Large-scale Environmental Monitoring by Indigenous Peoples

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Changes in vertebrate populations in tropical ecosystems are often understood to occur at large spatial and temporal scales. Understanding these dynamics and developing management responses when they are affected by hunting and land-use change require research and monitoring at large spatial scales. Data collection at such scales can be accomplished only through the participation of locally resident nonscientists. To assess the feasibility of rigorous, scientifically valid data collection under such conditions, we describe the design and management of a three-year study of the relationships among socioeconomic factors, hunting behavior, and wildlife population dynamics in a 48,000-square-kilometer, predominantly indigenous region of Amazonia. All of the data in the study were collected by locally recruited and trained indigenous technicians. We describe data collection and verification systems adapted to the culturally influenced data-collection practices of these technicians and propose protocols and improvements on our methodology to guide future large-scale research-and-monitoring projects.

Keywords: participatory research, protected areas, hunting, Makushi, Wapishana

Natural and anthropogenically driven changes in Amazonian vertebrate populations occur over very large spatial and temporal scales (Hill and Padwe 2000, Novaro et al. 2000, Fragoso 2004, Bodmer et al. 2010). On indigenous lands, which constitute more than one-fourth of the Amazon basin (Amazonia 2009), effective game management is essential for ecosystem integrity, food security, and cultural survival, given the importance of hunting in subsistence-oriented livelihoods. With direct anthropogenic impacts on animal populations potentially exacerbated by climate change (Neilson et al. 2005), strategies for resource management on indigenous territories require long-term, scientifically sound monitoring programs and the direct involvement of the territories' permanent human inhabitants.

In addition to the preeminent issue of the rights of indigenous peoples to monitor and manage their own land and the importance of their codevelopment of or their participation in any project on their lands, there are other considerations that make the involvement of local and indigenous peoples imperative in large-scale research-and-monitoring projects. The extensive knowledge that subsistence-oriented peoples have of the ecosystems surrounding their communities is directly relevant to accurate data collection; the advantages of working with local hunters to help in the finding and identification of animals and their signs have been repeatedly noted and are typically due to the communities' ecological expertise, developed through lifetimes of experience as hunters (Hill et al. 1997, Fragoso et al. 2000, Hill and Padwe 2000, Noss et al. 2005). Professional biologists, despite their knowledge and training, may not have developed detection skills equivalent to those of hunters. In addition, the cost and limited time availability of trained biologists mean that large-scale research and monitoring is only economically and logistically feasible through voluntary or remunerated approaches in which local residents, rather than temporary teams of visiting professional researchers, regularly collect data. A further advantage of working with local technicians is their ability to serve as liaisons between research-and-monitoring projects and communities (Noss et al. 2005, Low et al. 2009).

High rates of illiteracy and innumeracy, however, and unfamiliarity with the hypotheticodeductive framework make the rigorous collection of scientifically valid data extremely challenging for remote communities. The necessary time commitment for such data collection is also complicated by livelihood systems in which subsistence-oriented activities generally demand a significant portion of peoples' time, even among those individuals engaged in full-time salaried work. These limitations must be overcome if both governments and indigenous and other local peoples are to have access to the information they require to manage and protect their lands.

Wildlife abundance and density estimates

Sustainable management of game populations for hunting requires quantitative information on the size of wildlife populations, reproduction and replacement rates, off-take rates, and catchment area. Of all these parameters, *density*—a

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quantitative measure of the abundance of animals—is the most difficult to obtain. There are many methods for estimating density, but results vary with the social structure of the animals, home range size, and movement patterns (Bodmer 1994, Caughley and Sinclair 1994, Jorgenson 1996). The most reliable density estimates come from tracking animals to estimate their home range size, but home ranges are known for few Neotropical vertebrate populations (see Eisenberg and Redford 1999, IUCN 2010). Density estimates are therefore usually obtained from visual observations made along line transects; such observations are affected by small-scale habitat variation and by species' social structure and require large amounts of replication to be reliable (Fragoso et al. 2010).

With four exceptions (Noss and Cuéllar 2000, Fragoso et al. 2002, Hill et al. 2003, Ferraz et al. 2008), indigenous and local peoples have not been incorporated into large-scale data collection on vertebrate population density and abundance in the Neotropics, although they are frequently and effectively involved in hunter self-monitoring programs (e.g., Townsend 1995, 2000, 2004, Campos-Rozo and Ulloa 2003, Bodmer et al. 2004, Noss et al. 2005, Townsend et al. 2005, Constantino et al. 2008, Danielsen et al. 2009). The bulk of the scientific literature on animal densities and the impact of hunting and habitat degradation on Neotropical game animals on indigenous lands has therefore been the result of data collection by individual or small teams of professional biologists on transects (e.g., Peres 2000, Peres and Nascimento 2006, Nuñez-Iturri et al. 2008, Zapata-Rios et al. 2009, Endo et al. 2010). This necessarily limits the spatial and temporal extent of data collection, given the limited number of biologists available for or interested in doing this work (Hill and Padwe 2000).

