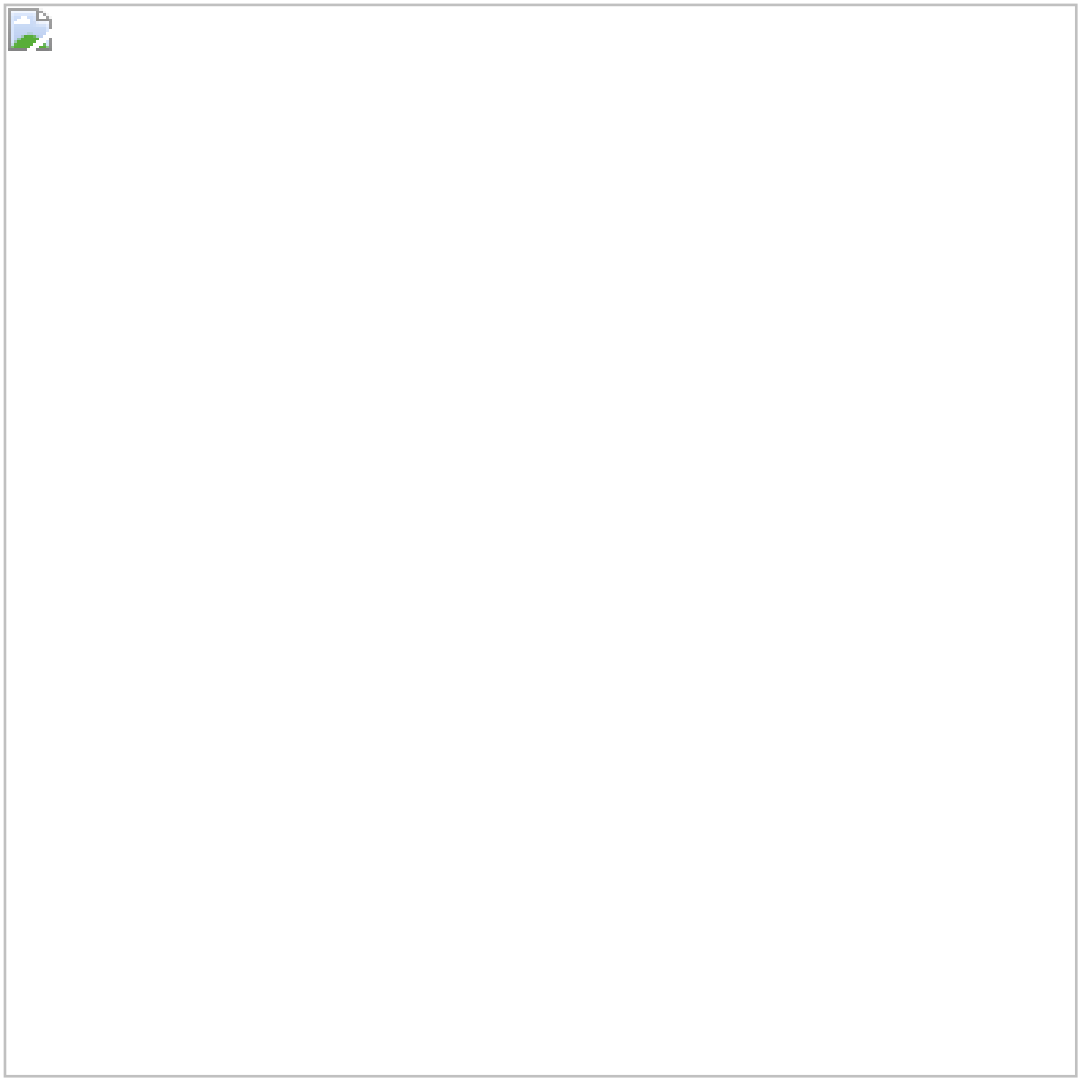

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Research Article

Environmental perceptions and resource use in rural communities of the Peruvian Amazon (Iquitos and vicinity, Maynas Province)

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Abstract

Individuals living in rural communities in tropical forests rely heavily on subsistence extraction of resources, and usually have strong ties to their local environment. In the Peruvian Amazon, patterns of resource extraction are of particular interest because the potential for human population growth is high, and international efforts to conserve biodiversity in this region are widespread. A survey was conducted to examine how residents of rural communities surrounding Iquitos, Peru use their local environment to procure household items (four food types, building materials, and firewood) with respect to age, gender, and level of education. Local perceptions of the environment and environmental resources were also documented. A second independent survey examined subsistence fishing practices in this region, with particular focus given to perceptions of fishery abundance and future stability. A follow-up market survey was subsequently undertaken in Iquitos to determine how fishing practices may influence the sustainability of the fishery. Results reveal that rural communities in the Iquitos region rely heavily on the local environment for their household needs, and the local environment is highly valued by residents of rural communities. Both governmental and self-regulation of natural resource use are generally viewed favorably. Although residents have mixed perceptions regarding what constitutes over-use of resources, rural community members strongly desire to implement sustainable practices to ensure that natural products will continue to be available in the future. Additionally, these results suggest that the fishery surrounding Iquitos may be experiencing overharvesting pressures that are reducing numbers and size cohorts of desirable fish species.

Keywords: environmental perception, fishery, Peruvian Amazon, sustainable extraction

Resumen

Los residentes de comunidades rurales en regiones de bosques tropicales dependen, en su mayoría, de los recursos que pueden obtener de su alrededor. El estudio de los patrones de extracción de recursos naturales en la región peruana del Amazonas es de particular interés pues el potencial para el aumento poblacional es alto, mientras que en paralelo, los esfuerzos internacionales para la conservación de la biodiversidad se expanden. Una encuesta fue diseñada para examinar cómo los residentes de las comunidades rurales en Iquitos, Perú utilizan su entorno local para adquirir objetos de uso diario (cuatro tipos de comida, materiales de construcción y leña), tomando en consideración la edad, el género y el nivel de educación de los encuestados. También se documentaron las opiniones de los encuestados con respecto al ambiente y los recursos naturales. Una segunda encuesta independiente examinó cuán sustentables son las prácticas de pesca, enfocada particularmente en las opiniones de los locales acerca la abundancia de peces y estabilidad futura de sus prácticas. Una encuesta de seguimiento se condujo en Iquitos para determinar cómo las prácticas de pesca de los locales pueden influenciar la sustentabilidad de la pesca en la región. Los resultados demuestran que las comunidades rurales en Iquitos dependen grandemente en los recursos naturales locales para su sustento, y que en general, el mantenimiento y permanencia del medio ambiente local es de gran valor para los residentes. En general, los residentes consideran que regulaciones tanto personales como gubernamentales son apropiadas. A pesar de las diferencias en opiniones acerca del abuso de recursos naturales, los miembros de estas comunidades rurales demuestran un alto interés en la implementación de prácticas sustentables, de manera que los recursos naturales disponibles al presente continúen disponibles en un futuro. Además, estos resultados sugieren que las prácticas de alta cosecha de peces en las regiones cercanas a Iquitos están reduciendo el número y tamaño de especies de peces disponibles.

