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Declining Use of Wild Resources by Indigenous Peoples of the Ecuadorian Amazon

Clark L. Gray[a,*], **Matthew Bozigar**[b], and **Richard E. Bilsborrow**[c]

[a]Department of Geography, Campus Box 3220, University of North Carolina at Chapel Hill, Chapel Hill, North Carolina 27599, USA, cgray@email.unc.edu

[b]Department of Geography, Campus Box 3220, University of North Carolina at Chapel Hill, Chapel Hill, North Carolina 27599, USA, mbozigar@live.unc.edu

[c]Carolina Population Center, Campus Box 8120, University of North Carolina at Chapel Hill, Chapel Hill, North Carolina 27516, USA, richard_bilsborrow@unc.edu

Abstract

Wild product harvesting by forest-dwelling peoples, including hunting, fishing, forest product collection and timber harvesting, is believed to be a major threat to the biodiversity of tropical forests worldwide. Despite this threat, few studies have attempted to quantify these activities across time or across large spatial scales. We use a unique longitudinal household survey (n = 480) to describe changes in these activities over time in 32 indigenous communities from five ethnicities in the northern Ecuadorian Amazon. To provide insight into the drivers of these changes, we also estimate multilevel statistical models of these activities as a function of household and community characteristics. These analyses reveal that participation in hunting, fishing, and forest product collection is high but declining across time and across ethnicities, with no evidence for a parallel decline in resource quality. However, participation in timber harvesting did not significantly decline and there is evidence of a decline in resource quality. Multilevel statistical models additionally reveal that household and community characteristics such as ethnicity, demographic characteristics, wealth, livelihood diversification, access to forest, participation in conservation programs and exposure to external markets are significant predictors of wild product harvesting. These characteristics have changed over time but cannot account for declining participation in resource harvesting. This finding suggests that participation is declining due to changes in the regional-scale social and economic context, including urbanization and the expansion of government infrastructure and services. The lesson for conservationists is that macro-scale social and economic conditions can drive reductions in wild product harvesting even in the absence of successful conservation interventions.

*Corresponding author: Phone 001-919-962-3876.

Keywords

hunting; fishing; non-timber forest products; timber; indigenous peoples; household survey

1. Introduction

Harvesting of wild resources by forest-dwelling peoples, via hunting, fishing, timber harvesting and forest product collection, has been identified a major threat to biodiversity in many tropical forest ecosystems (Asner et al. 2005; Peres et al. 2006; Castello et al. 2013). However, these activities are often central to the livelihoods of the poor and isolated populations that live at forest frontiers (Brashares et al. 2011; Wunder et al. 2014). This conflict is particularly salient for indigenous peoples of the Amazon Basin who have harvested wild products for centuries, control large areas of forest, and have populations that are growing rapidly (McSweeney & Arps 2005; Nepstad et al. 2006; Wunder et al. 2014). The discussion of potential solutions to this conflict has generated a large literature (e.g., Redford & Sanderson 2000; Terborgh 2000), but this discussion has taken place largely in the absence of landscape-scale evidence on levels and trends of wild resource use (Peres et al. 2006; Wunder et al. 2014). This lacuna is the result of difficulties in conducting large-scale social and biological surveys in this context, the near-invisibility of small-scale wild product harvesting to remote-sensing methods (Peres et al. 2006), as well as enduring barriers between conservation science and the quantitative social sciences (Fox et al. 2006).

Using a unique longitudinal survey dataset, we confirm that indigenous peoples of the Northern Ecuadorian Amazon (NEA) are highly dependent on wild resources, ask whether their harvesting activities have changed over time, and also ask whether household or community-level factors can account for these changes. The NEA is a center of Amazonian biodiversity for many taxa, the home of a large and growing indigenous population, and the site of high-profile conflicts between biodiversity conservation and resource use (Finer et al. 2008; Bremner et al. 2009), making the region particular interest for these questions. The data capture changes in wild resource use across 480 households, 32 communities, 5 ethnicities, an 11 year time period, and low to moderate connections to external markets. We first use this dataset to characterize various dimensions of wild resource use by this population, including hunting, fishing, timber harvesting and forest product collection. Building on this descriptive analysis, we subsequently use multilevel regression models to investigate the social and economic predictors of wild resource use across time. This effort expands on previous studies which have investigated indigenous resource use via cross-sectional surveys (e.g., Brashares et al. 2011; Wunder et al. 2014) or small longitudinal samples (e.g., Vickers 1991; Gill et al. 2012), and points to significant additional opportunities at the intersection of conservation science and the quantitative social sciences (see Godoy et al. 2010).