In addition to the large-scale, long-term work by the Aché and their collaborators in Paraguay (Hill et al. 1997, 2003, Hill and Padwe 2000); the Izoceños and their collaborators in the Bolivian Chaco (Ayala and Noss 2000, Noss and Cuéllar 2000, Noss and Painter 2004, Noss et al. 2005); the Xavante and their collaborators in Mato Grosso, Brazil (Leeuwenberg 1997, Fragoso et al. 2000, Prada and Marinho-Filho 2004); and the ProBuc community-based monitoring program instituted in three protected areas by the Brazilian state of Amazonas, we are aware of only a few smaller studies that have relied exclusively or almost exclusively on indigenous or other local technicians to collect abundance and density data on transects (e.g., Ino et al. 2001). We conducted keyword searches in the Thomson Reuters Web of Science to address the English-language literature and reviewed the proceedings of the Wildlife Management in Amazonia conferences (Congreso Internacional sobre Manejo de Fauna Silvestre 2010) and various Spanish-language publications (Ulloa et al. 1996, 2004, Rubio Torgler et al. 2000, Campos-Rozo and Ulloa 2003) in order to identify other studies in which the relationships between hunting and wildlife populations were assessed using local technicians. Although these studies provide insights into the effectiveness of participatory methodologies for estimating hunting pressure, animal abundances, and local capacity building, little if any discussion has been offered regarding data quality and governance, the motivation of hunters over long study periods, or the best practices for effective incorporation of local people into the data-collection process.

In the present article, we address the feasibility of large-scale, high-quality data collection by indigenous peoples; describe the methodology used; and provide recommendations on how the approach that we have used in data collection can be improved. We focus on the training, data-checking methods, and governance system developed to implement and sustain the project, while demonstrating that large-scale, field-intensive research efforts with indigenous peoples are both feasible and effective. We also intend to provide guidance for related work by other researchers, conservation organizations, and government entities by documenting the challenges encountered and the solutions devised to meet these challenges. Although we focus on studies of hunting and vertebrate populations in Neotropical systems, our approach may also apply to other areas of study regarding the interface of human livelihoods and natural systems.

Overview of the project

The Coupled Human and Natural Systems project (NSF 2010) was designed to describe the changing relationship between indigenous peoples and the elements of their environment (in this case, game animals) during the process of economic and cultural interaction and integration with surrounding national societies. The project uses the lens of linked socioecological systems coupled with feedbacks and flows of information between people and their environment. The research design, including community and control-site selection, responded to the project's statistical and modeling approach to hypothesis testing, the need to incorporate between 20 and 30 communities representing a measurable range of socioeconomic conditions, and community interest in participating in the project. Of the communities consulted regarding participation, one opted out of the study. During the project consultation process, it was necessary to balance the interests of the regional leadership in including specific villages in the project with budget constraints and community suitability for the study; several communities that wished to participate could not be incorporated. Given the need to preserve a standardized scientific approach to data collection, with some exceptions (e.g., modification of questions in hunting-return surveys and the inclusion of locally important animals in the wildlife guide), most of the data-collection process was established a priori, without local input. However, we sought substantial input regarding the format and content of research results to be returned to collaborating communities.

As part of the project, we collected social and biological data, including socioeconomic surveys of households, hunting preferences, hunting effort and wildlife harvests,

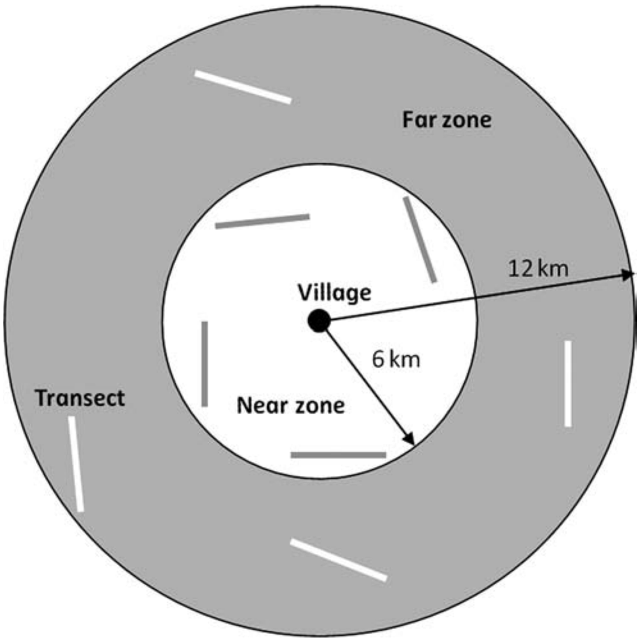

Figure 1. A distribution of transects around a hypothetical village. Abbreviation: km, kilometers.

vertebrate population and community dynamics, forest structure, and fruit availability. Biological data collection, which is the focus of this article, took place at 28 sites, 23 of which are centered on villages and 5 of which are in uninhabited, unhunted "control" areas located between 24 and 40 kilometers (km) in a straight line from any village. At each site, biological data were gathered by teams of two or four technicians on eight straight-line transects, each 4 km in length and randomly distributed around each village center or around a randomly chosen central point in the case of the uninhabited control areas (figure 1; methodology adapted from Fragoso et al. 2000). The transects were walked twice each month; data on animal observations were collected during the first visit and those on animal signs and fruit abundance during the second, resulting in monthly data collection for each parameter.