Palabras clave: percepción del ambiente, pesca, región peruana del Amazonas, extracción sustentable

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Introduction

The interactions of humans residing in remote tropical regions have come under recent scrutiny as issues concerning resource utilization and extraction rights conflict with conservation management practices (e.g. [1-5]). Local communities rely heavily on natural resources obtained from forests and rivers (e.g. [6,7]), and conventional conservation ideals may clash (e.g. people-free parks; [8]) or coincide (e.g. sustainable extraction; [9]) with the perceptions and practices of rural inhabitants. Rural population pressure accelerates tropical deforestation [10] and has, therefore, prompted interest in understanding the environmental perceptions and resource use within rural communities in order to design conservation and management plans that may be reasonably integrated into local practices.

When compared to other tropical forests worldwide, the Amazon Basin has been described as a relative holdout against deforestation [11] but paradoxically ranks as the most rapidly deforested tropical habitat on Earth [12]. Protected by its size and biodiversity, there is currently a narrow window of opportunity to protect the remaining forests in the Amazon Basin: to do so, existing reserves should be expanded and strengthened, and local economies must remain viable [13].

The city of Iquitos is the primary urban center in the upper Peruvian Amazon, and has an economy deeply rooted in fisheries, timber, and tourism. The ostensibly competing interests of these distinct sectors set the stage for conservation conflicts in the surrounding rural communities. About 65% of the rural population outside of Iquitos is classified as economically disadvantaged, and rural communities are rapidly growing with about half the population under the age of 15 [14]. Here, families rely heavily on natural products (e.g. [15,16]) and their well-being and livelihoods are dependent on a biodiverse and healthy environment [17]. However, implementing sustainable practices can have negative effects on rural Amazonian household economies [7,18], creating significant conflict between local short- and long-term management approaches.

This study was conducted to examine how rural communities currently use their local forests and rivers, and to examine how conservation practices are perceived by the inhabitants of rural communities. Residents from rural communities were surveyed to determine the origin of common household items (i.e., four food types, building materials and firewood), and whether age, level of education, or gender influenced patterns of land use. Agreement with statements about the current state of the local environment and its future was also recorded. After examining responses to the initial survey, a second in-depth survey was subsequently conducted to understand current fishing practices and perceptions in rural riparian communities. Stability of the fishery is vital to rural families, and fish habitats are currently in generally good condition in the Amazon Basin; however, intensive use of the fishery is likely to threaten

stocks [19] and the biodiversity of the aquatic environment [20] in the future. This fishery survey prompted a short market study to examine one potential consequence of fishing practices on aquatic wildlife.

Methods

Study Population and Sites

Interviews were conducted in 19 small rural village communities located along the upper Amazon River located near the city of Iquitos, Peru (3° 44.887' S, 73° 14.833' W; Fig. 1a). Iquitos is the capital city of the Loreto Region and Maynas Province. Residents from surrounding communities are known as *ribereños*, and are of Amerindian and Caucasian descent. Families from these communities live within or close to a small central village. Resource extraction questionnaires (described below) were distributed in 7 communities (Fig. 1b; each community indicated by the letter following its geocoordinates): Canal Pinto (3° 24.978' S, 72° 46.676' W; *A*), Nuñez Cocha (3° 20.893' S, 72° 48.951' W; *B*), Nuevo Triunfo (3° 32.647' S, 73° 0.095' W; *C*), Sucusari (3° 14.604' S, 72° 55.770' W; *D*), Timicurillo II (3° 33.116' S, 73° 2.274' W; *E*), Tres de Mayo (3° 21.948' S, 74° 41.193' W; *F*), and Villa Maria (3° 32.528' S, 72° 52.536' W; *G*). Fishery questionnaires were distributed in 13 communities (Fig. 1b; each community indicated by the letter following its geocoordinates): Chispa de Oro (3° 25.557' S, 73° 1.524' W; *H*), Irlanda (3° 25.399' S, 72° 42.330' W; *I*), Leon Isla (3° 19.678' S, 72° 51.762' W; *J*), Nuevo Jerusalen (3° 18.570' S, 72° 59.220' W; *K*), Nuevo San Juan (3° 28.485' S, 72° 55.880' W; *L*), Nuevo Triunfo (3° 32.647' S, 73° 0.095' W; *C*), Nuevo Uchiza (3° 29.519' S, 72° 58.651' W; *M*), Ramon Castilla (3° 30.059' S, 72° 48.572' W; *N*), Santa Isabel (3° 27.832' S, 72° 55.081' W; *O*), Santa Teresa (3° 29.310' S, 73° 0.270' W; *P*), Tamanco (3° 18.906' S, 72° 59.369' W; *Q*), Timicuro Grande (3° 33.586' S, 73° 01.410' W; *R*), and Yarina Isla (3° 17.212' S, 72° 55.264' W; *S*). A thorough survey of the fish sold at an open-air market was conducted at the Belen outdoor market in Iquitos, Peru.

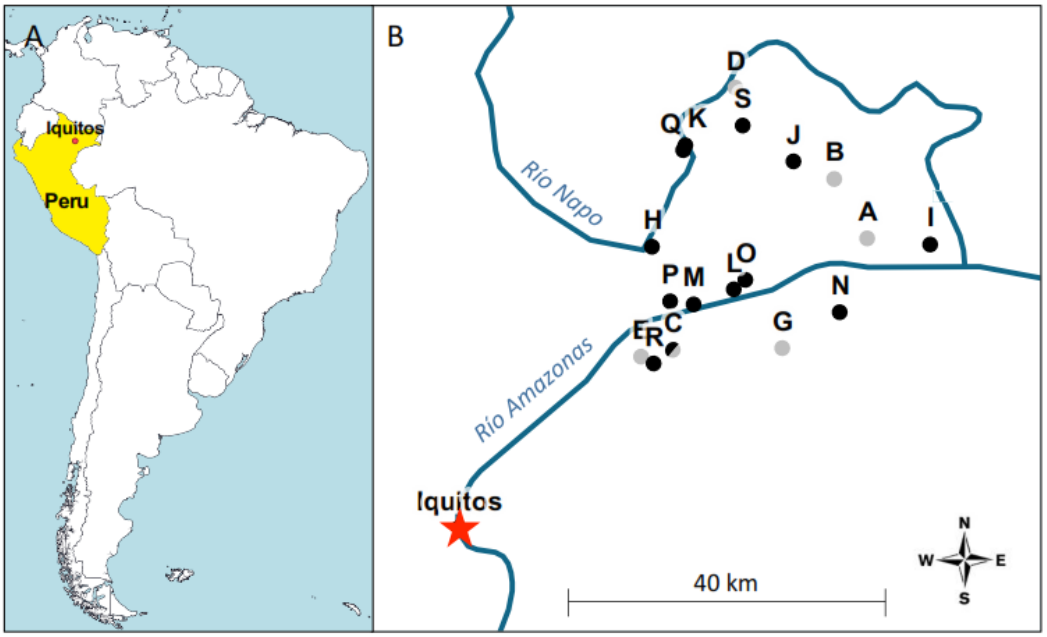

Fig. 1. (a) Location of Iquitos, Peru, and b) locations of communities sampled in the Resource Extraction Survey (grey circles) and Fishery Survey (black circles). See Methods for community names and geocoordinates corresponding to circles labeled *A* through *S*. One community (*C*) was surveyed during both studies, and is indicated by a two-tone circle. Community *F* (not shown) is located approximately 160 km west of Iquitos.