2. Methods

2.2 Study Area

The NEA is located at the western periphery of the Amazon Basin (Fig. 1) and overlaps the center of Amazonian species richness for amphibians, birds, mammals and vascular plants, marking it a globally important region for biodiversity conservation (Finer et al. 2008). The region has been inhabited for millennia by Amerindian indigenous peoples, but its current large-scale environmental transformation began in the 1970s with the initiation of oil exploration. Road construction by the oil industry enabled large-scale agricultural colonization from outside the region and was facilitated by government land tenure policies (Bilsborrow et al. 2004). These processes have transformed the area between Coca and Lago Agrio (Fig. 1), where soils are productive for agriculture, into an urbanizing agricultural hinterland with only remnant forests, while colonization and oil extraction continue to penetrate into previously remote areas (Holland et al. 2014). Indicative of this ongoing transformation, the urban population of Sucumbíos and Orellana provinces, which overlap the study area, increased from 76 thousand to 129 thousand between 2001 and 2010 (INEC 2014).

These processes have radically transformed the regional context for five resident and culturally distinct indigenous groups, the Cofán, Kichwa, Shuar, Secoya and Waorani, via territorial displacement and circumscription as well as increased contact with the outside world (Lu & Bilsborrow 2011). Despite these changes, all five groups, particularly the Waorani and Cofán, have retained a significant degree of spatial, economic and cultural isolation from urban economies and the dominant mestizo culture, and continue to practice traditional livelihood activities such as wild resource use and swidden agriculture in landscapes dominated by forest (Gray et al. 2008; Lu et al. 2010). At the same time, all five groups have also taken advantage of new opportunities created by regional transformation, as evidenced by their participation in wage labor, sales of agricultural products, purchases of manufactured goods, use of government services, and engagement in political activism (Lu 2007; Suarez et al. 2009; Bremner 2013). High fertility and access to basic health services have also contributed to rapid population growth, with the indigenous population of Sucumbios and Orellana increasing from 40 thousand to 67 thousand between 2001 and 2010, 88% of whom continue to live in rural areas (INEC 2014).

2.2 Household Surveys

Our analysis draws on longitudinal household survey data collected in 2001 and 2012 in 32 indigenous communities of the NEA (Fig. 1). In 2001, a judgment sample of 36 communities was selected to include all five ethnicities and to span the regional spectrum of community accessibility and exposure to the outside world. Among these, 32 communities were selected for follow-up in 2012 as described below. Within each community, 22 households were sampled for participation, either randomly or to include all households in smaller communities. In each sampled household, structured interviews were separately conducted with both the male and female heads of household (i.e., one man and woman per household) for approximately one hour in order to collect a wide variety of information on household characteristics and activities. In the case of single-headed households or the

prolonged absence of the male/female head, both interviews were conducted with the available household member. Interviews with the male head collected information on wild product harvesting, agricultural activities and off-farm employment, with the first of these described in detail below. Interviews with the female head asked about household composition and assets, among other topics. In the 32 longitudinal communities, 484 households completed a male interview, 489 households completed a female interview and 476 completed both interviews. Community-level data was also collected through the use of GPS as well as through structured interviews with community leaders focusing on community institutions, infrastructure and exposure to outside actors, among other topics. To collect these data, a survey team of six Ecuadorian interviewers spent approximately five days in each community. Interviews were conducted primarily in Spanish and occasionally with the assistance of a local translator.

The 2012 follow-up survey targeted households within the study communities who successfully completed a female interview in 2001 and thus provided a household roster. The first priority for follow-up was the 2001 female ahead and her 2012 household, followed, in the case of absence or death, by the 2001 male head, and finally by the oldest child resident in 2001. Three communities from the 2001 survey were excluded for logistical reasons, and in one community all baseline households had departed, leaving 32 communities for the longitudinal sample. Among the 489 targeted households, 401 completed a male interview, 399 completed both interviews, and 75 had permanently left the area. Split-off households, where a 2001 household member was now male or female head, were also targeted. Among split-offs, 200 completed a male interview, all of whom also completed a female interview, for a total of 599 households with a complete interview in 2012. A questionnaire similar to the baseline was used, updated to include questions about changes experienced since 2001.

The male interview in both rounds collected detailed information about household participation in hunting, fishing, timber harvesting and forest product collection. The specific questions asked in 2012 (which differed only in minor ways from 2001) are presented in the Supplement (Tables S1–S4)[1]. For households that had hunted in the past year, the following information was collected about the most recent hunt: the duration of the hunt, the number of hunters, the equipment used, whether any game was sold, and the number and type game caught. Additional questions were asked about normal hunting frequency and its changes over time, as well changes in resource quality over time. The weight of game animals from the last hunt was also collected in 2012. To estimate the weight of game in 2001, we used the 2012 mean weight per animal from five locally recognized categories (peccaries, rodents, monkeys, birds, and others) (Supplement Table S5).

For households that had fished in the past year, a similar set of questions asked about the number of fishers, the equipment used, the sale of fish, and the number, the type and weight of fish caught, all from the last outing. Additional questions asked about changes in fishing frequency and resource quality over time. Whether households collected or sold forest

[1]The full set of questionnaires in Spanish can be accessed by contacting the corresponding author.

products was measured for several categories including firewood, fruit, medicinal plants, seeds, *sangre de drago* (*Croton lechleri*), plant fibers, mushrooms, timber and others. For households that sold timber in the past year, wood volume, income from sales and tree species (using local names) were collected for three locally-recognized levels of timber quality (high, medium and low), as well as reports of which timber species had become rare or extinct locally.