The project was situated in the forest–savanna ecosystem of the Rupununi (figure 2) and included most of the Guyanese territories occupied by the Makushi and Wapishana people (called the Macuxi and Wapixana in Brazil). The Makushi, a Carib-speaking indigenous group, occupy an area straddling the Guyana–Brazil border, with over 9500 people living in Guyana. The Wapishana, an Arawakan-speaking indigenous group, also occupy the savannah–forest transition area in both Guyana and Brazil and number approximately 8000 individuals in Guyana (figure 3). Most Makushi communities are located in the northern portion of the study area (North Rupununi), whereas the Wapishana tend to reside in the southern region. Both peoples practice shifting agriculture, hunting, and small-scale extraction of timber and nontimber forest products. Their wildlife exploitation includes subsistence

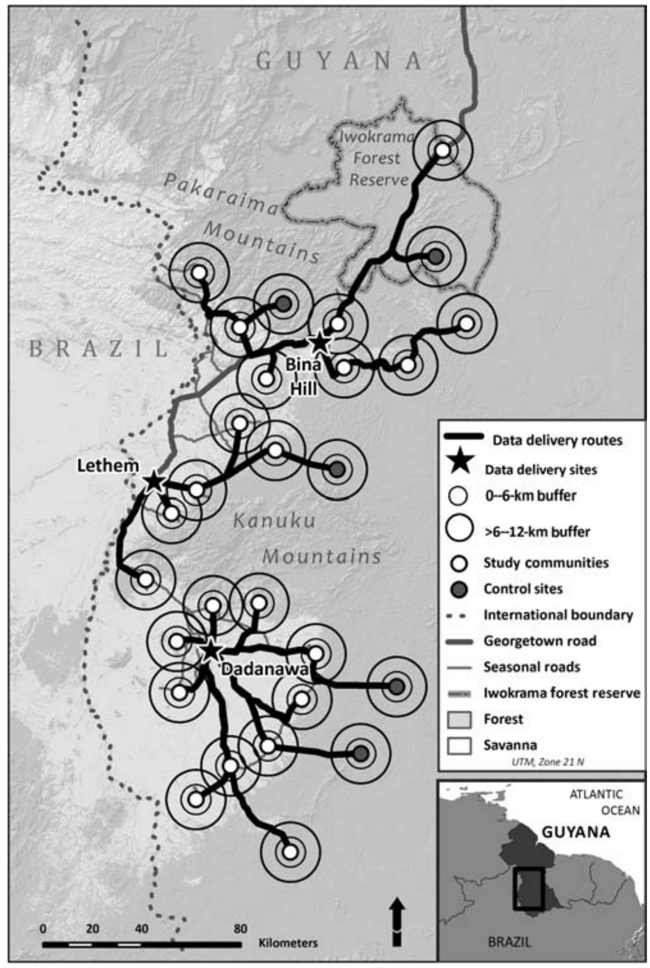

Figure 2. The location of the Rupununi study region in Guyana, South America, with routes used by local technicians to reach the monthly meeting locations.

Figure 3. A Wapishana home in the South Rupununi. Photo credit: Jeffrey B. Luzar.

hunting and fishing and commercial fishing and bird trapping (figure 4).

The indigenous communities in the study region are governed by a *toshao* (village leader) and a village council,

*Figure 4. Makushi preparing a white-tailed deer (***Odocoileus virginianus** *sp. aff.* **cariacou***) after a hunt. Photo credit: José M. V. Fragoso.*

elected by the community at three-year intervals. Under Guyana's Amerindian Act of 2007, village councils wield significant authority over local affairs, including the ability to develop and implement natural-resource management plans pertaining to such issues as farming, hunting, logging, and small-scale mining; they levy taxes and regulate the entry of nonresidents into the community. Village councils also determine whether the community will engage with external organizations (e.g., nongovernmental organizations [NGOs], research projects, missionaries).

In order to coordinate regional-level natural-resource management (e.g., fisheries on shared rivers) and interactions with external organizations, including the national government, many communities in Guyana have opted to participate in district-level umbrella organizations. These include the North Rupununi District Development Board (NRDDB), an NGO representing a subset of 16 Makushi communities in the North Rupununi, and the South Central and Deep South District Toshaos Councils (DTCs) in the south central and southernmost Rupununi, respectively. For the purposes of this and many other projects that are undertaken at a community and regional level, the regional representative associations were necessary and sufficient intermediaries, since they operate at the same geographic and social scale as these projects. No such organization currently exists for the communities in the center of our overall research region or for communities located to the northwest. Communities without an umbrella organization tend to have a lower degree of participation in projects, although the cause-and-effect relationship here is not clear.

Consultation with local leadership

Senior researchers on this project, who were already known to several regional and national indigenous representatives, began discussions in 2006 (one year prior to data collection) with the leaders of the NRDDB about the nature and objectives of the research project, advantages (e.g., capacity building, economic gain, and the creation of baseline data to inform management plans) and disadvantages (e.g., the need for a long-term commitment in order to inform meaningful reports) of participation, and the overall feasibility of conducting the research. In recognition of the different governance mechanisms and concerns regarding resource management and land rights in different parts of the Rupununi, a decision was made to initiate research in the north of the region, with later outreach to and incorporation of southern communities. With NRDDB support, in late 2006, two graduate students affiliated with the project visited the Rupununi to conduct an on-the-ground evaluation of potential study sites. This preliminary visit to prospective sites also allowed villagers to learn firsthand about the project.