Resource Extraction Survey

In 2006, 100 heads of households (both male and female) were interviewed to determine their use of natural products along with their environmental attitudes. In a written questionnaire, participants were asked to indicate whether they procured each of six types of household items (edible plants, fruit, meat, fish, building materials, and firewood) *mostly, sometimes,* or *never* from the following sources: forest/river, garden/farm, or market/city. Participants were then asked if they *agree, strongly agree, disagree,* or *strongly disagree* with 41 statements that focused on their environmental attitudes. These statements addressed six topic areas: a) the local and global importance of the forest, b) current abundance of natural resources, c) changes in abundance of natural resources and the environment, d) future abundance of natural resources, e) regulation of natural resources, and f) education initiatives. Each participant's age, number of years of formal education, and household size were also recorded.

Fishery Survey

In 2008, 42 households were surveyed via a written questionnaire about fishing practices and perceptions of their local fishery. Participants were asked to indicate all of their preferred fishing months, times of day, locations, type of transportation, and the number of fish caught. Participants were then asked to *agree, strongly agree, disagree,* or *strongly disagree* with 45 statements regarding their use of the fishery, fishing equipment, perceptions of the fishery, and extraction of other aquatic animals. Participants were also requested to specify their age, household size, and number of years of fishing experience.

For both the resource extraction and fishery surveys, questionnaires were distributed in hardcopy and read aloud to ensure comprehension. A small stipend (~$2 USD, or S./ 5.50 Peruvian Nuevo Soles) was given to each participant upon completion of the questionnaires. Informed consent was obtained from all subjects. This research was conducted according to the ethical principles for studies involving human subjects expressed in the Declaration of Helsinki.

Market Survey

A survey of fresh fish vendors in the Belen outdoor market in Iquitos was conducted on 27, 28, and 30 June 2008 in order to estimate the sizes of fish being harvested in the region. The market survey was not intended to be exhaustive, but provided a random sample of average harvesting lengths of some common species. After obtaining permission from each vendor, a random subset of the fish on display was identified and photographed. Only whole fresh fish displayed on a flat surface were photographed. No data were collected on filleted, salted, or dried market fish. One species (*carachama*, *Pterygoplichthys multiradiatus*) commonly encountered in the market was photographed alive since their capacity to withstand ambient atmospheric conditions after capture far surpasses most other species.

Photographs were taken approximately 1 meter above the display facing directly down using a Sony Cyber-shot DSC-T70 digital camera (Sony Electronics, Inc., San Diego, CA, USA), next to a ruler for scale. Adobe Illustrator (version 12; Adobe Systems Incorporated, San Jose, CA, USA) was used to measure the standard length (SL, measured from the upper lip to the last vertebrae) of all full bodied fish that were visible in photographs.

Statistical methods

Using responses from the resource extraction questionnaires, an examination of how age, gender, and level of formal education influenced participants' utilization of the forest/river, garden/farm, and market/city was undertaken. Levels of utilization (*always, sometimes,* and *never*; see above) of sources of

household items were converted to numeric scores (3, 2, and 1, respectively). For each participant, scores of all six household items (edible plants, fruit, meat, fish, building materials, and firewood) were summed for each source (forest/river, garden/farm, and market/town), resulting in one total utilization score per source. Proportional uses of each source (e.g. "forest/river use" score divided by the sum of "forest/river use," "garden/farm use" and "market/city use" scores) were calculated for every participant in order to standardize all participants' scores to account for individual variation in self-reporting. If the proportion for each source was greater than 0.5, the participant was assigned a "1" for that source, otherwise "0." This procedure was repeated for each source, so that each participant was assigned a "0" or "1" for each of the three sources: forest/river, garden/farm, or market/town.

An information theoretics approach was used to examine how age, gender, and level of education influenced participants' reliance on each source (forest/river, garden/farm, and market/town). This model selection approach (Akaike Information Criterion; AIC) is highly suited to analysis of observational data [21]. Seven candidate generalized linear mixed models for each of the three sources were constructed, which represented all possible combinations of the continuous predictor variables age and education, and one factor, gender: 1) age alone, 2) gender alone, 3) education alone, 4) age and gender, 5) age and education, 6) gender and education, and 7) age, gender, and education. In each model, the village of the participant was included as a random effect. A binomial error distribution was assumed for all models. To assess if data transformations were needed before models were fit, Cook's distances of individual observations of continuous variables were examined. Diagnostic plots (binned residuals) of the chosen models were assessed and shown to be adequate. The quasibinomial family was used to estimate the dispersion parameter for the models, and it was ascertained that overdispersion was not apparent. Analyses were performed in R (version 2.11.1, R Development Core Team 2010, Foundation for Statistical Computing, Vienna, Austria).

Results

Resource Extraction Survey

Of the 100 participants from 7 communities, 60 were male, 27 were female, and 13 did not specify gender. The average age was 37.5 years (± 15 SD), and the average number of years of formal education was 5.8 (± 2.6 SD), not including 3 participants with higher education.

Most participants obtained household items from the forest/river and the garden/farm (Fig. 2). Participants *always* (84.38%) or *sometimes* (12.50%) obtained edible plants from the garden/farm, and *always* (22.35%) or *sometimes* (67.06%) from the forest/river. Most participants *never* (72.41%) or only *sometimes* (17.24%) obtained edible plants from the market/city (Fig. 2a). Similarly, most community members *always* (84.44%) or *sometimes* (13.33%) obtained fruit from the garden/farm, and *always* (26.19%) or *sometimes* (52.38%) from the forest/river. Participants *never* (54.32%) or *sometimes* (41.97%) obtained fruit from the market/city (Fig. 2b).

The forest/river was *always* (73.96%) or *sometimes* (23.96%) a source of meat (Fig. 2c), and was *always* (91.49%) or *sometimes* (7.45%) a source of fish (Fig. 2d). The garden/farm was relied on less heavily for meat and fish (*always* = 20.24%, 16.47%, *sometimes* = 60.71%, 35.29%, respectively), and the market/city even less so (*always* = 12.64%, 7.22%, *sometimes* = 19.54%, 46.98%, respectively). Building materials were *always* (87.50%) or *sometimes* (12.50%) procured from the forest/river, and *always* (17.86%) or *sometimes* (71.43%) from the garden/farm, but *never* (87.34%) or only *sometimes* (12.66%) from the market/city (Fig. 2e). Firewood was *always* (48.84%) or *sometimes* (40.70%) procured from the

forest/river, and *always* (64.04%) or *sometimes* (30.34%) from the garden/farm, but *never* (91.46%) or only *sometimes* (4.88%) from the market/city (Fig. 2f). Of the 100 participants, 39 failed to indicate their degree of utilization of at least one of the 18 item x source combinations, and 3 participants indicated two degrees (e.g. *always* and *sometimes*) of source utilization per item; these responses were not included in final counts or used in analyses.

