foods), and a higher but statistically insignificant mean nutrient adequacy ratio (MAR) (Student's t-test p=0.114, 0.781, vs. 0.753 for those not using forest foods).

Those who reported use of forest foods were not different from those reporting no use in terms of wealth[3], wage labour participation, acres owned, age of mother, education, size of household or ethnicity (all elevations and low elevation only). However, in addition to elevation, a couple of other potential confounding variables were identified. There was a trend for individuals reporting use of forest foods to be more likely to come from a male headed household (Chi squared test for low elevation villages mothers p=0.48 and children p=0.057). The percentage of mothers and children who reported using foods from the forest was significantly different among villages [higher in Kiwanda (71%) and Kwatango (81%) than in Misalai (30%) and Shambangeda (39%), Bombani (24%) and Tongwe (25%)]. It is impossible to determine which of the differences between villages are responsible for the observed differences in forest food use; however a number of characteristics of Kiwanda and Kwantango merit consideration, including their greater isolation, lower access to wage labour and lower population densities (Tanzania 2002). In multivariate logistic regression analyses with forest food use by mothers or children as the dependant variables, controlling for village and elevation, amount of tree cover within 1.5km from the house made a significant addition to the model but gender of the head of household and wealth did not (for mothers using forest foods to those not $R^2 = 0.324$, $p<0.01$ (of change from adding tree cover), N=260; and for children using forest foods to those not $R^2 = 0.297$, $p<0.05$ (of change from adding tree cover), N=254).

Trips to the forest

Of household heads in all 6 villages, 67.4% reported having visited the forest within the last year, 46.4% within the last month and 33.8% within the last week. The average number of trips for respondents who had gone to the forest in the last month was 8.1±8.6 and the last week was 3.0±2.0. Household heads from upland villages reported significantly more trips to the forest than households from lowland villages (past year 75% upland vs. 63% lowland, past month 60% upland vs. 40% lowland, and past week 45% upland vs. 30% lowland).

In the lowland villages, households reporting trips to the forest had lower tree cover within a distance of 1.0, 1.5 and 2.0km from their homes, but greater area of teak plantation. They also had significantly less unprotected forest within a 0.5km radius of their homes (Table 4). These relationships can be seen clearly on the map (Figure 1). These findings are likely linked to the interpretation of the word *forest*, as explained below.

TABLE 4 *Differences between households visiting the forest and those not for tree cover, teak plantation cover, unprotected forest and leaf area for lowland villages only*

Land cover Characteristics	Forest in last year		Forest in last month		Forest in last week	
	YES (N=116)	NO (N=68)	YES (N=74)	NO (N=110)	YES (N=56)	NO (N=128)
Leaf Area 200m (Average)	2.88	3.02*	2.73	3.06*	2.70	3.03*
Tree Cover 1.0km (ha)	163.0	256.3**	146.6	231.7**	133.5	225.5**
Tree Cover 1.5km (ha)	550.2	849.3**	512.3	760.6**	470.8	743.9**
Tree Cover 2.0km (ha)	1341.4	1946.7**	1237.6	1785.4**	1144.9	1749.0**
Teak Cover 1.0km (ha)	194.9	38.7**	253.9	58.6**	275.1	76.8**
Teak Cover 1.5km (ha)	614.6	180.2**	782.3	233.2**	832.1	288.6**
Teak Cover 2.0km (ha)	1371.0	443.9**	1665.2	600.0**	1755.5	710.3**
Unprotected Forest 500m (ha)	2.38	4.60**	1.72	4.19**	1.61	3.89**

* statistically significant in an independent Student's t-test p<0.05

** statistically significant in an independent Student's t-test p<0.001

[2] Likely in part due to the ecological differences between the dense humid upland forest and more open the lowland forest types

[3] Using asset based wealth ranking there is a trend for children who had used forest foods to be from less wealthy households (but not mothers)

Dietary intake was related to reported trips to the forest in a number of unexpected ways. In the lowlands, individuals from households who reported visiting the forest had significantly lower dietary diversity than those that did not report visiting the forest. Individuals from households who visited the forest obtained a lower percentage of their diet from the farm and a higher percentage from purchased sources. Additionally, individuals from households who visited the forest consumed fewer types of animal foods and borrowed food more often than those from households who had not visited the forest. Those from households who reported trips to the forest (across most time periods) also obtained a lower percentage of fruit, fish and animal foods from the forest, consumed fewer wild species and tended to be less likely to use forest foods. This is likely due to the strong relationship between trips to the forest, wage labour and wealth in the lowlands. The 50 year old mature teak plantation is considered forest by local people and was being actively harvested during the study period.

Individuals from households who had visited the forest in the previous week or month were significantly less wealthy than those who had not (high and low elevation). Chi squared tests showed that those who reported trips to the forest were more likely to engage in wage labour (for high and low elevation, in the last week, month and year $p<0.005$). In the upland, those who engaged in labour on the tea estates were more likely to report trips to the forest (for all time frames). In the lowland, those who engaged in wage labour in the timber industry were more likely to report trips to the forest in the last week and month. Compared to households who did not report trips to the forest (at all elevations), those reporting trips to the forest tended to be less likely to have been born locally (possibly because most immigrants to the area engage in wage labour), to own fewer acres of land and spend fewer hours in the farm; however, there were no differences between ethnic groups nor male and female headed households. In logistic regressions with 'visited the forest in the last year or month' as the dependant variables, controlling for elevation and wage labour in the tea or timber industry, tree cover within 2km from the house and whether the household members had been born locally made significant contributions to the model. With 'visited the forest in the last week' as the dependant variables, wealth and tree cover within 2km were the variables added to the model in forward (stepwise) conditional analysis.

DISCUSSION

Limitations of the study: The complexity of the data and the many potential confounding variables meant that this study was only able to identify associations between variables. The collinearity between variables and the cross-sectional study design (rather than longitudinal), prohibit conclusions about causality. While the methodology section notes limitations of dietary assessment methods, alternatives such as anthropometric and biochemical measures of nutrition can be even more problematic in settings where parasitic infection rates are high, such as the East Usambara Mountains (Semba and Bloem 2008). Given the local history of forest policy and governance, reporting may have been biased by hesitancy to disclose illegal forest use / activities. The fact that this study only describes relationships in the wet season, the season with the greatest use of wild and forest foods, could mean that they differ during other times of the year. Further research, especially longitudinal studies examining the impact of changes in forest cover and access over time on the use of forest foods and nutrition would improve the current state of knowledge. Although the relationships described herein remain unsubstantiated their potential implications for policy and practice provide food for thought for conservation researchers and practitioners.

The importance of forests and wild foods in contemporary diets: Although the Shambaa people historically obtained much of their starchy staple food items from agriculture, Feierman (1974) and Fleuret (1979) suggest that much of the leafy vegetables and meat in the traditional diet were obtained from wild sources. Over 30 years later, wild foods, accounting for 15% of the items in the diet, still make a significant contribution.