With the guidance and logistical support of the NRDDB, we invited the leaders of all the Makushi communities in the region, including communities not affiliated with the NRDDB, to a three-day workshop held at the NRDDB headquarters to discuss the possibility of participating in the research project. The leaders of all 25 communities accepted the invitation, leading ultimately to 16 sites being selected. The next year, following consultations with the South Central and Deep South DTCs, an additional 12 sites were incorporated into the project. During further consultation with the elected leaders of the specific communities selected for and agreeing to participate in the study, we requested that they identify two village residents whom they could recommend as responsible, capable, and open to a multiyear, stipend-supported commitment to research work.

Balancing interests

Informal conversations and group discussions during workshops and meetings with leaders, community members, and project technicians, both prior to and during the course of the project, revealed a wide range of reasons among communities for participating in the project. Given the large number of communities (23) and technicians (approximately 75 at any given time) involved in the study, these differing motivations influenced the accuracy and consistency of the technicians' work and the turnover rate among technicians. The quality of a technician's work could be affected both by his or her own motivation and by the motivation of the community he or she represented. In turn, a community could be influenced by the motivation of regional decision-makers as well as by their own interests. Understanding these dynamics and motivations was key to our ability to provide communities and technicians the support they needed to successfully participate in the project and to ensure continuity in data collection.

Most of the communities were attracted by the potential of project data and reports to inform village wildlife-management decisions. Conversations with village leaders indicated that such motivation was generally higher in communities in which hunting played a central role in livelihoods than in others, in which the villagers relied heavily on other activities, such as fishing and commercial farming. In at least two communities in which the residents and leaders were initially indifferent to the project, the decision to participate came after significant persuasion by regional leaders who perceived benefits to the inclusion of the communities in the study.

Given the scarcity of salaried jobs in the region, the attractiveness of two or more positions paying reliable monthly stipends was also a draw for nearly all of the communities. The exceptions were two villages that had several more-lucrative options for income available in or near the communities; these villages elected to participate for reasons other than gaining stipends. In the villages that wanted to participate in the study but could not identify suitable technicians, it was necessary to recruit individuals from neighboring communities to assist in the transect delineation or data collection. In at least two of the communities that were negotiating with the government for an extension of their titled lands, the village leaders saw participation in the project as a means of documenting traditional use of the surrounding lands—information that might be used in support of their land claims.

Among the technicians, a key draw to participation in the research project was the possibility of earning a reliable stipend without moving away from their homes. On the basis of our conversations with the technicians, we determined that many also saw their participation in the project as a means to develop the skills and work history that would allow them to obtain similar work in the future (with, e.g., research projects, NGOs) or higher status in their communities as resident experts about the community's natural-resource base.

Most communities had little or no prior experience with projects that were seeking neither profit (e.g., timber and mining operations) nor change (e.g., conservation and development projects), and the concept of scientific research for the sake of knowledge generation was therefore unfamiliar to many people. Continued discussion with the village leaders, village councils, technicians, and community members was necessary to address misconceptions and to explain exactly what the research project was and what it was not. For instance, participation by villages and by individuals would be voluntary, and the resulting information would help the communities to better understand wildlife and livelihood dynamics, but it would be left to the communities whether and how to act on the information. Importantly, we explained that the quality of the final reports to be given back to village councils would be only as good as the quality of the work by the local technicians that would inform it, providing an additional incentive for community oversight over the quality of data collection. In cases of leadership turnover in a given community, it was generally necessary to repeat this process with the new leadership. Otherwise, the new leaders might dismiss the study as an artifact of the prior leadership, which would result in a loss of collaboration in overseeing the community's data-collection process.

Training and stipends

Over the course of three years, we trained approximately 345 individuals in research methodologies to conduct social and biological data collection. Prospective technicians traveled to a central location to attend training workshops led by senior researchers, postdoctoral researchers, and graduate students. The training consisted of both classroom instruction on research goals and methodology and hands-on training in field settings on the skills necessary for data collection (figure 5). The number of trainees exceeded the number of technicians at any given time (approximately 75) because of periodic turnover in some communities and because training was provided both for permanent technicians and for substitutes who would work when the permanent technicians were unavailable.

Most of the technicians worked in pairs as full-time para-biologists and para-anthropologists, spending approximately four days a week collecting biological transect data and one day a week collecting social data in their communities (for safety and methodological reasons, all transect work was done in pairs). All technicians received a monthly stipend from the project. Given that the amount of work involved was roughly equivalent to that of a full-time job, a strictly volunteer approach to data collection was out of the question. The stipends allowed the technicians to purchase food for their families that they might otherwise have procured from hunting, fishing, and farming, had they possessed the time necessary to pursue these activities. The stipend levels at the start approximated the standard wages paid locally within the general labor pool, with subsequent raises to levels equal to or slightly higher than the salary levels for local schoolteachers.