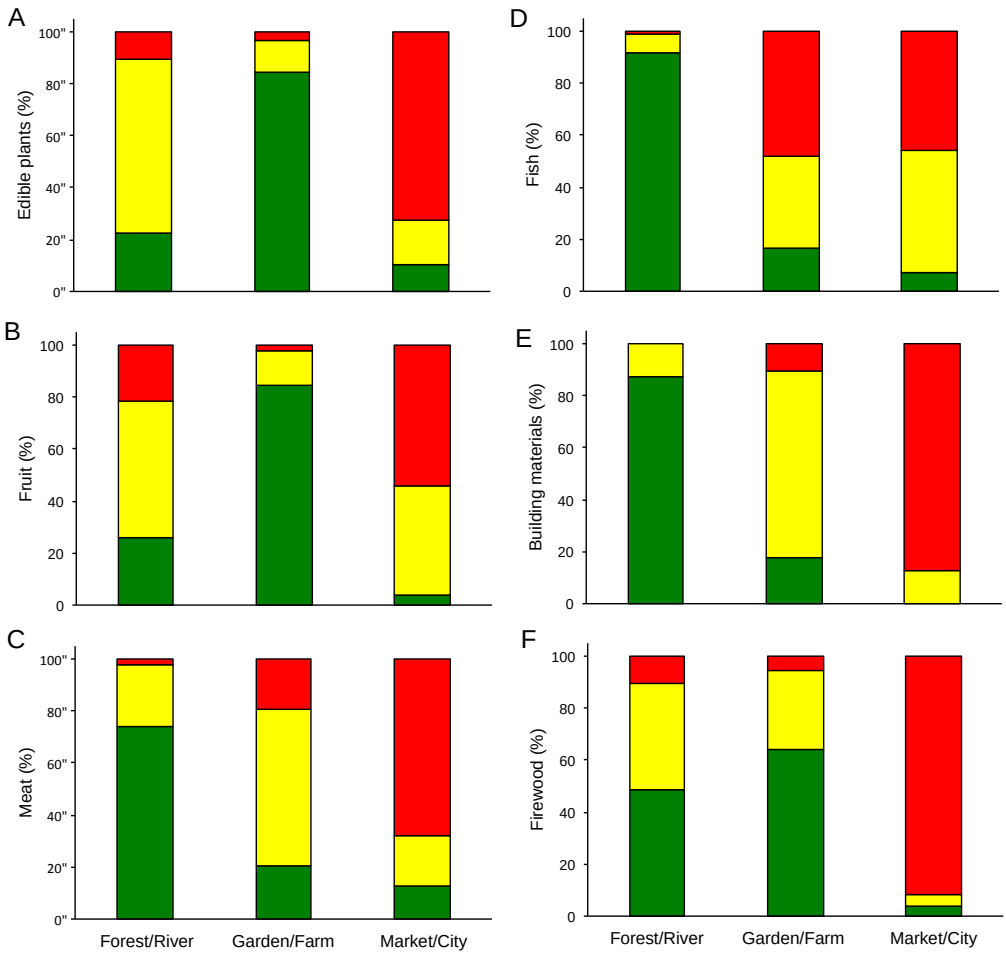

Fig. 2. Patterns of resource extraction in rural villages near Iquitos, Peru. Percent of participants in the 2006 Resource Extraction Survey that utilized the forest/river, garden/farm, and market/city to *always* (green, bottom), *sometimes* (yellow, middle), or *never* (red, top) obtain a) edible plants, b) fruit, c) meat, d) fish, e) building materials, and f) firewood.

Age, gender, and level of formal education were used as predictors in forest/river, garden/farm, and market/city utilization models. Of the seven candidate forest/river use models, the model containing all three predictors had a large Akaike weight (0.88) and was considered the top ranked model (Table 1a). None of the models predicting garden/farm (Table 1b) or market/city use (Table 1c) had sufficiently high Akaike weights and, therefore, model averaging was used to produce composite models for both garden/farm and market/city use. Coefficients of fixed effect parameters in all models were routinely near zero, with the exception of the gender variable. Among the participants in our study, the tendency to rely on the forest/river or garden/farm for household items increased with age, and the tendency to obtain household items from the market/city decreased with age. Women tended to utilize the forest/river more than men, and they utilized the garden/farm or market/city less than men. The likelihood of using the forest/river or garden/farm increased somewhat with education, whereas market use decreased. The random effect of the village was close to zero for all models.

Table 1: Comparison of the 7 candidate generalized linear mixed models examining the effects of age (A), gender (male = "0"; female = "1") (G), and level of education (E) on the utilization of the a) forest/river, b) garden/farm, and c) market/city for obtaining household items. Beta coefficients (β) are displayed for the forest/river models, and weighted beta coefficients are displayed for the garden/farm and market/city models. K (number of effects), log likelihood (log*L*), Akaike Information Criterion (AIC) values, AICc (adjusted for sample size), Δ_i (AIC difference between given and best model), deviance (Dev), and Akaike weights (w_i) are displayed for all models. Asterisk denotes top-ranked models.

Model predictors	K	log*L*	AIC	AICc	Δ_i	Dev	w_i	Int (β_0)	Age (β_1)	Gen (β_2)	Ed (β_3)
a. Forest/River											
A	3	-62.67	131.3	131.6	25.6	125.3	<0.01	-1.61	0.04	0	0
A, G	4	-51.09	110.2	110.6	4.5	102.2	0.09	-2.49	0.05	1.06	0
A, E, G*	5	-47.83	105.7	106.4	0	95.6	0.88	-2.91	0.05	1.07	0.09
G	3	-56.56	119.1	119.4	13.4	113.1	<0.01	-0.61	0	0.929	0
E, G	4	-52.43	112.9	113.3	7.2	104.9	0.02	-1.00	0	0.986	0.08
E	3	-62.12	130.2	130.5	24.5	124.2	<0.01	-0.35	0	0	0.04
E, A	4	-57.68	123.4	123.8	17.7	115.4	<0.01	-2.01	0.04	0	0.06
b. Garden/Farm											
A	3	-44.68	95.3	95.6	9.1	89.3	<0.01	-0.01	<0.01	0	0
A, G	4	-39.68	87.3	87.8	1.3	79.3	0.19	-0.53	0.01	-0.06	0
A, E, G	5	-37.83	85.6	86.4	0	75.6	0.38	-1.16	0.01	-0.06	0.01
G	3	-42.83	91.6	91.9	5.4	85.6	0.03	-0.03	0	-0.02	0
E, G	4	-39.04	86.0	86.6	0.1	78.0	0.36	-0.66	0	-0.11	0.02
E	3	-43.16	92.3	92.6	6.1	86.3	0.01	-0.039	0	0	<0.01
E, A	4	-42.11	92.2	92.7	6.2	84.0	0.01	-0.05	<0.01	0	<0.01
*Composite**								-2.50	0.017	-0.26	0.038
c. Market/City											
A	3	-35.16	76.3	76.5	11.0	70.3	<0.01	>-0.01	<0.01	0	0
A, G	4	-30.71	69.4	69.9	4.4	61.4	0.03	-0.02	>-0.01	-0.02	0
A, E, G	5	-27.34	64.6	65.4	0	54.6	0.36	-0.10	-0.02	-0.21	-0.02
G	3	-32.69	71.3	71.6	6.1	65.3	0.01	-0.03	0	-0.02	0
E, G	4	-28.89	65.7	66.3	0.8	57.7	0.24	-0.47	0	-0.14	-0.02
E	3	-30.76	67.5	67.8	2.3	61.5	0.11	-0.26	0	0	>-0.01
E, A	4	-29.01	66.0	66.5	1.0	58.0	0.22	-0.09	-0.01	0	-0.01
*Composite**								-1.01	-0.03	-0.39	-0.041

Responses to the 41 statements regarding environmental attitude are presented in Appendix 1. Overall, participants felt very strongly about the importance of their local forest, both locally and globally (Appendix 1a). Most participants (93%) stated that the local forest is important to themselves and their families, and 82% agreed the local forest is also important to people in other countries. Wild game and air quality in the forest were valued by the majority of participants, and most also recognized that many plants and animals in the Amazon Basin are endemic. Concern for the current abundance of local resources was mixed among participants (Appendix 1b). Local wild game was thought to be in abundance by about half of all participants, and almost 75% of participants thought that fish were plentiful. Few participants felt that their community overexploits game or harvests too much timber. Participants on average did not have strong opinions about whether or not their local natural resources were sufficient to support their community, but strongly agreed that there are too many people living on the planet to be supported by the world's natural resources. Respondents did not think that people from outside their community hunted wild game or harvested timber near their community.