Of the wild species consumed (from any source) 40% were vegetables, 27% were fruit, 23% were small mammals and birds, and 11% were mushrooms. Of the items obtained from the forest 39% were birds and small mammals, 28% were fruit and 25% were leafy vegetables (figures and total do not include wild fish species / fish from wild sources, e.g. rivers) (Figure 4). Because fruits, vegetables and animal source foods are important sources of micronutrients, even in small amounts they make an important contribution to local diets. These types of foods, compared to starchy staples and snack foods obtained through agriculture or purchasing, have higher density of most micronutrients relative to energy, carbohydrates and sugars. Data on the nutrient composition of wild foods are lacking so direct comparison between wild and non-wild fruits or vegetables is difficult (and impossible for animal source foods). Moreover, nutrient content of all fruits and vegetables can be extremely variable depending on variety, climate, ecology, harvest and storage factors. Msuya and colleagues (2008) found high variation in iron, zinc and beta-carotene content of wild vegetables harvested from different regions in Tanzania. In the East Usambaras they found high levels of these 3 nutrients in wild vegetables (compare for example the three most commonly consumed wild vegetables *Launaea cornuta*, *Corchorus olitorius* and *Bidens pilosa* with beta-carotene 6800, 6310, 2320 μg/100g, iron 9.9, 4.2, 12.05 mg/100g and zinc 0.579, 0.196, 0.484 mg/100g values respectively to the three most commonly consumed cultivated vegetables *Amaranthus* spp., sweet potato leaves and pumpkin leaves with beta-carotene 5716, 5870 and 3600 μg/100g, iron 2.3, 0.5, 0.6 mg/100g and zinc 0.6, 0.2, 0.1 mg/100g values respectively).

Rural African diets are notorious for the high percent of energy obtained from staples such as maize and cassava and low intake of animal source foods (Stephenson *et al.* 2010). The low intake of the latter leads not only to a low intake of protein but also to inadequate intake and low bioavailability of many micronutrients (Murphy and Allen 2003). Consumption of animal source foods (from domesticated animals or sustainably harvested wild mammals, birds or fish) is a preferred strategy for improving micronutrient status and therefore children's growth and cognitive development in developing countries (Murphy and Allen 2003). It is important to note that the wild animal species consumed in this study included two types of small antelope and two types of rodent[4]. Of the 16 reports of wild animal consumption, 10 were for *Thryonomys* spp. (a common small rodent). In another part of the Eastern Arc, the Udzungwa Mountains, populations of all mammals except *Thryonomys* spp. were found to be so depleted that the author felt that no level of hunting could be sustainable (Nielsen 2006). It seems very likely that in the East Usambaras, faunal resources are similarly depleted and overexploited (possibly with the exception of *Thryonomys* spp.).

In this study population Powell et al. (forthcoming) report that wild species contribute an average of 2% of daily energy intake, 2% of fat intake, 7.4% of protein intake, 19.2% or iron intake, 20% of vitamin C intake and 31% of vitamin A (in Retinol Activity Equivalents) intake. The finding here that, compared to those who had not, children who had consumed forest foods had higher nutrient adequacy (not statistically significant) and nutrient density across multiple nutrients further supports the contribution of wild and forest foods to nutrition.

Uncultivated food species from cultivated land: Although the results of this study do not allow for conclusions about the net trade-offs between agricultural intensifications vs. maintaining biodiverse agricultural systems[5], they do show that biodiversity within agricultural land makes an important contribution to the local diet by way of the significant amount of uncultivated foods being collected on-farm (62%). Other research has similarly found a large portion of wild species obtained from agricultural land, coining these foods "the hidden harvest" (Bishop and Scoones 1994).

Wild species from farm land included fruit from trees and shrubs growing in field margins and fallows, mushrooms from recently cleared fields, leafy vegetables from field margins and fallow areas, and many leafy vegetables which would otherwise be considered weeds growing among (and often competing with) newly planted maize and other crops. Micro-climates provided by diversity of land use on farms provide for a diversity of wild plant foods. A recent review of wild foods in agricultural systems by Bharucha and Pretty (2010) highlights the fact that labels of hunter-gather vs. agricultural imply a false dichotomy in which wild foods are of limited importance in agricultural livelihoods. Most rural human populations engage in active management of useful wild species; in fact many farmers do not make clear distinctions between cultivated and uncultivated (Bharucha and Pretty 2010). In the East Usambaras people tolerate (do not clear while weeding) wild leafy vegetables, such as *mchunga* (*Launaea cornuta*), in their fields and teach their daughters to harvest in a manner that ensures regeneration (Powell *et al.* 2010). Human activity in forested landscapes tends to increase the density, diversity and/or value of plant, but not animal, species useful to humans (Ambrose-Oji 2003, Parry *et al.* 2009, Toledo and Salick 2006).

The importance of agricultural biodiversity for agriculture and conservation has been established (Sunderland this issue); although further substantiation is needed, the results of this study suggest that the maintenance of farms with biodiverse fallows, field margins and agro- and working forests could benefit human health and nutrition as well, through the provisioning of wild foods. Less than 25% of households in this survey reported having fallow land in the last 12 months (of those the average area was 1.8 acres for 1.5 years). Conservation efforts should focus on the landscape scale approaches; encouraging mosaics of forest, agroforest, fields and fallow within agricultural landscapes surrounding protected areas will likely enhance biodiversity and human health simultaneously (CBD 2006, Dudley *et al.* 2005, Hall *et al.* 2010).

Wealth, time, proximity of forests and other constraints on use of forest species: Wild and forest foods are often suggested to be more important to poorer households (Colfer *et al.* 2006, Harris and Mohammed 2003), although these relationships are not always consistent (Ambrose-Oji 2003, Bharucha and Pretty 2010). In this study there were no significant quantitative associations between forest food use and wealth (assessed by community-based ranking); however, qualitative evidence suggests that cash availability is a contributing factor in the use of wild and forest foods: "*Those leafy vegetables are in the farm and if today I do not have money it will force me to leave home and waste time and go to look for that vegetable so that it can fill that gap.*" Beatrice Akida (single mother and farmer in Tongwe village).