Absenteeism and substitutes

In the opening phase of data collection, after technician training was complete, it was not uncommon to receive incomplete data from a team with the justification that one of the technicians had other obligations, such as farm work, fishing, gathering new palm fronds for a leaking roof, and so on. Some of the problems arose from a misunderstanding of the scientific data-collection process by technicians who did not realize the potential for bias arising from improper data-collection practices such as omitting distant transects or only conducting hunting returns with hunters who were regularly in the village. However, the problem was primarily rooted in the fact that most Makushi and Wapishana households

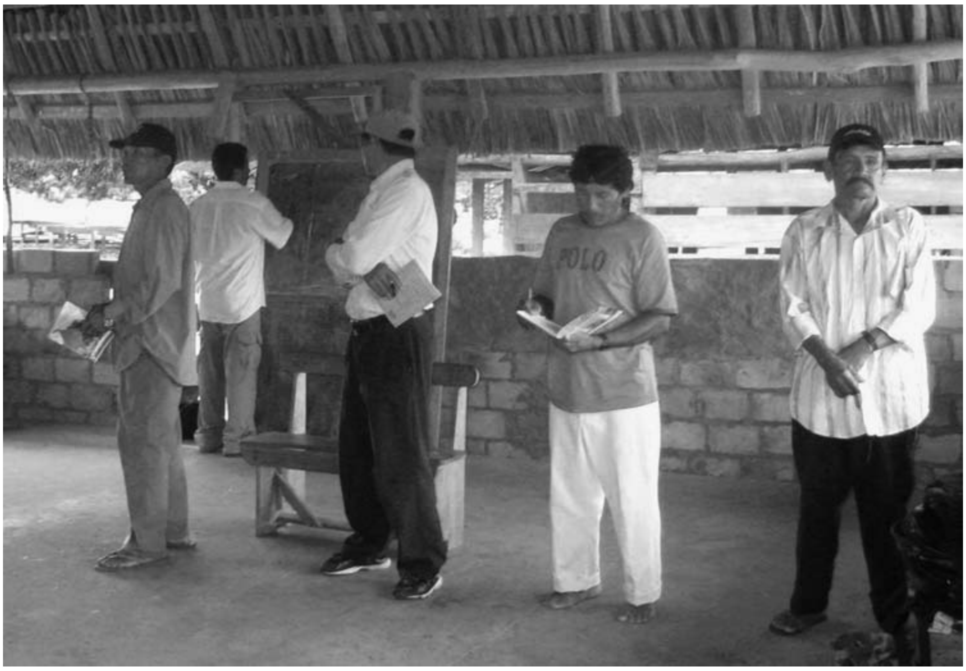

Figure 5. Retraining workshop for South Rupununi technicians. Photo credit: Jeffrey B. Luzar.

currently operate in a mostly subsistence-oriented economy, where food for purchase is limited and economic specialization is rare. Therefore, each household is usually responsible for growing or catching most of its own food and performing time-consuming tasks such as food preparation and house repairs, as well as periodic compulsory community work. In response to this reality, we adopted a substitute system to allow technicians to care for such concerns without interrupting data collection. *Substitutes* were other trained individuals in the village who could step in and do the work when one or both of the regular technicians were unavailable.

Data verification and management

Data-quality problems resulting from mistakes and deliberate falsifications are a concern in all research projects, including those staffed by professional biologists (where data falsification results in not-infrequent retraction of published papers) as well as those staffed by parabiologists and volunteers (Bonney et al. 2009, Hand 2010). We expected to see frequent errors early in the project, until the technicians became familiar with the methods and tools and had had an opportunity to ask questions regarding confusing situations in the field. We had some a priori expectations of data falsification as well, on the basis of experiences with other projects. Given that the benefits of prospective data fabrication would accrue to individual technicians, whereas the cost (weaker final reports) would accrue to the community as a whole, we expected that the most reliable data would probably be collected in those communities where strong local governance systems were matched by technicians who expressed an interest in the work extending beyond their personal stipend. We were also aware that we would encounter differences in the consistency of data collection, given that some technicians had participated in other monitoring projects and had some schooling, whereas others had neither background. We attempted to detect both expected and unexpected problems during data-checking sessions, site visits, and retraining sessions.

In the earliest stages of the project, we met with technicians during monthly visits to each community to collect and review data sheets and to deliver monthly stipends. However, after data collection had begun in all of the communities, it became clear that regularly scheduled meetings with all of the teams in three centralized locations would be more efficient and would also facilitate cross-village exchange among the teams, thus enhancing data quality, increasing congruence in data-collecting methods, and contributing to peer-to-peer capacity building.

Most of the NRDDB communities attended the northernmost meeting location, and the DTC communities attended the southernmost location about 150 km distant. Lethem, located midway between these locations, served as a meeting place for some members of both groups, plus two unaffiliated communities (figure 2). In addition to facilitating communication and the exchange of data for monthly stipends between project coordinators and technicians, these meetings developed project cohesiveness by allowing the technicians to interact with technicians from other communities on a regular basis.