2.3 Statistical Analyses

We first describe various dimensions of wild resource use for the sample as a whole and by ethnicity (Table 1), using data from 484 households in 2001 and 601 households in 2012 that completed a male interview. Because most communities include members of other indigenous ethnicities as well as non-indigenous (mestizo) residents, we classified households by the ethnicity of the male head. To compare values across time, we conducted Pearson's chi-squared tests for dichotomous variables and Wald tests for continuous variables, all of which are adjusted for clustering at the community level. To account for the possibility of non-random selection into our multi-year sample, all analyses presented here were repeated using the subset of data from panel households who were interviewed twice, with results very similar to those presented here (Supplement Tables S6–S7).

To better understand the drivers of these practices, we combined data from 2001 and 2012 and used multilevel regression models (Skrondal & Rabe-Hesketh 2004) to predict nine key measures of resource use. By stacking data from 476 households in 2001 and 599 households in 2012 that completed both male and female interviews, we created a dataset of 1075 household-years. To account for clustering at the household and community levels in this dataset, we estimated multilevel regression models with the following form:

$$y_{ijt}=y_{000}+\beta x_{ijt}+\delta w_{jt}+\alpha_j+u_{ij}+e_{ijt}$$

where y_{ijt} is the outcome for household i in community j in year t, y_{000} is an intercept, β is a vector of household-level coefficients, x_{ijt} is a vector of household-level predictors, δ is a vector of community-level coefficients, w_{jt} is a vector of community-level predictors, α_j is the community-level random effect, u_{ij} is the household-level random effect, and e_{ijt} is the residual error term.

The nine outcomes that we examined using this approach include key measures of hunting, fishing, forest product collection and timber extraction. Hunting was measured by whether the household hunted in the past year (a dichotomous variable), and, for households that did, their reported frequency of hunting (a five point scale) and the estimated weight of game harvested in the last outing (a continuous variable). Fishing was captured by whether the household fished in the past year (dichotomous), and for households that participated, the weight of fish harvested in the last fishing trip (continuous). Collection of non-timber forest products was measured by the number of types of products collected (continuous) and whether any products were sold (dichotomous). Finally, timber harvesting was captured by whether the household sold timber in the past year (dichotomous), and, if so, the volume sold (continuous). The multilevel model described above was estimated as a logit for

dichotomous outcomes, as an ordered logit for hunting frequency, and as a linear model for continuous outcomes, which have been transformed as ln(x+1) to remove skewness. Logit and ordered logit coefficients are presented as odds ratios, which can be interpreted as the multiplicative effect of a one unit increase in the predictor on the odds of participation, or, for ordered logit, the odds of being in a higher category.

The predictors for these models included measures of ethnicity, demographic characteristics, wealth, livelihood diversification, access to forest, participation in conservation programs, and exposure to external markets and oil companies. These measures are defined in Table 2, with the additional explanation that wealth was measured as the first polychoric principle component from a set from asset and housing indicators available in both 2001 and 2012, a value which was standardized to range from zero to ten (Supplement Table S8; Kolenikov & Angeles 2009)[2]. Additional measures of participation in a cash transfer program, receipt of migrant remittances, and community population size were evaluated for inclusion but ultimately excluded as providing no additional explanation. This selection of predictors is consistent with the rural livelihoods framework (Ellis 2000) as well as with previous household-level studies of wild resource use in tropical forests (Amacher et al. 2009; Coomes et al. 2001; Godoy et al. 2010; Brashares et al. 2011).

3. Results

Descriptive results are displayed in Table 1. The first panel reveals high participation in hunting with large declines across time, for the full sample and for all six ethnicities. The proportion of households who hunted in the past month, for example, declined from 72% to 47% ($p < 0.001$). Household effort per hunting trip also declined from 10.4 person-hours to 7.2 ($p = 0.020$). At the same time, the weight of animals harvested declined significantly for birds only. Aggregating across all animals hunted, the global weight per animal increased from 7.8 to 9.4 kg, and the global weight hunted per person-hour increased from 1.4 to 1.7 kg (Supplement Table S5). Households' own observations of changes in hunting similarly reveal declines in both the proportion of households reporting increased hunting as well those reporting declining resource quality. These changes occurred while hunting technology remained nearly the same (94-91% using firearms) and reported sales of game remained very rare (1–2% sold from the last hunt). Taken together, the results suggest declining participation in hunting that is not driven by declining resource quality. However, stable productivity could also be explained by increasing access to remote hunting areas or by declining participation by the least effective hunters.