In many contexts, it is access, rather than availability that limits use of wild and forest foods. One important constraint on access is the free time required to collect wild and forests foods (Kuhnlein and Receveur 1996), mediated by travel time to reach the harvesting site and efficiency of harvesting. Although wild foods are free, they can be inaccessible when daily chores, livelihood efforts and / or wage labour take all of person's time and energy. In Cameroon, Koppert *et al.* (1993) found that due to women's time-demanding daily

[4] Two households reported *digi digi* or *paa* (said to be the same species, *Rhynchotragus* spp.) and two households reported *funo* (probably a species of Duiker, *Cephalophus* spp.), all from the forest without specification (because hunting in reserved forests is illegal all informants would presumably claim to obtained animals from unprotected forests only). The exact species of antelope is impossible to determine due to error in informant identification, and importantly inaccurate reporting. The other species of rodent was kuhe (*Cricetomys gambianus*)

[5] Agricultural shifts towards specialized, intensified systems are often touted as key to development, however improved income does not always translate to improved diet and nutrition (see Kennedy 1989 and Dewey 1989).

tasks, wild or forest foods had to be close to forest camps and in sufficient quantities to be included in the diet. In the East Usambaras wild and forest foods are used by many households when there is not enough available cash to purchase cultivated vegetables, dry fish or legumes. The period just before and during the rains is one of the most agricultural labour intensive (land preparation, planting and early weeding), but is also the period when higher wild food use was recorded. Conversely, despite low labour inputs in the post harvest period at the end of the dry season (when cash is readily available), households reported less use of wild and forest food resources at that time (Powell *et al.* forthcoming). Although many species of wild foods, especially wild leafy greens, are less available in the dry season, there are many which persist in shaded field margins and wet areas (as well as many wild fruits which ripen in the dry season). This might suggest that free time and availability of wild and forest foods are not strong factors determining use in the East Usambaras. Of course if a household lacks available cash to purchase foods, but also has constraints on access to wild and forest foods (e.g. is far from the forest or has limited free time), this could preclude any increased use of wild and forest foods, even if the low *percent of diversity used* for wild and forest foods used suggests that these foods could make greater contributions to the diet. Lack of free time may underpin the finding that female headed households were less likely to use forest foods than male headed households (with a reduced adult work force they may not have the time needed to collect forest foods).

Other research has suggested that wild and forest foods are important as a ‘safety-net’ in times of hardship (Colfer 2008, Johns and Maundu 2006, Vinceti *et al.* 2008). In the East Usambara Mountains, this importance seems to be mediated by forest proximity (as households far from forests require more travel time to access forest foods). These findings suggest that maintaining forest cover around villages and homes may be necessary if forest foods are to remain in the diet, with important implications for village and household level land management.

Interpretation of questions about forest: In part due to the long and complicated history of forest research and conservation in the East Usambaras, local people have sensitivities to questions about forests and forest use (Vihemäki 2005). Rantala (2010) notes “. . . whenever a tree-dominated area is privately owned, even if it is left to regenerate as forest, it is still called shamba (farm), not msitu (forest). . . . it is common that ‘msitu’ is only used to refer to a reserved area” such as a government or a village forest reserve. The conservation history in the region has created significant hesitation to admit use of forests; however, this varies from person to person (Vihemäki 2005). The vegetation cover local people refer to as forest (or non-farm land) when women report where a food product has been obtained is likely more closely related to scientific definitions based on vegetation structure or canopy cover. Conversely, questions about ‘visiting a forest’ conjure ideas about places that are reserved or officially protected, similar to Rantalla’s (2010) description. The strong association between wage labour and reported trips to the forest in this study may be related to the fact that wage labour provided legitimate reasons to visit government owned forests. In the lowlands the timber industry provided the majority of wage labour, and in the uplands the tea industry workers often passed through tea estate or reserved forests to reach harvest locations. Had harvesting of the mature teak forest not been underway at the time this study was conducted, results may have been quite different. Vihemäki and colleagues (forthcoming) suggest that historic forest management practices, in which local people had restricted access to forests and no involvement in management and decision making, led to local peoples’ unwillingness to use forest products (forests are seen as a place where illegal activities are undertaken), and that this an important factor in the limited forest food use in the area. Vihemäki and colleagues (forthcoming) describe the current forest management regimes (including joint forest management and community based forest management of village forests) in the area and the use rights to forest foods associated with each, and note that despite efforts to decentralization forest management local people perceive a major decrease in the importance of the forest as a source of food. Within the frame-work of these local definitions, two possible conclusions can be drawn from the finding that those who reported visits to the forest had lower area of tree cover and less unprotected forest within a close proximity of their houses. Firstly, the relationship could simply be an artefact of the fact that lowland households who engaged in wage labour lived in areas with less unprotected forest cover nearby[6]; alternatively (or additionally) this finding could suggest that households in areas with greater area of tree cover within the agricultural mosaic obtained subsistence products from treed land which they did not consider forest (such as agroforests, farms and fallows). Households in the uplands, where there was significantly greater tree cover, were more likely to report visiting the forest and yet fewer of them used forest foods. The significantly higher average leaf area and amount of unprotected forest around households not visiting the forest compared to those that did reported visiting the forest lends support to the latter conclusion (see Table 4).

CONCLUSIONS

The food-security and nutrition situation in Tanzania remains discouraging. Recent improvements in children’s growth rates have not changed the fact that rates of stunting in Tanzania are still among the highest in the world and that micronutrient deficiency remain a major problem (UN-SCN 2004). Globally, Tanzania is one of the lowest ranked countries in

[6] Not including teak forests. Households involved in wage labour had a greater area of teak cover around their homes. In the uplands there is no difference in tree cover around the home between households that engage in wage labour and those which do not

terms of percent caloric intake from fats and simple sugars (Millstone and Lang 2003); however a nutrition transition from a traditional diet to a diet high in processed foods, salt, sugar and fat has begun. Because of this, communities may face increased rates of obesity and chronic diseases (such as type II diabetes and hypertension) before overcoming food insecurity and micronutrient deficiency (Maletnlema 2002). Research from the 1970's suggested that at the time a transition had begun (Fleuret and Fleuret 1980), and the high percentage of foods purchased in this study (even in Kwatango, the most remote village) demonstrates that this trend may be becoming ubiquitous. Overcoming micronutrient malnutrition and mitigating the nutrition transition simultaneously will require diets rich in micronutrients but without excess energy, fat, sugar or salt. Many forest and wild foods, especially those of plant origin, meet these criteria and could play an important role, especially if appropriate and timely nutrition education can ensure that they are consumed in place of increasingly accessible processed and fried foods. The contribution of wild and forests foods to dietary diversity may support local people's nutritional resilience in the face of social-cultural, economic and environmental change.

The findings of this study show that in the East Usambaras use of forests for food resources by local people is currently limited, but use of wild species is higher, primarily obtained from the farm. Households with greater tree cover in close proximity are more likely to consume wild and forest foods even while reporting fewer visits to protected forests, underscoring the importance of tree cover and fallow within the agricultural mosaic.

Food plays a central role in cultural and personal identity and fulfils multiple symbolic and cultural functions (Khare 1980, Kuhnlein and Receveur 1996); promoting the cultural importance as well as health and nutrition benefits of forests foods (and the maintenance of the traditional food system) may provide impetus for conservation-positive actions by local communities, people and governments. As population densities in the rural landscapes of Africa continue to increase forest remnants are being reduced and eliminated, as are fallow length and area in the agricultural landscape. Health is one of the strongest motivators for people; the health of their families is a particularly high priority for women, who bear the burden of care of ill family members (Wan *et al.* this issue). In a setting where participatory strategies for engaging local people in conservation have been only partially successful (Vihemäki 2005), the results of this study linking forest cover, forest food use and nutrition offer potential motivation for local people to maintain forest cover within the landscape mosaic. As paradigms in forest conservation shift, it is important to not lose sight of the importance of forests for human diet and nutrition.