We used standardized check sheets to verify completeness and to check for commonly made errors. We also reviewed work reports that were validated by the community leader each month. This oversight by the community leader was a reflection of the ownership of the project by the communities and a formal way of maintaining communication between the technicians and village leadership. In addition, during these meetings, the technicians and the professional researchers discussed other issues that had arisen during the prior month, such as questions about methodology and equipment needs.

The data sheets included entries that readily served as quality checks at these meetings. For instance, as well as recording transect start and end times, the parabiologists

*Figure 6. Lowland tapir (***Tapirus terrestris***). Photo credit: José M. V. Fragoso.*

also recorded sighting time and distance and location data using meter marks for each animal observation. If the data recording the distance of the observer on the transect and the amount of time walked were incompatible (e.g., walking 1 km across difficult terrain in 10 minutes), we were alerted to problems with the data. Similarly, since the data sheets for animal observations had both the bearing of the animal and the bearing of the transect, it was possible to determine the direction relative to the observer of any given animal by looking at the data sheet. We requested that the technicians point out the direction to an easily remembered animal, such as jaguar (*Panthera onca*) or tapir (*Tapirus terrestris*; figure 6), and we compared the direction that they had indicated to the compass bearing written on the data sheet, along with other relevant details. Similar testing methods were devised for animal signs, fruit abundance, and social data.

During the final year of data collection, recognizing significant variation in the ability of village leaders to identify instances of data fabrication because of the heavy demands of their leadership position, which often required extended periods of time spent away from the community, we instituted across-the-board data checks, whereby all technicians were asked to answer a minimum of five questions for each month's set of data. In most cases, the technicians had an accuracy level of 90%–100%. When the technicians were able to answer half or fewer of the questions correctly, fabrication or difficulty with the data-collection process was strongly suspected. If we remained unsure of the reliability of the data after these tests, a researcher or an experienced technician from another village walked the transects in question and examined the vegetation, soils, and footprints to determine whether the transects were being regularly walked. If we concluded that fabrication or errors in data collection had occurred, the data in question were not included in the database.

Of the eight communities in which fabrication of transect data was detected, four were either unaffiliated or loosely affiliated with one of the regional umbrella organizations (NRDDB, South Central DTC, or Deep South DTC), which suggests the hypothesis that the lack of a clear governance structure operating at a scale higher than the community may have contributed to this problem (table 1). The lack of an umbrella organization for these communities resulted in less-frequent interaction between the project coordinators and the village leaders. The project coordinators could meet with and provide updates to the village leadership in the course of meetings both with the umbrella organizations and with the individual community councils for those communities that had an umbrella organization, whereas in the case of the unaffiliated communities, the coordinators could meet only with the individual community council, which generally led to a decreased frequency of interaction with the leadership of those communities. Other contributing factors to variation among villages in the accuracy and consistency of data collection included the motivation factors discussed earlier (e.g., land titling, hunting management, income) and the amount of prior experience that the communities had with research and conservation projects.

All of the data were checked again during their entry into a digital database. When questionable or missing data emerged at this point, the original data sheets were taken to the technicians at the next meeting day for clarification. Finally, the data were subjected to a third verification when project personnel checked the data entered in the database for systematic errors that might not have been apparent from individual data sheets but that became evident when several months' data were examined at once. For instance, a review of the database might reveal animals consistently reported to appear in unsuitable habitat. Since these checks occurred while data collection was ongoing, it was possible to clarify and correct mistakes with the technicians (table 2).

Interrater reliability and technician turnover

An important concern when working with a large number of local technicians is *interrater reliability*, the ability of two

Table 1. Data fabrication and umbrella governance structures.

	Number of affiliated communities	Number of unaffiliated or loosely affiliated communities	Total number of communities
Evidence of data fabrication	4	4	8
No evidence of data fabrication	18	2	20
Total	22	6	28

Table 2. Types of data collected and potential sources of error.

Type of data collected	Potential sources of error	Measures implemented
Animal observations	Misreading of bearings	Checks for rounded numbers
	Estimation in distance to animal	Spot checks of data collection on transects
	Misidentification of animals	"Quizzes" for technicians
	Selective recording of observations	Animal guide
Animal signs	Misidentification of animals	Spot checks of data collection on transects
	Selective recording of signs	"Quizzes" for technicians
		Animal guide
Fruit abundance	Misidentification of fruits	Fruit guide
	Selective recording of fruits	Guide for unknown fruits
		Spot checks of data collection on transects
		"Quizzes" for technicians

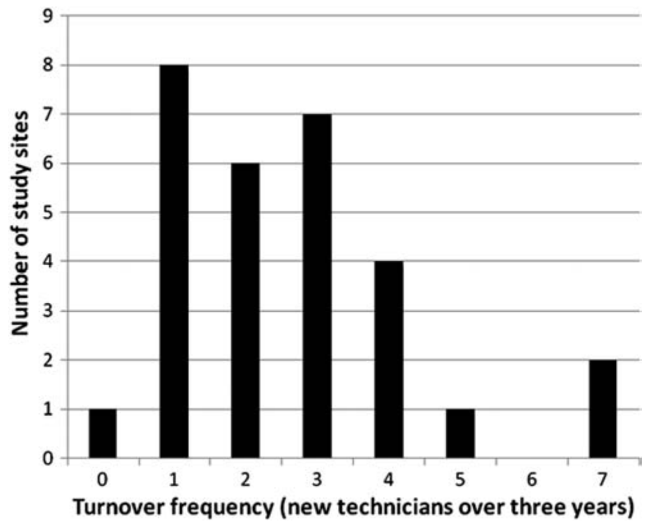

Figure 7. Technician turnover. Because of logistical considerations, responsibility for one of the study sites was divided between two pairs of technicians from neighboring communities, with each team working independently of the other. For the purpose of this graph, we consider this site to represent two separate study sites, resulting in a total of 29 study sites.