Results in the second panel reveal similar results for fishing. Participation in fishing was high but declined across time for all ethnicities, from 84% of households in the past month to 67% for the full sample ($p < 0.001$). As for hunting, the weight per catch did not change significantly, the global weight per fish increased (0.73 to 0.98 kg), and the proportion of households reporting increases in participation or poorer resource quality both declined over

[2]Data on assets is missing for 22 households across both years (i.e., less than 2% of the analytical sample). To account for this, missing values are replaced with the median value for that community and year and an indicator variable is included in the regression analysis for "missing wealth value". This coefficient is not statistically significant from zero in any model, and for clarity of presentation is excluded from the presented results.

time. The locally-named catch composition also did not change noticeably over time, with *bagre* (*Siluriformes* spp.) remaining the most important fish by weight. Use of destructive fishing technologies such as dynamite and *barbasco* (*Lonchocarpus urucu*) was uncommon and became even rarer, as were market sales of fish.

The third and fourth panels describe harvesting of non-timber forest products and timber respectively. Similar to hunting and fishing, participation in non-timber harvesting was high but declined across time for all ethnicities, from 5.8 to 5.1 types of products collected per household for the full sample ($p < 0.001$). Participation in market sales also declined across time. However in contrast to the results for the three previous resource domains, the proportion of households harvesting any timber *increased* across time (from 67% to 79%; $p = 0.026$), the proportion selling timber declined only slightly (from 21% to 15%; $p = 0.18$), and the volume sold per participating household remained nearly constant (from 29 to 28 m^3; $p = 0.96$), though no Waorani households reported selling timber in either time period. Additionally, sales of high quality timber declined, and the high quality species *cedro* (*Cedrela* sp.) went from the second-most harvested to rarely harvested. Many households also reported that *cedro* had become rare or extinct locally. Thus in contrast to the other three resource categories, the results for timber suggest flat participation and a declining resource base.

Finally, the bottom panel of Table 1 reveals that, while per-household use of wild resources was declining, the number of households and individuals per community increased significantly over time, reflecting both natural increase and in-migration. If we extrapolate from our household sample to the study communities as a whole, declines are still evident in the total number of households hunting in the past month (by 9%), selling forest products (22%), and selling timber (4%), but we estimate that the number of households fishing in the past month increased by 10%.

Mean values of the regression predictors by year are displayed in Table 2. Examining changes over time reveals increases in household wealth, participation in conservation programs, levels of education, and accessibility to urban areas, a decline in the household area under agricultural use, and a small decline in the proportion of forest cover around the study communities. The difference between the latter two measures can be attributed to the growing number of households per community (Table 1). Small changes in the ethnic composition of our sample reflect the creation of new households and the departure or dissolution of old households.

The results of our multilevel regression analyses (Table 3) provide additional insight into the drivers of the changes described above. All forms of resource use were significantly affected by ethnicity, demographic characteristics and the time trend, and some activities also responded to wealth, livelihood diversification, forest cover, and exposure to factors such as external markets, oil companies or conservation programs. Participation in hunting was higher among younger, larger and more isolated households, and among the Secoya, Cofán and Waorani relative to the Kichwa. Among participating households, the reported frequency of hunting was lower among educated, wealthy, Shuar and Secoya households, and higher among the Cofán and those with better access to forest. Among hunting

households, the weight harvested per hunt was lower among the Shuar and higher for wealthier households, those with greater agricultural area (likely reflecting higher overall capability), and those with greater access to forest.

Participation in fishing was higher for younger and more isolated households and those exposed to conservation programs as well as oil companies (likely reflecting the placement of oil facilities along major rivers), and lower among mestizo households. Among fishing households, more weight was harvested per catch by households that were larger, wealthier and where the head was born locally. Participation in non-timber forest product collection (as measured by the number of types harvested), was higher among larger and older households, those where the head was born locally and those with better access to forest, and lower among Shuar and mestizo households. Participation in sales of forest products was higher among larger and less educated households, those with more agricultural area or that participated in off-farm employment, and among the Cofán, Secoya and Waorani. Finally, participation in timber sales was higher among households closer to markets, with cattle or with greater agricultural area, and lower among older households, mestizo households, and those that participated in off-farm employment or were exposed to conservation programs. For participating households, the volume of timber sold was higher among the Cofán, among wealthier households and those with greater access to forest, and lower among mestizo households and those exposed to conservation programs.

Also notable is that the effect of the time trend (year 2012 relative to 2001) is in the negative direction in all nine models, including six in which the effect is significant ($p < 0.05$) and two in which it is marginally significant ($p < 0.10$), with the primary exception again being timber sales. This result indicates that changes in the household and community-level predictors cannot fully account for the declining trends across time observed in Table 1.

4. Discussion

Our results provide important insights into the direction and drivers of social and environmental change in indigenous communities of the Amazon Basin. The descriptive results reveal a population that is highly dependent on wild resources, but this dependence has consistently declined over time across resource types and ethnicities. Even while the population of these communities is increasing, we estimate that the total number of households participating in key activities is declining. This decline has occurred in the absence of landscape-level environmental change, during a period of improving human well-being, and while various measures of resource productivity have improved or remained stable, suggesting that declining dependence is not driven by resource quality. Small-scale timber harvesting is the primary exception to both of these findings.