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When formal and market-based conservation mechanisms disrupt food sovereignty: impacts of community conservation and payments for environmental services on an indigenous community of Oaxaca, Mexico

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SUMMARY

The impacts of Payments for Environmental Services (PES) and creation of formal Voluntary Conserved Areas (VCAs) on local diets, agricultural practices, subsistence hunting and livelihoods, were assessed in a Chinantec community of southern Mexico. The community has set aside VCAs covering 4 300 ha of its 5 928 ha of communal lands and forests, and has received over $769 245 in PES for protection of 2 822 ha of watersheds roughly overlapping the VCAs. Community members attribute decreased maize and other subsistence crop yields, reduction of area available for agriculture, and shortened fallow cycles to the new conservation policies. Meat consumption has decreased after a hunting ban, accompanied by increases in purchasing meat still consumed. By agreeing to conservation measures that restrict their use of ancestral agricultural land and prohibit hunting, villagers have seen local food security become less stable, leading to greater dependency on external food supplies. Continued strict preservation measures under the guise of community conservation could lead to losses of agrobiodiversity, dietary diversity, hunting skills and associated environmental knowledge. Appropriate application of the precautionary principle is essential to avoid structural displacement of local peoples and to ensure the success of community conservation initiatives.

Keywords: Community conservation areas, nutritional transition, precautionary principle, shifting cultivation, traditional food systems

Quand les mécanismes de conservation formelle et basée sur le marché dérangent la souveraineté des aliments: impacts sur la conservation de la communauté et les paiements pour services environnementaux dans une communauté d'Oaxaca au Mexique

J.T. IBARRA, A. BARREAU, C. DEL CAMPO, C.I. CAMACHO, G.J. MARTIN et S.R. McCANDLESS

Les impacts des paiements pour services environnementaux (PES) et la création de zones de conservation volontaires formalisées (VCAs) sur la nutrition locale, les pratiques de l'agriculture, la chasse de subsistance et les revenus ont été évalués dans une communauté Chinantec du Mexique du sud. La communauté a mis à part des VCAs recouvrant 4300 ha de ses 5928 ha de terres et forêts communautaires et a reçu plus de 769 245$ de PES pour sa protection de 2822 ha de bassins versants dont la superficie coïncide en gros avec celle des VCAs. Les membres de la communauté attribuent une décroissance des récoltes de maïs et d'autres cultures de subsistance, la réduction de la surface disponible pour l'agriculture, et les périodes réduites de jachère aux nouvelles politiques de conservation. La consommation de viande a décru depuis un interdit de chasse, accompagné d'une augmentation de quantité viande qu'il faut maintenant acheter pour consommer. En acceptant des mesures de conservation restreignant l'utilisation des terres arables ancestrales et interdisant la chasse, les villageois ont vu la sécurité de leurs aliments locaux devenir moins stable, les conduisant à une dépendance plus grande sur vis à vis des fournisseurs extérieurs. La continuation de mesures de conservation strictes sous le couvert de conservation de la communauté pourrait conduire à des pertes de l'agrobiodiversité, de la diversité nutritionnelle, de l'habileté à chasser et de la connaissance environnementale associée. Une application appropriée du principe de précaution est essentielle pour éviter un déplacement structurel des populations locales et pour assurer le succès des initiatives de conservation communautaires.

Cuando mecanismos de conservación formales y de Mercado perturban la soberanía alimentaria: Impactos de la conservación comunitaria y de los pagos por servicios ambientales en una comunidad indígena de Oaxaca, México

J.T. IBARRA, A. BARREAU, C. DEL CAMPO, C.I. CAMACHO, G.J. MARTIN y S.R. McCANDLESS

Se evaluaron los impactos de los Pagos por Servicios Ambientales (PSA) y de la creación de Áreas de Conservación Voluntaria (ACVs) formales, sobre la dieta local, prácticas agrícolas, cacería de subsistencia y sustento local de una comunidad chinanteca del sur de México. La comunidad ha asignado 4 300 ha de sus 5 928 de tierras comunitarias y bosques a ACVs, y ha recibido más de $769 245 en PSA por la protección de 2 822 ha de cuencas que se traslapan con las ACVs. Miembros de la comunidad atribuyen disminuciones en la producción de maíz y otros cultivos de subsistencia, una reducción del área disponible para agricultura y un acortamiento del período de descanso de las tierras agrícolas, a las nuevas políticas de conservación. El consumo de carne ha disminuido luego de una prohibición de cacería, acompañado de un aumento en la compra de carne que aún se consume. Estando de acuerdo en estas medidas de conservación que restringen el uso de tierras agrícolas ancestrales y que prohíben la cacería, los pobladores han visto que la seguridad alimentaria local se ha vuelto menos estable, llevando a una mayor dependencia por suministros alimenticios externos. La continuidad de medidas de preservación estrictas, bajo la apariencia de una conservación comunitaria, podrían llevar a pérdidas de agrobiodiversidad, diversidad dietaria, habilidades de caza y el conocimiento ambiental asociado. La aplicación apropiada del principio de precaución es esencial para evitar el desplazamiento estructural de comunidades locales y asegurar el éxito de las iniciativas de conservación comunitaria.

INTRODUCTION

Payments for Environmental Services (PES) to local communities have been touted nationally and internationally as a market-based mechanism to reward the protection of biodiversity, forests and watersheds on communally owned land. In Mexico, financial subsidies that are part of a national PES programme (McAfee and Shapiro 2010) have been provided to some communities that have Indigenous and Community Conserved Areas (ICCAs), including ones that are certified Voluntary Conserved Areas (Martin *et al*. 2010). Internationally, ICCAs are seen a possible solution to multiple problems associated with conservation practices that exclude local communities (Borrini-Feyerabend and Kothari 2008).

There is a growing interest in exploring the ways in which these financial subsidies and new trends in community conservation are evolving and affecting various aspects of local rights and livelihoods, including food sovereignty.

Food sovereignty

Food sovereignty is broadly conceived to include the diverse rights that people exercise to protect domestic agricultural production, maintain nutritious diets and regulate market access, all as part of a quest to achieve sustainable development. As Pimbert (2009: 5) notes, food sovereignty is an alternative agricultural and food policy framework that "aims to guarantee and protect people's space, ability and right to define their own models of production, food distribution and consumption patterns." He characterises food sovereignty as a process that seeks to regenerate autonomous food systems that are equitable, socially just and ecologically sustainable.