or more observers to measure the same phenomenon in the same way (Ayala and Noss 2000, Bernard 2002). New technicians varied in their knowledge of local fauna, in their ease in conducting social surveys, and in their ability to record data. The technicians also varied in their ability to identify less-common wildlife (e.g., rare birds) and used varying names (e.g., Creole English, Makushi, and Wapishana) to identify animals. With the assistance of especially knowledgeable technicians, we created a wildlife guide that included the scientific, US English, Creole English, Makushi, and Wapishana names, along with a picture and numeric code, to ensure standardized animal identification.

Although the initial workshops presented an opportunity to provide identical training to all incoming technicians, thus reducing data-collection differences among the observers, differences emerged over time with gradual technician turnover. Therefore, after several months of data collection, we found that our teams were mixed, including veterans, who had gone through the training workshops, and newcomers, who might have only had *in situ* training from their partners. Technician turnover varied greatly among communities (figure 7) and presented a challenge to interrater reliability, not only within communities but among communities as well, especially in cases in which both original technicians had left the project, leaving their replacements with no formal training in the project's data-collection methodology. We addressed this concern by holding midterm retraining workshops toward the end of the first year of data collection for both cohorts; this allowed us to provide systematic training to newer technicians.

Over time, when we were confronted with problems in reliable data collection, we learned to distinguish contributing factors operating at the community level from factors related to the individual technicians. When poorly suited or poorly matched technicians were detected, we sought to have a more direct role in the selection of the technicians in that community. If it was possible, we would match an older individual with hunting experience who could bring "bush skills" with a younger person possessing "book skills," such as reading and the simple mathematics involved in recording data. When it was possible, we sought advice and guidance on these matters from the residents and leaders of neighboring communities.

Returning research results

As a complement to periodic visits to villages and updates given to village councils by senior project staff, the village technicians themselves gave regular updates at village meetings, a technique shown in other studies to build trust with communities (Kubo and Supryanto 2010) and to increase the alignment between community and project goals (e.g., Noss and Cuéllar 2001, Noss et al. 2005). We also prepared reports, which were delivered to the collaborating communities and the local institutions in March 2011 and which contained the relevant key findings for local natural-resource management. Before creating these reports, we held formal and informal meetings with the local leadership and community members regarding the appropriate content and format of these reports. For instance, given the high levels of spatial (as opposed to verbal) literacy in the region, combined with local interest in documenting hunting areas for key species, the final reports were individually tailored for each community and included detailed maps showing the areas in which various important game species were harvested by the residents of that village.

Conclusions

Research designs in which local nonscientists collect substantial portions of the data in large-scale socioecological research projects in remote areas present a range of advantages and challenges. Our approach has allowed us to collect data of a temporal and spatial scale sufficient to test hypotheses and to model relationships among hunting patterns, animal populations, and social variables. Once all transects were established and data collection was under way at all sites, the technicians walked nearly 2000 km of transects every month. At the three-year mark, 335 indigenous technicians had recorded 48,099 wildlife sightings of 267 species along 21,729 km of transects and 84,028 records of animal sign and 33,446 fruit patches along 21,393 km of transects. The sample sizes were large enough to allow density estimations for rarely observed animals such as tapirs and paca; these species often go unreported in studies of limited spatial or temporal extent, even when they are probably present (e.g., in the greater Manu area; Nunfiez-Iturri et al. 2008, Terborgh et al. 2008, Endo et al. 2010). The technicians also collected socioeconomic and hunting data from at least 9523 people from 24 villages. The numbers are indicative of the large magnitude of information that can be collected by local technicians in remote areas of the world. The key concern regarding the quality of data collection proved to be justified: Error rates were initially high, resulting in three communities in which their early months' data had to be removed from the data set; by the end of the study, 18 technicians in eight villages were documented as having fabricated transect-based data on at least one occasion. These issues were detectable and correctable once they were identified and understood.

Lessons learned. Several methodological modifications, which we describe below, could have minimized or allowed us to avoid various obstacles to the project.

Visits to communities—including those in which no problems with data collection were evident—should have been more systematically scheduled. Doing so would have allowed us to more quickly identify instances of fabrication among those technicians whose data did not, at the surface, seem problematic. This implies a larger core project staff and greater transportation costs.

We should have identified at an early state the various motivations affecting the participation of communities and technicians in the project, as well as the nature of governance structures in each community. For example, in a study site in which the community and technicians are not motivated strictly by financial incentive and in which an effective governance system is in place, fewer problems with data collection can be anticipated than in communities in which they are not.