Perceived changes over time in the abundance of wild game, fish, and plants in the forest (Appendix 1c) were only noted by approximately half of the participants. Similarly, opinions were mixed on whether rainfall and river level were as predictable as they were previously. However, most participants (88%) felt that the number of game animals in the forest surrounding their community had changed in recent years. Perhaps relating to this, most participants (92%) felt that the ways natural resources were used should be changed to ensure enough food for the future. All other predictions of future resource abundance were mixed (Appendix 1d): overexploitation of wild game and timber were not consistently perceived to be a threat to future resource use, or necessarily "harmful" to the Earth.

Participants had strong opinions about the regulation of natural resource use (Appendix 1e). People from outside of the community should not be permitted to harvest timber, even if it was paid for; feelings were even mixed regarding whether or not people from the community should be permitted to sell timber. Most participants felt that people should not be allowed to take unlimited amounts of natural resources, and that natural resource use should be limited to ensure availability for future generations. Participants as a whole trusted community leaders to make decisions, and felt that laws should exist to limit natural resource extraction. However, participants had mixed opinions about who should make those laws, if there are enough laws, and whether existing laws are being sufficiently enforced. Almost all participants wanted to learn how to protect the forest (92%), and many thought people should be taught how to extract resources without harming the forest (81%). Most participants (84%) indicated they would accept help from people outside their communities to achieve this goal (Appendix 1f).

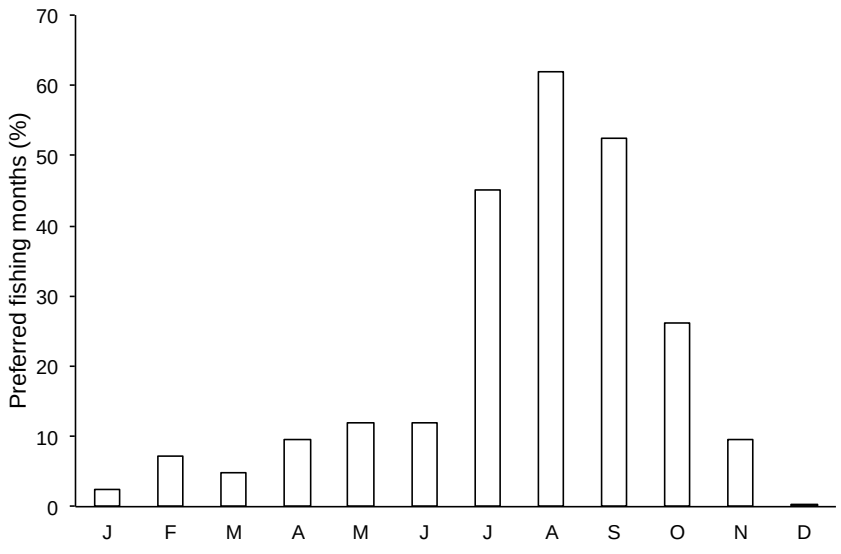

Fig. 3. Preferred fishing months of subsistence fishermen near Iquitos, Peru. Percent of participants in the 2008 Fishery Survey preferring to fish each month, January (J) – December (D).

Fishery Survey

Forty-two individuals from 13 communities participated in the 2008 fishery survey. The adult member of the household who primarily conducted fishing activities was surveyed; as such, all participants were male. The average age was 44.6 years (± 13.4 SD). Most participants (64%) supported 5 to 8 person households, 29% of households had 2 to 4 family members, and 7% of households had 8 to 12 family members. Participants varied in their levels of fishing experience: 29% of participants had more than 30

years experience, 21% had 11 to 30 years, 24% had 6 to 10 years, 24% had 1 to 5 years, and only 1 participant had less than 1 year experience.

July, August, and September were considered the best months for fishing (Fig. 3). These months are also some of the driest [22], suggesting that lower water levels facilitate fishing in this area. Participants most commonly fished before dawn (47.62%) or from dawn to noon (30.95%), with fewer fishing in the afternoon (4.76%) or evening/night (19.05%). Fishing occurred in the main channel of the Amazon River (33.33%) and its tributaries (23.81%), in the Napo River (16.67%) and its tributaries (35.71%), and at the juncture of the Amazon and Napo Rivers (9.52%). Lakes (52.4%), stream edges (33.33%), and river edges (26.19%) were preferred to the centers of small streams (2.38%) and rivers (0%). Frequency of fishing varied among participants, with 38.10% fishing daily, 28.57% fishing 3-6 times per week, 30.95% fishing 1-2 times per week, and only 1 participant fishing less than weekly. Boats without motors were the primary mode of transportation among participants (90.48%). Only 3 participants used a boat with a motor (Fig. 4a), and none walked to fishing locations. Most participants (80.95%) fished in a boat with 1-5 others, and none of the participants fished with more than 6 people. The typical number of fish caught per trip was 11-30 for 64.29% of participants, and 1-10 for 28.57% of participants. Only 7.14% of participants reported catching more than 31 fish per trip. Participants mostly caught 2-5 species of fish each trip (76.19%), with fewer catching more than 6 species (16.67) or only one type (7.14%). One third of participants (33.33%) reported access to a fish farm (Fig. 4b).

a)

b)

c)

Fig. 4. (a). Family fishing boat outside the village of San Luis, Maynas Province. Few families have access to a boat with a motor, and those who do may use it to transport (as shown above) a smaller boat without a motor to a preferred fishing location; (b) An example of a community fish farm. Young fish are harvested alive from the river and placed in small, community-maintained ponds for later consumption; (c) Fish vendors in the Belen outdoor market, Iquitos.

Fishing was an important source of food to participants' families (Appendix 2a), and most stated that that their families ate fish more than other types of meat. Despite this, some participants (45.24%) ate fish only rarely, and only some participants (42.86%) caught enough fish to feed their families. Few participants (26.19%) caught more fish than needed to feed their families. Fishing was an important

source of income only to some families (Appendix 2b); few families sold fish at the market (19.05%) or sold a variety of types of fish (16.67%).

Nets and fishing line were the most widely used fishing equipment (Appendix 2c), both used by 78.57% of participants. Some participants used fishing spears (42.86%) or boats that required gasoline (33.33%). No respondents reported using poison derived from local plants to catch fish. Fishing practices and preferences were somewhat uniform among participants (Appendix 2d). Participants tended to release fish that were too small. Although they caught a variety of fish, most participants had favorite types that they went greater distances to capture. It was generally felt that there are too many people using the local fishery. Almost all participants believed that fish farming is a good option for their communities, and were receptive to the idea of creating a fish farm.

Participants felt very strongly that there have been changes in the fishery over the past 5 years (Appendix 2e). During this period, most participants noticed that there were fewer fish in the river, and that fewer fish were caught per fishing trip. Consequently, participants must now travel farther to fish, although traveling farther did not often result in larger catches. Most participants felt very strongly that the fish they now catch are smaller, and that it is necessary to travel farther to catch large fish because they were more difficult to find. It was also generally thought that fish diversity has been reduced in the river, and that fewer species of fish are being caught.