Key to food sovereignty are traditional food systems (TFS), which incorporate a wealth of acquisition, production, processing, distribution and recycling techniques (Kuhnlein and Receveur 1996, Pimbert 2009). These localised food systems, laden with social meanings and ecological realities, are an integral part of people's cultural identities, knowledge systems, health and economies throughout the world (Johns and Sthapit 2004, Kuhnlein *et al.* 2009). TFS provide edible plants, animal protein and animal micronutrients from traditional agroecosystems, agroforestry and livestock grazing. In addition, they incorporate foods derived from gathering, fishing and hunting as well as exchange with other communities.

Many peoples throughout the world are increasingly distanced from self-sufficiency, as they abandon local dietary traditions and increase their dependence on industrialised foods (Kuhnlein *et al*. 2004, Uauy *et al*. 2001). These changes, part of a complex process referred to as nutritional transition, generally have adverse impacts on local subsistence, food quality and variety, and ultimately public health (Damman *et al*. 2008, Kuhnlein *et al*. 2007, Popkin 2003, 2004). Transitions in various aspects of food sovereignty have occurred with industrialisation, urbanisation, economic development and the globalisation of markets (Damman *et al.* 2008, Pimbert 2009). Dietary changes are a non-directed consequence of other environmental or external forces, and they appear to be accelerating especially in low- and middle-income countries (Kuhnlein and Receveur 1996). These dietary changes are generally promoted by national policies or international programmes that are influenced by global economic and political priorities, rather than responding to local concerns (López and Mariano 2008).

The emergence of community conservation

International and national laws and policy require the protection of not only the biodiversity that provides sustenance for the entire world's population, but also the traditional systems of knowledge, management and use of this biodiversity that meet the basic needs of local people. In the quest to achieve biodiversity conservation, the global tendency has privileged an approach which excludes people in protected areas (West and Brockington 2006), leading to displacement of communities and restrictions on their access to resources (Agrawal and Redford 2009). By ignoring the role of local cultures in resource management, this trend has promoted a disarticulation between human populations and their environments (López and Mariano 2008). This has resulted in negative impacts such as the disruption of livelihood opportunities, increase in damages to crops by wild animals, and alteration of local economies (Hough 1988, Igoe 2006, Mishra 1982).

The increasing appreciation of the interdependence of diverse environments and local communities and the roles they play in conserving biological diversity and agrobiodiversity has inspired community-based conservation approaches around the world (Gibson and Marks 1995). ICCAs and other modes of community conservation have become important alternatives to government protected areas. In 2004, the IUCN included ICCAs as a distinct category of governance of protected areas (Martin *et al.* 2010), and they have now been recognised in diverse ways throughout the world, including in Africa (Metcalfe 1994, Wainwright and Wehrmeyer 1998), Asia (Bajracharya *et al.* 2005), and Latin America (Camacho *et al.* 2010, Ellis and Porter-Bolland 2008, Toledo 2003).

There is little information about the effectiveness and consequences of this new approach to conservation (Berkes 2009), especially when community protected areas receive external support guided by market mechanisms. Empirical analysis of these arrangements is especially important when ICCAs are linked to new paradigms such as enterprise-based and payments-based conservation (Lele *et al*. 2010). These neo-liberal approaches have spread globally as influential environmental and economic institutions act on the premise that environmental degradation is due to market malfunction or to a lack of financial incentives to protect the services that ecosystems provide (Turner *et al.* 1994). Gómez-Baggethun *et al*. (2010) posit that the shift toward monetisation of ecosystem services marks a conceptual swing from economic recognition of the use value of nature toward a focus on the exchange value of resources.

Food sovereignty and community conservation in Mexico

The majority of indigenous peoples in Mexico base their food consumption on small-scale agricultural and livestock production, complemented by hunting and gathering of wild foods. The agricultural system is centred on the *milpa*, a traditional Mesoamerican polyculture in which maize and many other food plants are cultivated or available as spontaneous semi-domesticates (Hernández X 1977).

In tropical forested areas, the *milpa* forms part of swidden cultivation in which a section of forest is cut and burned for cultivation as part of the agricultural cycle (Ávila 2010). The parcel is then left fallow for several years enabling regeneration of herbs, shrubs, and later trees. The cultivation of *milpas* in forest ecosystems generates a mosaic of landscapes, biotic communities, species and genetic diversity that are intimately linked to local TFS (Vandeermer and Perfecto 2007) and the maintenance of broader patterns of biological and cultural diversity. For indigenous peoples, biodiversity within and around *milpas* is essential in order to achieve a complete and healthy diet (Johns and Sthapit 2004).

In Mexico, many ICCAs are community initiatives closely related to local systems of management of natural resources, lifestyles, political organisation and land tenure security (Martin *et al.* 2010). Civil society and governmental institutions have supported these local initiatives in recent years. Beginning in 2003, the National Forestry Commission (Conafor; Comisión Nacional Forestal) established PES to support local landowners – if they maintain areas of forest cover – through a series of subsidies (compensatory payments) paid out over periods of five years to avoid changes in land use (Anta 2007). Other governmental programmes, in conjunction with the National Commission of Natural Protected Areas (Conanp, Comisión Nacional de Áreas Naturales Protegidas), have supported the establishment and certification of ICCAs. In May 2008, the General Environmental Law of Mexico (LGEEPA, Ley General del Equilibrio Ecológico y Protección al Medio Ambiente) was modified to allow inclusion of certified ICCAs as a new category of Protected Natural Areas, called Voluntary Conservation Areas (Camacho *et al.* 2010).

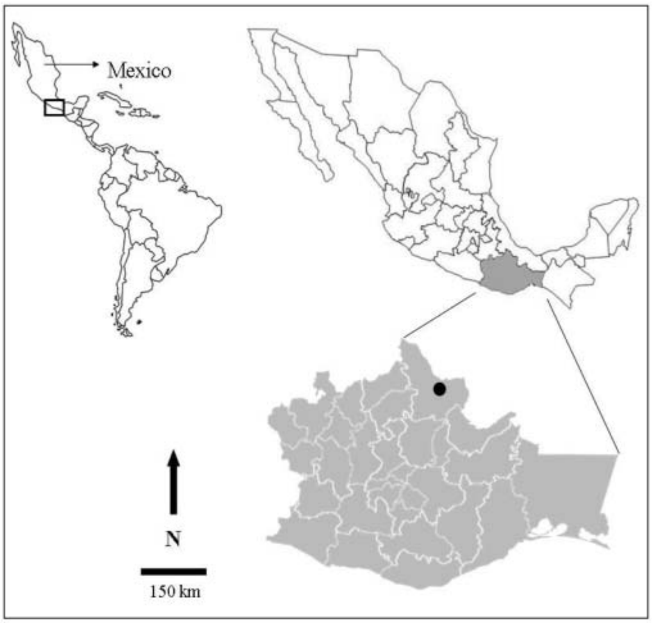
Despite these new policies, official state views continue to characterise human disturbance as a threat to forests. For example, in December 2010 during the celebration of World Forest Day, as part of the 16th Conference of the Parties to the UN Framework Convention on Climate Change in Cancun, Mexican President Felipe Calderón blamed traditional forms of agriculture of indigenous peoples and peasants for deforestation in Mexico (Presidencia de la República 2010). In addition, he stated that one of the nation's priorities is to approve and promote financial mechanisms for reducing deforestation, allowing peasants to receive economic compensation instead of continuing to cultivate the land.