The multivariate results additionally reveal that ethnicity, demographic characteristics, wealth, livelihood diversification, access to forest, participation in conservation programs, and exposure to external markets are all important predictors of resource use but in ways that vary distinctly across resource types. However the opening presented for conservation interventions by these results is small at best: Education, livelihood diversification, and conservation programs generally had mixed and weak effects on resource use. Additionally,

these factors cannot fully account for the substantial declines in resource use across time, suggesting that regional-scale processes are driving these changes.

Like many formerly remote Latin American forest frontiers (Browder 1997; Espinosa 2008), over recent decades the NEA has experienced rapid urbanization, agricultural colonization, and expansion of government infrastructure and services. Across all five indigenous groups, these changes have increased exposure to new sources of income, new expectations of material prosperity, and new services such as education and development programs (Lu 2007; Suarez et al. 2009; Bremner 2013), above and beyond what we are able to account for in our regression analysis, and we hypothesize that these region-wide processes of modernization are the key drivers of declining resource use. If that is the case, similar dynamics may be at work on many other forest frontiers that are increasingly influenced by external economies, societies and government policies.

Our work also illustrates the utility of methods from the quantitative social sciences for understanding household resource use across large spatial scales (see also Coomes et al. 2001; Amacher et al. 2009; Godoy et al. 2010; Brashares et al. 2011). Through the use of repeated household surveys, we are able to provide region-wide quantitative estimates of resource use practices that are rarely observed at this scale. Desirable extensions of this approach include integration with biological sampling, extension to a larger sample of communities, and replication in other study areas.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Highlights

- We examine changes over time in wild product harvesting by indigenous households.
- Data are derived from a longitudinal household survey conducted in 2001 and 2012.
- Hunting, fishing and non-timber forest product collection declined over time.
- Characteristics of households predict these activities but not declines over time.
- A changing regional context appears to drive declining reliance on wild resources.