Surveys also examined if fishery users exploited other aquatic species such as river turtles (e.g. *Podocnemis* spp.), caimans (e.g. *Caiman crocodilus*), and the Amazon river dolphin (*Inia geoffrensis*) (Appendix 2f). River turtles were occasionally caught in fishing nets (54.76%) and only sometimes released (42.86%), as river turtle was a preferred food item by most participants (76.19%). Few participants (7.14%) reported dolphin entanglement in fishing equipment and, if dolphins were caught, most participants indicated they would release them (69.05%). No participants reported that they liked to eat dolphin, and most (64.29%) thought that dolphin should never be eaten—perhaps because they are sacred or spiritual animals (54.76%) or because eating dolphin would bring bad luck (52.38%). This is notable as there is considerable interest and conflict surrounding this species and the people who fish throughout Amazonia [23]. Caimans, on the other hand, are a preferred food item and were routinely hunted by most participants (71.43%).

Market survey

The fresh fish on display at 105 stalls over three days in the Belen outdoor market (Fig. 4c), primarily on the avenues Ramirez Hurtado and 15 de Julio, were surveyed. Most vendors purchased fish from middlemen at the Iquitos ports, although some captured their own fish or purchased fish directly from local fishermen. A total of 655 fish from 19 species (five of which were only identifiable to genera; Table 2) were identified and digitally measured. The most abundant species photographed was *Prochilodus nigricans* (*boquichico*, N = 150). Some species were not common in the market or whole specimens were difficult to find and, therefore, few (< 20) measurements of these species were obtained.

Table 2: Average standard lengths (Avg SL) of fish sampled in Belen market survey, Iquitos, 2008, and literature review of species' lengths at maturity (Avg L_m; M = male, F = female). N indicates number of fish sampled in the market survey. When fish in the market survey were not identified to species, published L_m are provided for species within the genus. An asterisk indicates no data available. Superscript m (^{m}) indicates minimum L_m instead of average L_m. Measurement type (MT) of published L_m is standard length (SL), total length (TL), or forked length (FL).

Species	Common Name	N	Avg SL (cm)	Avg L_m (cm)	MT	Reference
Anodus elongatus	Yulilla	21	18.8 +/- 1.2	21.0^m (F)	SL	35
Astronotus ocellatus	Acarahuazu	15	20.2 +/- 1.7	25.5-26.5 (F)	TL	36
				24.5-25.5 (M)	TL	36
Brycon spp.	Sábalo	45	25.8 +/- 3.3	*		
Cichla monoculus	Tucunaré	25	33.9 +/- 4.7	26.5 (F)	SL	37
				21.4 (F), 26.2 (M)	TL	38
Colossoma macropomum	Gamitana	9	30.1 +/- 2.8	70^m (F), 62^m (M)	TL	39
				62 (F), 60 (M)	SL	40
Hoplias malabaricus	Fasaco	37	25.0 +/- 4.2	16.7 (F)	TL	41
Hypophthalmus spp.	Maparate	24	26.6 +/- 5.0			
H. marginatus –				29	FL	42
Mylossoma spp.	Palometa	28	14.9 +/- 4.0	*		
Osteoglossum bicirrhosum	Arahuana	3	66.6 +/- 4.3	*		
Plagioscion squamosissimus	Corvina	66	25.0 +/- 9.7	24.7 (F), 24.2 (M)	TL	43
				17.8 (F), 16.2 (M)	SL	44
Potamorhina altamazonica	Llambina	8	10.5 +/- 2.0	20.5	FL	42
Prochilodus nigricans	Boquichico	150	20.9 +/- 2.5	27^m	SL	45
				24.3 (F), 23.9 (M)	FL	46
Psectrogaster amazonica	Ractacara	8	15.0 +/- 2.2			
P. rhomboids –				15 (F), 15.3 (M)	TL	47
Pseudoplatystoma fasciatum	Doncella	4	62.8 +/- 21.1	93.9 (F), 78.5 (M)	TL	48
Pterygoplichthys multiradiatus	Carachama	34	24.0 +/- 2.6	30-40	TL	49
P. pardalis –						
Pygocentrus nattereri	Piraña	26	14.2 +/- 3.0	12.9-14.1 (F), 10.9-11.4 (M)	SL	50
Schizodon fasciatus	Lisa	52	23.6 +/- 3.1	19	SL	51
Semaprochilodus spp.	Jaraqui	9	17.7 +/- 1.0			
S. insignis –				26.4	TL	52
S. taeniurus –				36	TL	52
S. laticeps –				27.4 (F), 24.4 (M)	U	53
Triportheus spp.	Sardina	91	15.7 +/- 2.9			
T. angulatus –				16.3 (F), 15.5 (M)	TL	54

Lengths obtained from digital measurements were compared to published accounts of lengths at maturity (L_m; Table 2). If fish in this survey were not identified to species, or if no published data were available for an identified species, L_m was provided for species within that genus where available. Based on this random sample of fish in the Belen market, six species were harvested, on average in late June, above their published L_m: *Cichla monoculus, Hoplias malabaricus, Plagioscion squamosissimus, Pygocentrus nattereri*, *Schizodon fasciatus* and *Triportheus* spp. (when compared to L_m of *T. angulatus*). Two fish species were harvested below L_m: *Anodus elongatus* and *Prochilodus nigricans.* Our data also suggested that *Astronotus ocellatus, Hypophthalmus* spp., *Potamorhina altamazonica*, *Psectrogaster amazonica*, *Pseudoplatystoma*

fasciatum, Pterygoplichthys multiradiatus, and *Semaprochilodus* spp. were harvested below L_m, although small sample sizes, lack of species-level specificity, or a discrepancy between our measurement type (SL) and published L_m measurement type (total length, TL, or forked length, FL) should be taken into account (see Table 2). In particular, all nine specimens of *Colossoma macropomum* were found to be well under their published L_m by some 30 cm. To our knowledge, published L_m were not available for *Brycon* spp., *Mylossoma* spp., or *Osteoglossum bicirrhosum*.

Discussion

Rural communities outside of Iquitos, Peru are extremely reliant on natural products derived from their local environment. These surveys helped to discern the patterns of use of natural products, factors affecting utilization of the environment, and environmental perceptions within rural communities, with a focus on the family fishery. Results of the resource extraction and fishery surveys highlight that participants heavily rely upon the local environment for their household needs, and natural products tend to be used for subsistence and are infrequently purchased or sold by average families. The local environment is highly valued by residents of rural communities, and both governmental regulation and self-regulation of natural resource use are viewed favorably. As a whole, rural residents voiced their desire to implement sustainable practices to ensure that animals and plants will continue to be available in the future.