The study presented here – conducted in a Chinantec community in Oaxaca, a biologically and culturally diverse state of southeast Mexico – explores the consequences of external support for ICCAs that follow official conservation policies and receive financial subsidies. To better understand the interactive impacts, the study specifically examines the consequences of PES and the creation of certified VCAs for food sovereignty in a broad socio-ecological context, including food acquisition, dietary patterns, domestic economy, and socio-cultural significance.

STUDY AREA

The Chinantla, defined culturally by the presence of Chinantec indigenous people, is located in northeast portion of the State of Oaxaca, Mexico (Figure 1). It forms part of the Papaloapan hydrological region and the "*Sierras del Norte de Oaxaca-Mixe*" Priority Area for Biodiversity Conservation (Conabio 2008). The zone exhibits one of the highest levels of biodiversity and encompasses the third largest and best conserved tropical humid forest in Mexico (Hernández 2007).

FIGURE 1 *Map of Mexico, showing the State of Oaxaca (in gray). Study area was located in the Chinantla area (black dot; 17°33′N 95°31′W) of Oaxaca*



The study took place in Santiago Tlatepusco, a Chinantec community of 591 residents[1] who have a communal territory of 5 928 ha located between 250 and 2 800 m of elevation in the Municipality of San Felipe Usila. The territory encompasses a mosaic of different habitat types including tropical evergreen, cloud and pine-oak forests, active swidden agricultural areas, coffee plantations, and secondary vegetation (GeoConservación 2006). There are approximately 536 vertebrate species, including jaguar, jaguarondi, margay, tapir, owls, woodpeckers, toucans and other fauna, most of them endemic to Mesoamerica and some rare and endangered (Martin 1996). In addition, there are hundreds of plant species that have not yet been fully inventoried.

Residents combine the *milpa* agricultural system with agroforestry (including shade coffee plantations), extraction of non-timber forest products, subsistence hunting, fishing and, recently, fish production in ponds (Pérez *et al*. 2006). The *milpa* system allows the integration of cultivation of maize, beans, chilli, manioc and squash, among other species, with the collection of other edible plants that complement local diets (Anta and Mondragón 2006). Hunting of birds and mammals in *milpas*, fallow fields and forests, along with fishing, has historically been the main animal protein source in the Chinantla (Weitlaner and Castro 1973).

Santiago Tlatepusco is part of the Regional Committee for Chinantla Alta Natural Resources (CORENCHI), an organisation comprised of six Chinantec communities formed in 2004 by a regional accord with the objective of improving natural resource control, strengthening conservation efforts and obtaining more economic benefits from resource management (Bray *et al.* 2008, Mondragon n.d., Pérez *et al.* 2006).

Between 2003 and 2006, the communities conducted community territorial planning with the help of a non-governmental organisation, which subsequently advocated for a revision of community-level statutes concerning natural resource use and management and the demarcation of different land use zones, including conservation areas to protect biodiversity and ecosystem health (Martin *et al.* 2010).

Large expanses of well-conserved cloud forest and tropical rainforest in the CORENCHI communities are *prima facie* evidence of the adequacy of traditional management practices. As in other parts of the Chinantla (Robson 2009), there has been reduced agriculture and increased fallow forest in Santiago Tlatepusco over the last twenty years (Edward A. Ellis, personal communication, May 16, 2011), a trend not readily attributable to community conservation efforts alone. Because the area is relatively isolated due to limited communication facilities and poor accessibility (Pérez *et al*. 2006), there is no broad commercialisation of bush meat, non-timber forest products or timber species at present (Anta *et al.* 2008), although some small-scale local trade exists. In 2004, Conanp officially certified the communities' conserved areas, promising increased visibility, financial support, and certification of agricultural and non-timber forest products. The certified area included 4 300 ha in Santiago Tlatepusco, putting 72.5% of the communal lands under protection. The community obtained its certification at the same time as three others belonging to CORENCHI, giving a combined area of 22 148 ha certified in 2004 for the four communities.

Processes of community conservation were further supported by Conafor's programme of payment for hydrological environmental services (PES-H), financed by the World Bank (McAfee and Shapiro 2010). The communities were able to access these funds because of the hydrological value of the Chinantla, one of the areas of highest rainfall in the country. Its watersheds benefit many rural and urban areas in the State of Oaxaca, as well as the hydroelectric and other diverse manufacturing industries (Mondragon n.d.).

In 2004, Santiago Tlatepusco submitted 1 969 ha for PES-H, for which Conafor approved 3 938 000 MXN (345 349 USD at the 2004 average exchange rate) for a period of five years (Conafor 2004). In 2007, the community submitted a proposed expansion of the PES-H area that included an additional 853 ha, leading to approval by Conafor of a second payment of 1 401 311 MXN (129 392 USD at the 2007 average exchange rate) for another full five-year period. Finally, in 2009 they recommitted 1 716 ha of the original assigned area to extend the PES-H for an additional five-year period, receiving in exchange 3 786 171 Mexican pesos (294 415 USD at the 2009 average exchange rate). In sum, a total area of 2 822 ha – 47.6% of communal lands – are covered by PES-H payments, totalling $769 245 at the

[1] Demographic statistics from the Centre for Rural Health of Santiago Tlatepusco, belonging to Health Jurisdiction Nº3 of Tuxtepec, Health Services of Oaxaca, Mexico.

summed average exchange rates. To receive these funds, the community – and others in CORENCHI – agreed to maintain vegetation cover, avoid land use change (including conversion to grazing) and pollution in the conserved area, as well as to monitor the territory over time (Conafor 2010, Mondragón n.d.). In Santiago Tlatepusco, these measures were incorporated into a restrictive agreement that prohibits a broad range of activities in the community conserved areas, including: (a) deforestation or damage to vegetation for agricultural, animal husbandry or other purposes; (b) hunting; and (c) extraction of any plants, animals, fruits seeds, or wood.

Most of the payments (97.5%) received are divided among community members and their families, and the other portion (2.5%) has been used for CORENCHI activities and infrastructure (Anta *et al.* 2008). Each family receives an average PES contribution of US \$1.48/day, or US \$44.40/month, equivalent to 27.2% of the basket of consumer goods per year across the four communities (Mondragon n.d.).

METHODS

Methodological considerations: The ideal way to determine the presence of cultural changes is through diachronic analysis in which socio-ecological phenomena from two different time periods – such as before and after a particular intervention – are directly compared (Balée 1994). As no systematic data on food sovereignty are available from before the advent of the establishment of PES and certification of VCAs, research relied on asking informants to recall the time prior to the PES and VCA programmes, an indirect means for documenting changes in the recent past.