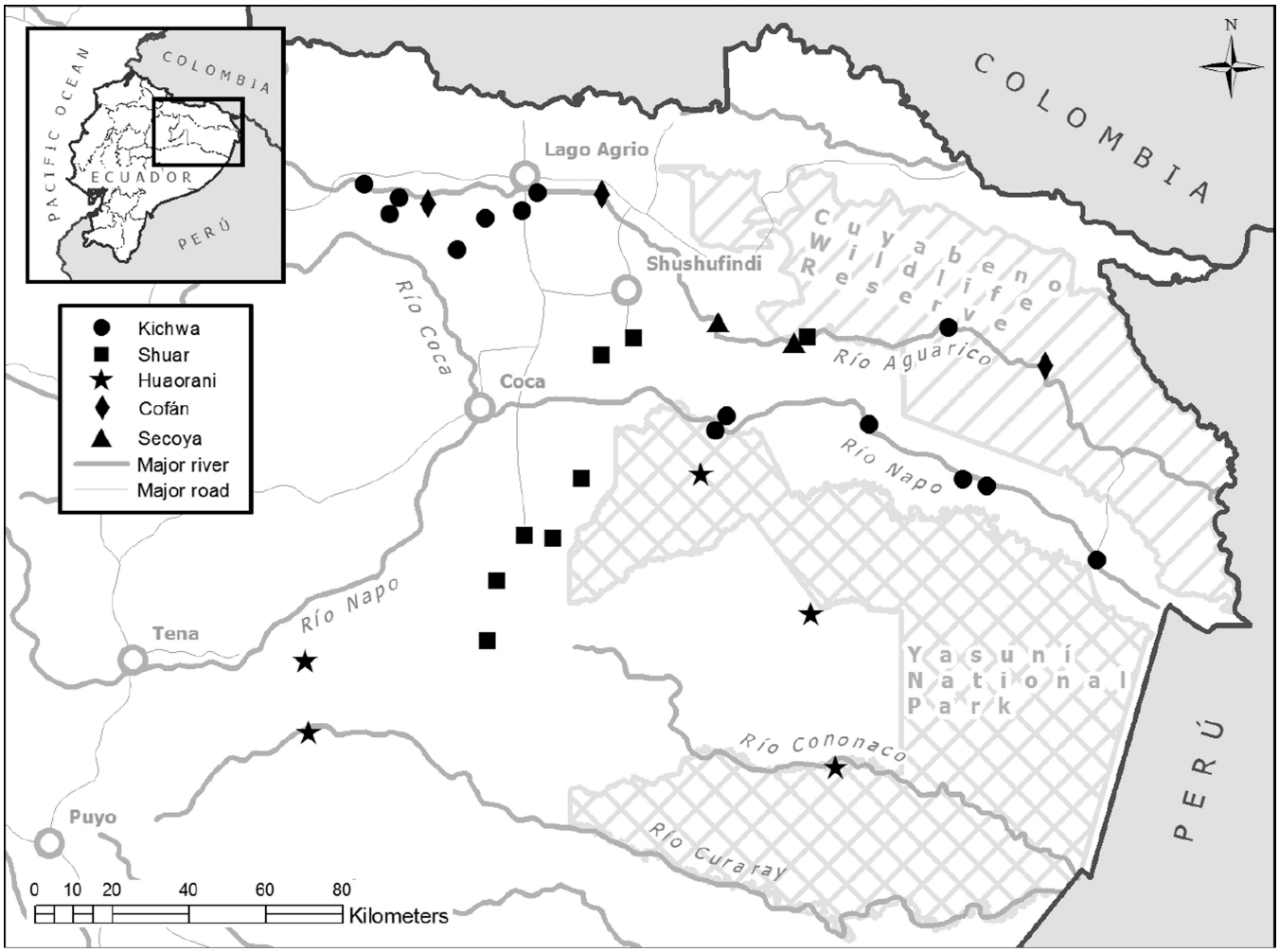

Figure 1.
Map of the study communities.

Table 1

Wild product harvesting by ethnicity and year (mean values and cross-year significance tests).

Measure of harvest	Full sample			Kichwa			Shuar			Secoya			Cofan			Waorani			Mestizo		
	2001	2012		2001	2012		2001	2012		2001	2012		2001	2012		2001	2012		2001	2012	
Hunting																					
Hunted in past month (0/1)	0.72	0.47	***	0.69	0.42	***	0.62	0.45	+	0.82	0.50	**	0.80	0.72		0.88	0.65	+	0.67	0.44	*
Hunted in past year (0/1)	0.88	0.65	***	0.84	0.59	***	0.84	0.64	**	1.00	0.76		0.93	0.87		0.98	0.87	*	0.83	0.59	
Animals hunted (#)	1.84	1.28	**	1.62	1.15	*	1.36	0.89	*	2.53	1.34		1.85	2.05		2.83	1.74		1.40	1.00	
Weight of animals (kg)	14.4	12.1		12.8	9.7		8.5	9.2		27.2	12.0		15.8	15.1		19.4	26.7		12.5	5.6	
Weight of peccaries (kg)	6.6	7.0		5.8	5.6		2.3	5.7		8.3	5.8		8.5	6.2		11.4	17.2		8.7	3.7	
Weight of rodents (kg)	2.4	2.2		2.4	2.0		2.6	2.9		3.5	3.5		4.2	3.4		0.6	1.5		2.7	0.8	*
Weight of monkeys (kg)	1.3	1.0		1.5	0.5	+	1.3	0.1		1.2	0.9		0.6	3.3		1.2	2.5		0.0	0.2	
Weight of birds (lbs)	1.0	0.3	**	0.8	0.3	***	0.7	0.3		0.5	0.2	+	0.4	0.4		3.0	0.7		0.6	0.1	+
Weight of others (lbs)	3.2	1.7		2.4	1.3		1.5	0.2		13.5	1.7	**	2.1	1.8		3.2	4.9		0.6	0.7	
Person-hours hunting (hrs)	10.4	7.2	*	9.6	7.0	+	13.1	5.4	+	9.2	8.9		8.9	10.9		10.8	6.8		10.9	6.2	
Used a firearm (0/1)	0.94	0.91	+	0.98	0.96		0.91	0.85		0.94	0.97		0.95	0.93		0.83	0.72		1.00	0.88	
Sold meat (0/1)	0.02	0.01		0.02	0.02		0.03	0.00		0.00	0.03		0.00	0.00		0.02	0.00		0.07	0.00	
Hunting frequency (0–4)	2.29	1.73	***	2.25	1.66	***	1.76	1.36	*	2.15	1.21		2.76	2.33		2.76	2.34		2.47	1.54	*
Hunt more than in past (0/1)	0.14	0.04	***	0.14	0.04	***	0.12	0.02	*	0.21	0.06		0.17	0.09		0.12	0.04		0.22	0.00	+
Hunt less than in past (0/1)	0.73	0.79		0.75	0.83		0.79	0.94	+	0.79	0.88		0.83	0.67	+	0.51	0.43		0.56	0.90	*
Hunting is better (0/1)	0.05	0.09		0.05	0.06		0.10	0.13		0.00	0.10	**	0.05	0.23		0.02	0.04		0.11	0.13	
Hunting is worse (0/1)	0.86	0.69	***	0.91	0.79	**	0.79	0.71		0.86	0.69		0.93	0.63		0.65	0.28	+	0.78	0.67	
Fishing																					
Fished in past month (0/1)	0.84	0.67	***	0.85	0.67	***	0.75	0.60	+	0.85	0.74		0.86	0.72	+	0.97	0.74		0.61	0.51	
Fished in past year (0/1)	0.95	0.84	***	0.94	0.84	***	0.96	0.77	**	1.00	0.92		0.95	0.91	*	1.00	0.91		0.83	0.68	
Fish caught (#)	19.3	12.8	**	15.6	12.3		31.1	12.9	*	16.9	11.2		14.9	14.1		20.7	15.0		17.2	14.0	
Weight of fish (kg)	6.4	5.7		6.2	4.8	*	3.7	2.6		4.8	6.7		10.1	12.4		9.6	8.2		3.0	5.3	
Used *barbasco* (0/1)	0.09	0.04	***	0.05	0.02		0.27	0.11	**	0.00	0.00		0.00	0.00		0.09	0.12		0.13	0.04	
Used dynamite (0/1)	0.04	0.01	**	0.03	0.00	*	0.06	0.00		0.00	0.00		0.02	0.02		0.06	0.00		0.20	0.04	**
Sold fish (0/1)	0.02	0.00	*	0.02	0.00	*	0.00	0.00		0.03	0.03		0.05	0.02		0.00	0.00		0.00	0.00	
Fish more now (0/1)	0.15	0.06	*	0.17	0.07		0.12	0.03		0.13	0.06		0.14	0.05		0.18	0.04	*	0.11	0.00	