Age, gender, and education may affect where residents of rural communities obtain household items. Obtaining food, building materials, and firewood directly from the environment or from a garden or farm was positively correlated with age and education among participants; market use exhibited the reverse pattern. The observation that younger rural residents may move away from traditional environmental use is supported by related studies and has also been used as a counter-argument to the suitability of indigenous communities as permanent caretakers of forest reserves [5]. The correlation of use of forest and garden products with education may perhaps be confounded by relative wealth; forest product extraction is positively related with household wealth in some communities in the Peruvian Amazon [6]. Even if this relationship is not causal, it deserves attention because individuals who more intensively harvest natural products also receive more education, and potentially a greater opportunity to formally learn about sustainable harvesting. Within our study area, women tended to use the forest/river more intensively than men, and men used the garden/farm and market/city more than women. As men traditionally perform most of the hunting and fishing activities, these results were somewhat unexpected. However, our selective distribution of questionnaires to the primary household provider may over-represent the average rural woman's utilization of the forest/river. For example, in households without an adult male, women may perform most of the fishing activities (e.g. [9]). Although this analysis describes the environmental use patterns of a relatively small subset of the *ribereño* population, it is one of the few that focuses on individual differences in patterns of resource use in rural communities in tropical forests. While valuable in their own right, most surveys of rural Amazonian communities focus on generalizations of resource use patterns (e.g. [6,9,24], but see [15,25]). Here, we provide an analysis that may help predict future patterns of resource use and target specific demographics for conservation initiatives in the Peruvian Amazon.

One notable trend among survey respondents was that concern for sustained natural resource abundance was not ubiquitous. Respondents varied greatly in their perceptions of current abundance of common resources such as wildlife, edible plants, and timber, and also had very mixed beliefs about whether or not the forest would be able to provide resources indefinitely when intensively used. Similar perceptions

of inexhaustible resources have also been found in other rural Amazonian communities (e.g. [26]). These perceptions of indefinite supply are concerning, as even subsistence extraction may severely deplete game populations [27]. In the 2008 fishery survey, for example, high opportunistic extraction of river turtles and caiman was noted, both of which have been historically overexploited [28,29]. Maintaining populations of wildlife and other resources for biodiversity and human consumption will not only require regulation, but also (and perhaps more importantly) will demand the education of rural communities in local resource management. *Ribereños* in our survey were very eager to learn how to "protect" their natural resources; however, based on their mixed responses to questions about sustained resource abundance, it is unclear whether respondents interpreted "protection of resources" as managing resources for continued use (our intended meaning), or protecting resources against exploitation from non-community members. Nevertheless, both interpretations suggest a role for education in sustainable management at the local community scale.

Among those surveyed in 2006, families nearly always obtained fish directly from the environment. Most participants thought that fish were plentiful in the river, and perceptions were mixed regarding whether or not there had recently been a change in the abundance of fish in the fishery. For most rural families, fish is the only dependable source of protein, and residents are estimated to consume about 4 to 7 times the world's average [30]. Because of the importance of fish in rural diets (e.g. [24]), and the high proportion of participants who procure their own fish locally, we were particularly interested to learn if changes in the fishery were noted by those who fished regularly. As expected from the pressure placed on the local fishery, our 2008 fishery survey indicated that most family fishermen did indeed perceive that aspects of the fishery changed from that of the previous five years, noting that fish are harder to find and fewer types of fish are available. The most dramatic responses pertained to a change in the average size of fish: almost all participants believed that the average size of fish had decreased. Participants also indicated that they had strong preferences for particular species of fish, and they travelled farther to obtain certain species. These selective extraction practices have the potential to stress populations of select species [9] and the ecological consequences have not yet been thoroughly ascertained.

Our market survey provides some evidence that the Iquitos-area fishery is currently being jeopardized by overharvesting practices. Many of the fish species examined appear to be harvested well below their average lengths at maturity (Table 2). Most notably, this survey provides evidence that three species comprising 62% of all fish marketed in Iquitos (*Prochilodus nigricans, Potamorhina altamazonica*, and *Psectrogaster amazonica*; [31]) may currently be harvested unsustainably. The broad applicability of the market survey is admittedly limited, as our results are drawn from a relatively small number of fish, sampled over a short period of time within a single season. Additionally, fish surveyed in the city of Iquitos are not necessarily representative of fish extracted by rural communities [31]. Nevertheless, viewed as a random snapshot of the regional fishery, these data suggested that the overall fishery may be stressed by a) extraction of fish prior to sexual maturation, which can preclude replenishing of stocks, and/or b) an evolutionary response to fishery overexploitation and extraction at small lengths, which may over time reduce average L_m (and therefore average fecundity) of a population (e.g. [32]). Our results are supported findings by others [33], suggesting that the Iquitos-area fishery is becoming overexploited.

Implications for conservation

Sustaining fish populations used by small family/community groups will be essential in the future as pressure placed on the commercial fishery begins to affect subsistence fishermen. The commercial fishing fleet is restricted from many productive areas near Iquitos to allow residents exclusive use of the local

fishery [31]; as a result, and perhaps to escape more stringent fishing regulations, the commercial fishing fleet may intensify its use of more remote rural waterways. The random sample of *ribereño* subsistence fishermen in our survey tended to be highly experienced individuals, fishing multiple times each week and catching relatively high numbers of fish with only simple fishing equipment. The encroachment of the commercial fishery, combined with the probable future adoption of more modern fishing equipment, may drastically reduce the availability of fish for rural families, especially if human population growth continues in and near the city of Iquitos at its current pace. Our surveys suggested that *ribereños* are supportive of environmental regulation, perhaps in part in reaction to the proliferation of for-profit, non-local enterprises such as commercial fishing. Increased regulation (often self-motivated) may be one method of protecting fish populations, but even sustainable management may not sufficiently address the high demand for fish in rural communities in the future. In our study and others (e.g. [34]), Iquitos-area *ribereños* are very willing to work with outside entities to initiate or promote local aquaculture. *Ribereños* appear highly enthusiastic about aquaculture, an observation that has the potential to be a crucial tool for feeding the rural population while conserving aquatic biodiversity within the Amazon Basin.

Management of tropical forests for both biodiversity conservation and human use is a complicated and contentious task. Looking forward, it is indeed likely that human/environment dynamics in the Peruvian Amazon will change greatly with improved technology, increasing human population pressure, and temporal and spatial alterations in natural resource abundance. The high value placed on forest utility and biodiversity by residents of rural communities, and their reported willingness to learn about sustainable practices and adapt to new challenges does however provide hope for future conservation initiatives in the Peruvian Amazon.

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Appendix 1: Responses to the 2006 resource extraction questionnaire. Participants indicated their level of agreement (4 = strongly agree, to 1 = strongly disagree) to statements pertaining to a) the local and global importance of the forest, b) current abundance of natural resources, c) changes in natural resource and the environment, d) future abundance of natural resources, e) regulation of natural resources, and f) natural resource education initiatives. Means, standard deviations (SD), and sample sizes (N) of responses to all statements are shown. Level of agreement was then categorized in the following manner. For each statement, counts of responses in each category were weighted ("strongly agree" x 3, "agree" x 1, "disagree" x -1, "strongly disagree" x -3), divided by the total count, and converted into five levels of agreement: Very high (weighted sum = 1.8 to 3.0), high (0.6 to 1.8), mixed (-0.6 to 0.6), low (-1.8 to -0.6), and very low (-3.0 to -1.8).