By maximising the number of people interviewed and triangulating information collected through diverse methods, substantial data were collected on how these initiatives have affected the community. Methods included participant observation, informal interviews and semi-structured interviews, which are among the best ways to learn about common and divergent perspectives held by community members (Bernard 2005). In addition to these approaches, formal elicitation techniques such as freelist exercises and structured interviews were used to examine patterning of environmental knowledge (Puri 2011a) and then interpret if these patterns are attributable to the aforementioned conservation initiatives.

Free Prior informed consent (FPIC): Following best practice as defined by professional codes of ethics and international conventions – including the United Nations Declaration on the Rights of Indigenous Peoples – FPIC was obtained from local authorities and the General Assembly of the community after explaining the scope of the project, and clearly stating the potential benefits and risks of our presence and proposed study. This built on community research agreements established with the Global Diversity Foundation, an international non-governmental organisation which has been active in the communities since 2008. Additional consent, rapport and willingness to participate in the study were gained after participating in diverse community events and work activities.

Participant observation: Participant observation (Puri 2011b) was conducted in the community between 2008 and 2011. Participation in community events and agricultural activities included firewood gathering, sowing, weeding, measuring agricultural productivity, identification of pest damage, participatory mapping, and community labour (*tequio*). Informal interviews were carried out during these activities with individuals or groups of people, with a total interaction of over 150 individuals (Table 1). Notes relevant to the research were made during these conversations and later developed in field notes recorded daily (Bernard 2005).

While the researchers were working in the community, local authorities arranged for them to have three meals per day with different families on a rotating basis. Families were encouraged to serve foods eaten daily and not to prepare special dishes, as is customary when receiving visitors. In order to assess household dietary patterns, the ingredients of every dish given to researchers were recorded during two months. These data were compared with statements by community members about dietary patterns at the household level (White *et al.* 2005).

Freelists: Women (n=30) were asked (in Spanish or Chinantec) to freelist the most common foods available in the household (Atran *et al*. 2002) in order to elicit information about household diets. Later, *Smith's index of saliency* (Smith's S), which is based on order and frequency of mention of items on a freelist, was used to measure the relative importance of the foods (Smith 1993). The index predicts that foods mentioned first and most frequently are more salient and, therefore, more important to individual women, as compared to foods mentioned last and least often (Smith 1993, Smith and Borgatti 1997).

Semi-structured and structured interviews: An interview question set was designed and piloted with a subsample of

TABLE 1 *Breakdown of informants according to major subsistence occupation, age, and gender*

Method used	Number of participants	Major subsistence occupation	Age range	Gender
Informal interviews	± 150	Farmers, hunters or ex-hunters and local authorities	16–55	± 100 male ± 50 female
Freelists	30	Farmers and housewives	20–46	All female
Semi-structured and structured interviews	76	Farmers, hunters or ex-hunters, local authorities and traditional healers	18–59	21 female 55 male

people from the villages (n=20) allowing researchers to minimise the possibility of errors in the data in later interviews (Bernard 2005, White *et al.* 2005). Afterwards, the interview was applied at the household level with married women and men (n=76; Table 1). Interviews consisted in a first semi-structured part of open-ended questions, and a second structured part of pre-determined questions. Together they revealed socio-economic information, dietary patterns, meat consumption, agricultural practices, productivity and pest species, foraging knowledge and attitudes towards conservation initiatives (Ibarra 2010).

RESULTS

Diet overview: Women mentioned a total of sixty-two common foods in the freelist exercises. Ranked by Smith's S, black beans, rice, noodles and chicken were the most salient foods currently consumed. Among mentioned meat resources, game animals such as the collared peccary, nine-banded armadillo, red brocket deer, and white-nosed coati were mentioned, but rarely. Meat from domestic animals, such as chicken, steak and pork, showed greater saliency than game (Appendix 1).

The most salient items were regularly consumed by families, as noted during participant observation. Based on meals actually consumed by local families, hand-made tortillas of maize were present in 99% of meals, including breakfast, lunch and dinner. As noted in Figure 2, black beans (39%) were the second most consumed, followed by onions (37%), hen's eggs (33%), tomatoes (29%), noodles (25%), and rice (18%). The main animal protein sources consumed were hen's eggs (33%), chicken (15%), ray-finned fish (0.07%) and canned tuna fish (0.02%). Armadillo, pork and canned herring occurred at a frequency of only 0.01% (Figure 2).

Purchased items were slightly more commonly consumed than foods locally obtained (Figure 3). As confirmed during participant observation, less than half of the most salient food items (such as black beans, squash vine, chayote fruits, nightshade and chayote vine) are still gathered or produced – including in small home-gardens – by local farmers. Of the animal protein sources consumed during participant observation, only chicken and ray-finned fish are locally produced, and armadillo is hunted. Several villagers have stopped raising poultry because of increased frequency of disease, especially during the dry season. Buying of hen's eggs and chicken – and almost all other meat sources – has increased.

Both men and women reported a change in the consumption of meat. Men stated that meat consumption has decreased from 1.75 ± 0.89 times/week before the hunting ban, to 0.83 ± 0.41 after the ban. Women reported a change from 1.50 ± 0.71 to 1.10 ± 0.32 times/week. Aggregated figures showed a perceived change from 1.61 ± 0.78 to 1.00 ± 0.37 times/week (Figure 4). In order to improve animal protein consumption, ray-finned fish production is increasing. Several families engage in this complementary activity, although the high cost of pellet fish food limits further expansion of fish farming.

During interviews, 90% of informants noted that the consumption of previously common food items has decreased after the implementation of the PES and VCA programmes. Although these changes were attributed the new conservation initiatives and financial subsidies, many respondents noted

FIGURE 2 *Frequency of food items present in meals (n=87) consumed during two months with different families one Chinantec community. Black bars show the four most salient foods, according to the* Smith's Index of Saliency *(Smith'S), currently used among Chinantecs (based on freelists). Black arrows show the animal protein sources consumed (note that hen eggs were the most important animal protein source consumed, and the others were never present in more than 15% of meals). Dashed arrow shows the only game meat (nine-banded armadillo), consumed once, among the meals documented*