Measure of harvest	Full sample			Kichwa			Shuar			Secoya			Cofan			Waorani			Mestizo		
	2001	2012		2001	2012		2001	2012		2001	2012		2001	2012		2001	2012		2001	2012	
Fish less now (0/1)	0.63	0.69		0.66	0.66		0.68	0.91	*	0.61	0.78		0.74	0.67		0.34	0.37		0.56	0.85	
Fishing is better (0/1)	0.05	0.06		0.04	0.07		0.05	0.03		0.10	0.00		0.05	0.12		0.05	0.10		0.00	0.00	
Fishing is worse (0/1)	0.73	0.56	***	0.78	0.58	**	0.78	0.70		0.65	0.58		0.79	0.53		0.48	0.18	*	0.56	0.72	
Non-timber forest products																					
Types collected (#)	5.77	5.06	***	6.08	5.12	***	4.60	4.59		5.18	4.71		5.86	5.24	**	6.78	6.78		4.83	3.44	+
Collect firewood (0/1)	0.92	0.93		0.94	0.96		0.80	0.91	+	0.97	0.97		0.95	0.93		1.00	0.98		0.89	0.68	
Collect fruit (0/1)	0.85	0.83		0.87	0.83		0.66	0.72		0.94	0.95		0.91	0.85		0.97	1.00		0.61	0.66	
Collect medicine (0/1)	0.81	0.71	*	0.87	0.68	***	0.52	0.64		0.85	0.76		0.98	0.98		0.92	0.91		0.61	0.51	
Collect seeds (0/1)	0.56	0.48	+	0.57	0.42	**	0.33	0.47	+	0.47	0.47		0.73	0.63		0.83	0.87		0.44	0.29	
Collect *sangre de drago* (0/1)	0.61	0.50	**	0.64	0.50	*	0.48	0.48		0.56	0.55		0.48	0.39		0.83	0.69		0.56	0.34	+
Collect plant fibers (0/1)	0.81	0.60	***	0.82	0.63	**	0.62	0.48		0.79	0.42		0.98	0.59	**	0.95	0.96		0.67	0.37	*
Collect mushrooms (0/1)	0.46	0.35	*	0.61	0.46	**	0.44	0.26	*	0.09	0.05		0.18	0.09		0.30	0.43		0.44	0.10	*
Collect other (0/1)	0.75	0.67	+	0.75	0.65		0.75	0.65		0.50	0.53		0.66	0.78		0.98	0.94	+	0.61	0.49	
Sold forest product (0/1)	0.22	0.12	**	0.11	0.08		0.17	0.09		0.09	0.21		0.73	0.30		0.48	0.28		0.06	0.05	
Timber																					
Harvest timber (0/1)	0.67	0.79	*	0.73	0.83		0.51	0.74	*	0.76	0.63		0.66	0.78		0.66	0.91	*	0.50	0.56	
Sold any timber (0/1)	0.21	0.15		0.23	0.17		0.36	0.22		0.38	0.18		0.09	0.17	+	0.00	0.00		0.11	0.00	+
Volume sold (m^3)	28.7	28.0		12.9	10.4		27.2	80.7	*	113	28.2		11.4	24.9		-	-		1.4	-	
Sold high qual. timber (0/1)	0.13	0.05	**	0.13	0.03	***	0.25	0.10	*	0.18	0.18		0.05	0.11	*	0.00	0.00		0.11	0.00	+
Sold medium qual. timber (0/1)	0.13	0.12		0.14	0.15		0.19	0.14		0.21	0.08		0.09	0.11		0.00	0.00		0.00	0.00	
Sold low qual. timber (0/1)	0.03	0.01	+	0.06	0.02	*	0.02	0.00		0.03	0.00		0.00	0.02		0.00	0.00		0.00	0.00	
Sample households	484	601		235	336		89	86		34	38		44	46		64	54		18	41	
Sample communities	32	32		14	14		8	8		2	2		3	3		5	5		0	0	
Total households in communities	897	1242		522	738		100	169		90	95		109	114		76	126		-	-	
Total pop. in communities	4930	7363		2776	4332		619	950		326	530		679	779		530	772		-	-	

+ p<0.10,

* p<0.05,

** p<0.01,

*** p<0.001

Table 2

Definitions and mean values for the independent variables.