	Agreement	Mean	SD	N
a. Local and global importance of the forest				
The forest near my home is very important to me and my family.	Very high	3.58	4.47	88
I prefer to eat wild meat than chicken or beef.	High	3.32	0.75	88
I prefer to raise wild animals than to hunt them.	High	3.49	0.64	89
I do *not* like to eat wild meat from the forest.	Mixed	2.72	1.10	89
The air is healthier/has a better quality in a forest than in a city.	Very high	3.81	0.48	83
The air has the same quality in the forest and the city.	Mixed	2.45	1.10	87
The forest near my home is important even to people in other countries.	High	3.34	0.88	89
The Peruvian forest is important to people in other countries.	Mixed	2.59	1.09	90
Many of the plants and animals found in the Amazon forest are only found here, not in other parts of the world.	High	3.43	0.79	91
b. Current abundance of natural resources				
There are plenty of animals in the forest for me and my family.	Mixed	2.58	1.08	86
There are plenty of fish in the river for me and my family.	High	3.02	0.99	89
People in my community hunt too many animals from the forest.	Mixed	2.21	1.04	89
People in my community cut too many trees from the forest.	Low	2.09	1.04	88
People outside of my community cut trees and hunt animals in the forest near my community.	Low	2.02	0.89	90
There are enough natural resources in my community to support a larger population.	Mixed	2.31	0.83	89
There are too many people in my community to be supported by local natural resources.	Mixed	2.44	1.04	87
There are too many people living on the planet to be supported by the world's natural resources.	High	2.88	0.87	88
c. Changes in natural resource abundance and the environment				
There are fewer animals in the forest than before.	Mixed	2.43	0.96	88
The number of animals in the forest surrounding my community has not changed.	Low	1.73	0.73	90
There are fewer fish in the river than before.	Mixed	2.52	1.02	90
It is more difficult to find edible and medicinal plants in the forest than before.	Mixed	2.43	0.83	88
The river level change and amount of rain is less predictable than before.	Mixed	2.57	0.92	88

d. Future abundance of natural resources				
If we hunt too many animals, there will not be enough for future generations.	Mixed	2.35	1.07	88
The forest will not be able to provide food for us forever.	Mixed	2.29	1.05	86
To have enough food for the future, we have to change the way we use natural resources.	High	3.39	0.80	87
If we cut too many trees, there will not be enough for future generations.	Mixed	2.23	1.04	86
The forest has enough trees for my community to use for generations.	Mixed	2.63	0.91	86
If my community cuts too many trees, it will harm the earth.	Mixed	2.31	1.01	90
If my community cuts too many trees, it will *not* harm the earth.	Mixed	2.21	1.02	84
e. Regulation of natural resources				
People from my community should not be allowed to cut trees and sell them.	Mixed	2.21	0.96	87
People from outside my community should not be allowed to cut trees even if trees are paid for.	Low	2.13	0.92	88
People should be allowed to take as many natural resources from the forest as they want.	Low	1.87	0.77	89
People should be allowed to do whatever they want with natural resources even if it destroys resources for future generations.	Low	1.69	0.87	87
I trust leaders of my community to make decisions about our use of natural resources.	High	3.30	0.69	90
There should be laws that limit the amount of trees, animals, and fish taken from the forest and rivers.	High	3.55	4.47	88
People outside of my community should not be allowed to make decisions about our natural resource use.	Mixed	2.19	1.03	88
There are enough laws that protect our natural resources.	Mixed	2.78	1.09	87
Laws that protect our natural resources are not enforced.	Mixed	2.63	1.04	88
f. Education initiatives				
I would like to learn how to protect the forest.	Very high	3.59	0.73	90
People should be taught to farm and hunt in ways that will not damage the forest.	High	3.34	1.05	89
I would accept help from people outside of my community to learn how to protect our natural resources.	High	3.44	0.90	88

Appendix 2: Responses to the 2008 fishery questionnaire. Participants indicated their level of agreement (4 = strongly agree, to 1 = strongly disagree) to statements pertaining to a) the importance of the fishery as a source of food, b) importance of the fishery as a source of income, c) use of fishing equipment, d) fishing practices and preferences, e) changes in the fishery in the past 5 years, and f) other types of aquatic extraction. Means, standard deviations (SD), and sample sizes (N) of responses to all statements are shown. Level of agreement was then categorized in the following manner. For each statement, counts of responses in each category were weighted ("strongly agree" x 3, "agree" x 1, "disagree" x -1, "strongly disagree" x -3), divided by the total count, and converted into five levels of agreement: Very high (weighted sum = 1.8 to 3.0), high (0.6 to 1.8), mixed (-0.6 to 0.6), low (-1.8 to -0.6), and very low (-3.0 to -1.8).

	Agreement	Mean	SD	N
a. Importance of the fishery as a source of food				
Fishing is a very important source of food for my family.	Very high	3.56	0.63	41
My family and I eat fish more often than other types of meat.	High	3.00	1.10	42
My family and I eat fish rarely.	Mixed	2.50	0.97	42
I catch enough fish to feed my family.	Mixed	2.44	0.67	41
I catch more than enough fish to feed my family.	Low	2.14	0.75	42
b. Importance of the fishery as a source of income				
Fishing is a very important source of income for my family.	Mixed	2.53	0.97	39
My family and I sell fish often at the market.	Low	1.81	0.74	42
Because of the abundance of fish, I am able to sell many different types of fish at the market.	Low	1.67	0.75	42
c. Use of equipment				
Nets	High	2.88	0.89	42
Fishing line	High	2.81	0.99	42
Spears	Mixed	2.24	0.93	42
Poison	Very low	1.31	0.47	42
Boat that uses gasoline	Low	2.14	0.96	41
d. Fishing practices and preferences				
If the fish I catch are too small, I release them.	High	3.26	0.89	42
I have at least one favorite type of fish I like to catch and eat.	High	2.85	0.91	41
I like to catch all types of fish.	High	3.00	0.62	42
I often travel farther to catch my preferred type of fish.	High	3.00	0.92	41
I am willing to travel farther to catch my preferred type of fish.	Mixed	2.67	0.95	42
The boat I use doesn't have an engine.	Mixed	2.71	1.03	41
There are too many people fishing in the river.	High	3.22	0.88	41
Fish farming is a good idea for my community.	Very high	3.85	0.53	41
I am willing to create a fish farm in my community.	Very high	3.90	0.29	42
e. Changes in the fishery in the past 5 years				
There are more fish in the river now.	Very low	1.57	0.74	42
I catch fewer fish now.	High	3.17	0.93	42
It is more difficult to get a large catch now.	High	3.00	1.17	42
I travel farther to fish now.	High	3.17	1.02	41
I travel farther to catch as many fish as I did previously.	High	3.14	0.81	42
The fish I catch now are usually smaller.	Very high	3.44	0.59	41
It is harder to find large fish now.	Very high	3.49	0.87	41

I travel farther to catch large fish now.	Very high	3.45	0.88	42
I catch more types of fish now.	Low	1.83	0.70	42
There are more types of fish now.	Low	1.66	0.57	41
There are fewer types of fish in the river now.	High	3.05	1.10	42
f. Other aquatic extraction				
I sometimes catch river turtles in my nets.	Mixed	2.52	0.83	42
If I catch a river turtle, I release it.	Mixed	2.46	0.95	41
I like to eat river turtles.	High	2.90	0.74	41
I sometimes catch dolphins in my nets.	Very low	1.52	0.77	42
If I catch a dolphin, I release it.	High	3.15	1.06	41
I like to eat dolphin.	Very low	1.33	0.48	42
Dolphins should never be eaten.	High	2.93	1.15	41
Dolphins are sacred or spiritual animals.	Mixed	2.68	0.93	41
Eating dolphin will bring bad luck.	Mixed	2.70	1.02	40
I sometimes hunt caimans.	Mixed	2.76	0.80	41
I never catch caiman.	Mixed	2.49	0.81	41
I like to eat caiman.	High	3.18	0.78	40