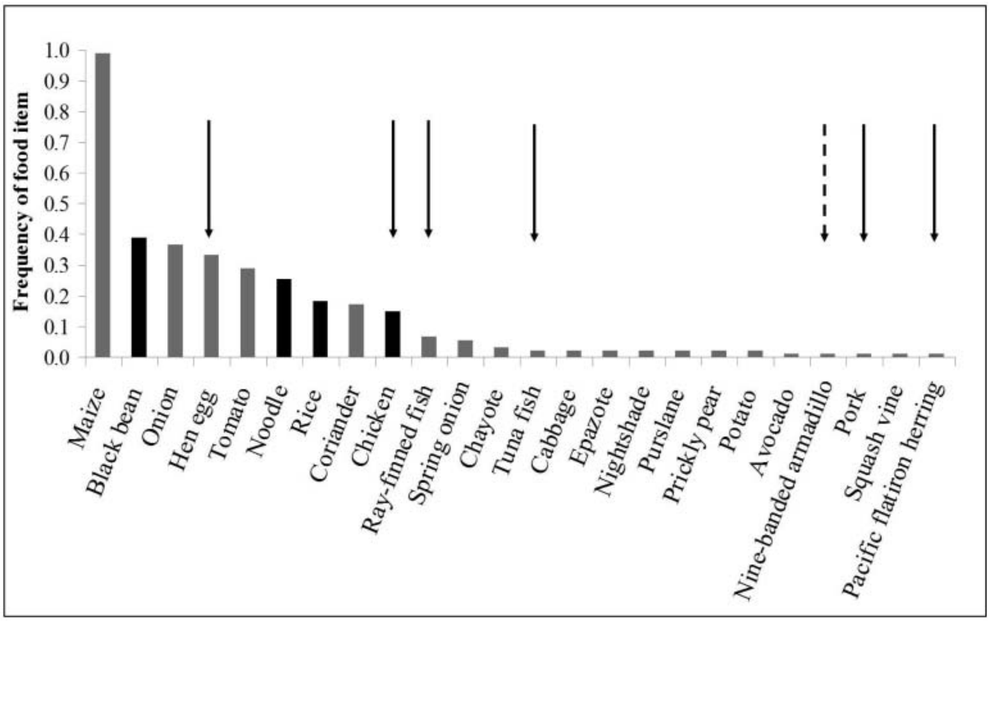
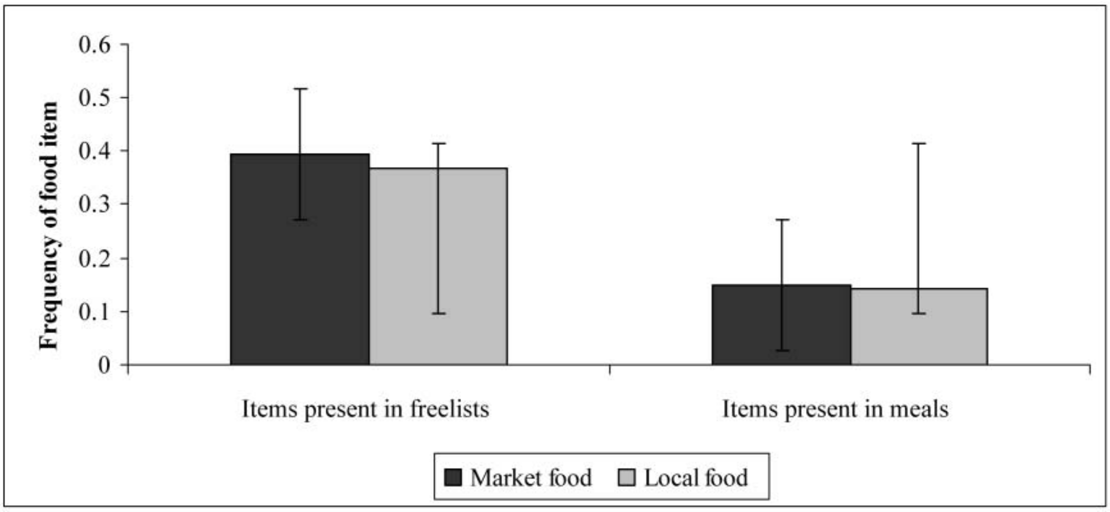


FIGURE 3 *Mean market purchased food item frequencies and mean locally obtained (through cultivation, gathering or hunting) food item frequencies in freelist exercises and in meals consumed by local Chinantec families (and researchers). According to* t*-tests, frequencies of market food items and local food items were not significantly different in both freelist exercises (*$t = 0.178$*, df = 58, P = 0.859) and in meals actually consumed by families (*$t = 0.042$*, df = 20, P = 0.967). Error bars (95% CI) are shown*

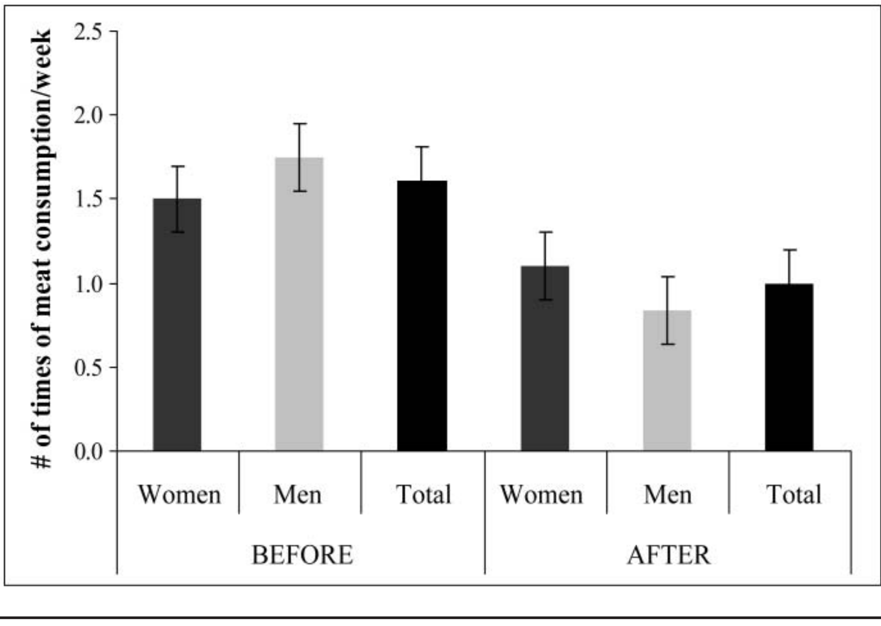


that the availability of local freshwater food (e.g. prawn, crayfish and trout) obtained from the river declined beginning in the 1980s, after the construction of the Miguel Alemán-Cerro de Oro dam on the Usila River during the 1970s.

Sixty-five per cent of informants said that they have incorporated new food items since the implementation of the PES and VCA programmes. The most common recently incorporated food items in local diets were rice, noodles, canned beans, steak, canned sardines, canned tuna fish, and soft drinks. According to informants, consumption of these foods increased after implementation of the PES because villagers were able to purchase these new goods with their annual income from this programme.

Agricultural production, meat consumption and domestic economy: Maize production has reportedly dropped from 31.08 ± 10.17 *zontles*[2] of maize/year before, to 20.63 ± 7.41 *zontles* of maize/year after the advent of the PES and VCA

FIGURE 4 *Reported incidence of meat consumption/week, before and after the implementation of hunting prohibitions in the Community Conservation Area. Error bars (95% CI) are shown*



[2] Area maize yields are measured in zontles: one zontle contains 400 well-formed ears, equivalent to 35 kg grain, equivalent to 87.5 g per ear (Van der Wal *et al*. 2006).