Predictor	Mean values		Definition
	2001	2012	
Characteristics of the head			
Kichwa (0/1)	0.49	0.56	Ethnicity of head is Kichwa; reference category
Shuar (0/1)	0.18	0.14	Ethnicity of head is Shuar
Secoya (0/1)	0.07	0.06	Ethnicity of head is Secoya
Cofan (0/1)	0.09	0.08	Ethnicity of head is Cofan
Waorani (0/1)	0.13	0.09	Ethnicity of head is Huaorani
Mestizo (0/1)	0.04	0.07	Ethnicity of head is Mestizo
Age (years)	39.0	41.0	Age of head
Born in community (0/1)	0.28	0.38	Head was born in the community
Primary education (0/1)	0.58	0.75	Head has completed primary education
Household characteristics			
Household size (#)	6.34	6.19	Individuals resident in household
Wealth index (0–10)	2.83	4.81	Continous wealth index ranging from 0–10; see text
Agricultural area (ha)	2.87	2.36	Area under annual or perennial crops
Owns cattle (0/1)	0.15	0.16	Household owns cattle
Off-farm employment (0/1)	0.58	0.52	Member worked off-farm in past year
$N_{households}$	476	599	
Community characteristics			
Travel time (hours)	3.51	2.44	Total travel time to closest urban area
Forest cover (%)	94.3	92.7	Percent forest cover within 8 km of community center
Oil company (0/1)	0.47	0.41	Oil company employs two or more community members
Conservation program (0/1)	0.38	0.66	Conservation program active in past 10 years
$N_{communities}$	32	32	

Table 3

Results of the regression analysis of wild product harvesting (coefficients and significance tests).

Predictor	Nonlinear models[a]												Linear models									
	Hunted in past year		Hunting frequency		Fished in past year		Sold forest product		Sold timber		Ln(weight of game+1)		Ln(weight of fish+1)		Number of forest products		Ln(timber volume+1)	
Characteristics of the head																		
Shuar	1.39		0.33	***	0.93		1.63		1.23		−0.75	**	−0.21		−1.38	***	0.30	
Secoya	4.26	*	0.47	*	3.10		2.65	+	1.49		0.27		0.25		−0.45		0.47	
Cofan	4.75	**	2.05	*	1.27		8.95	***	1.09		0.17		0.15		−0.19		0.89	*
Waorani	6.32	**	1.33		1.01		6.18	***	-		0.27		0.22		−0.40		-	
Mestizo	1.34		0.86		0.37	+	0.64		0.18	*	−0.34		−0.17		−1.20	***	−1.30	+
Age	0.97	***	1.01		0.96	***	1.00		0.98	+	0.00		0.00		0.01	**	0.01	
Born in community	1.01		1.27		1.73		0.79		0.90		0.14		0.24	**	0.27	*	−0.31	
Primary education	0.86		0.66	*	0.67		0.55	*	1.09		−0.03		0.09		0.12		0.29	
Household characteristics																		
Household size	1.14	***	1.01		1.04		1.07	*	0.99		−0.01		0.03	*	0.07	***	0.02	
Wealth index	0.91		0.92	+	1.04		0.89	+	0.97		0.07	*	0.06	*	−0.05		0.09	+
Ln(agricultural area+1)	1.43	+	1.05		1.03		1.53	*	2.48	***	0.25	**	0.02		0.31	**	0.18	
Owns cattle	1.03		0.82		1.17		0.99		1.74	*	−0.07		0.08		0.16		−0.15	
Off-farm employment	0.78		1.16		0.92		1.76	*	0.54	**	0.02		0.03		0.17		−0.14	
Community characteristics																		
Travel time	1.22	***	1.04		1.32	**	1.04		0.70	**	0.01		−0.02		0.02		−0.04	
Forest cover	1.01		1.08	***	1.01		0.97		1.02		0.05	+	0.01		0.10	**	0.05	*
Oil company	0.93		0.94		2.58	**	0.74		0.98		0.14		−0.12		−0.20		−0.17	
Conservation program	1.12		0.85		2.77	**	1.48		0.53	*	−0.12		0.15	+	0.19		−0.50	**
Survey year																		
Year is 2012	0.28	***	0.49	***	0.23	***	0.63	+	0.58	+	−0.28	*	−0.17	*	−0.47	**	−0.02	
Model	Logit		Ordered logit		Logit		Logit		Logit		OLS		OLS		OLS		OLS	
Resource category	Hunting		Hunting		Fishing		NTFP		Timber		Hunting		Fishing		NTFP		Timber	
$N_{households}$	1075		810		1075		1075		958		810		879		1075		176	

[a] Coefficients of nonlinear models are presented as odds ratios, which can be interpreted as a multiplicative effect on the odds of participation (or increasing in level for the ordered logit). Thus, values less than 1 represent a negative effect.

[+] p<0.10,

[*] p<0.05,

[**] p<0.01,

[***] p<0.001