We should have recognized the wide variation in the ability of local leaders to identify data fabrication and to develop complementary and systematically applied verification systems at the earliest stages of data collection.

We should have obtained funding for the systematic distribution of preliminary research findings to village councils, which would complement the reporting of informal observations by the technicians themselves, at regular intervals during the course of multiyear projects. This contributes to long-term interest in the research by the village leaders and residents while also contributing to timely local management decisions. However, in long-term studies, distribution of preliminary results will probably alter hunter behavior, and this must be incorporated into the data analysis, modeling, and conclusions. It would be best to build this data-return and behavior-modification feedback loop as part of the study and to structure the data return in such a way that its impacts are measurable. The consequences of this feedback loop for research are different from those for management projects. They are a decided advantage in the latter, because they can lead local communities and institutions to embrace adaptive management (Holling 1978, Walters 1986) of the resource-use systems. These considerations must be weighed and discussed with the communities ahead of time and reiterated throughout the project.

Recommendations. Researchers and managers considering the incorporation of local nonscientists in the data-collection process should recognize that this approach implies a shifting of roles, responsibilities, and attitudes among the professional researchers away from those expected with a more conventional research design. The principal researchers will spend less time collecting data and more time building capacity among local technicians and fostering collaboration with the local leaders who help oversee data collection. The on-site presence of the project leaders at important events is essential in maintaining trust and respect in the relationship between the project coordinators and the collaborating communities. A willingness to understand and remain constantly aware of the social, economic, and political motivations of the local technicians to collect high-quality data is essential and adds an additional dimension to any research or monitoring project.

Many of the challenges to effective high-quality data collection encountered in this study, as well as the responses to these challenges, are culture and situation specific. The overall approaches, however, are broadly applicable and can be considered up front in the design of future studies at other locations. Data drops, retraining events, networks of core and substitute technicians, data sheet entries that allow the verification of data, and most important, a reliance on existing intra- and intercommunity governance and decisionmaking structures are all applicable to other cultural contexts. Identification of the types and causes of data errors and deliberate falsification will also contribute to the design of data sheets and surveys that discourage or prevent inappropriate data entry at the source.

The issues identified in this article are applicable to the new wave of community monitoring, reporting, and verification systems that will be implemented in the next few years in the context of the REDD (Reduced Emissions from Deforestation and Forest Degradation) and Payment for Ecosystem Services (PES) projects. Research-and-monitoring protocols that provide remuneration for large numbers of local people have the added advantage of demonstrating the value of protected areas and channeling resources from PES and REDD schemes through activities that directly contribute to the measurement and protection of these ecological services.

The data-verification protocols developed here will be especially relevant to projects in which handheld devices (e.g., smartphones) are used. These projects will involve data drops directly into a database or statistical or GIS (geographical information system) program with no intervening paper data check (see Skutsch et al. 2009). For these projects to be effective, it will be necessary to identify governance issues in the participating communities, to identify individuals with the right level of commitment and interest, and to design data-entry platforms that prevent both data-entry mistakes and deliberate falsifications. The use of photographs and GPS (global positioning system) readings will be invaluable in this sense.

When evaluating the merits of large-scale research-and-monitoring projects in which data are collected by local nonscientists, funding agencies must recognize the special requirements of such projects, including sufficient time frames to permit pilot studies in which culture- and location-specific issues—such as the capacity of local governance structures to ensure quality data collection—can be assessed prior to larger-scale data collection. Additional budgets for the preparation and distribution of interim and final reports to the participating communities, although they are not necessarily valid as final research products, can be essential in securing continued interest and motivation by communities while also contributing to the capacity of those communities to manage their natural resources.

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References cited

Amazonia. 2009. Protected Areas and Indigenous Territories: Amazon Georeferenced Socio-environmental Information Network. Amazonia. (18 July 2011; *http://raisg.socioambiental.org/files/map-AMAZONIA2009_verso_english.pdf*)

Ayala J, Noss A. 2000. Censos por transectas en el Chaco boliviano: Limitaciones biológicas y sociales de la metodología. Pages 29–36 in Cabrera E, Mercolli C, Rewquin R, eds. Manejo de Fauna Silvestre en Amazonía y Latinoamérica. CITES Paraguay, Fundación Moises Bertoni, University of Florida.

Bernard HR. 2002. Research Methods in Anthropology: Qualitative and Quantitative Approaches, 3rd ed. Altamira Press.

Bodmer RE. 1994. Managing wildlife with local communities in the Peruvian Amazon: The case of the Reserva Comunal Tamshiyacu-Tahuayo. Pages 113–134 in Western D, Wright RM, Strum S, eds. Natural Connections: Perspectives in Community-based Conservation. Island Press.

Bodmer RE, Pezo Lozano E, Fang TG. 2004. Economic analysis of wildlife use in the Peruvian Amazon. Pages 191–210 in Silvius KM, Bodmer RE, Fragoso JMV, eds. People in Nature: Wildlife Conservation in South and Central America. Columbia University Press.

Bodmer RE, Puertas P, Antunez M, Perez P. 2010. Exitos en manejo comunal de fauna silvestre resulta en relaciones Lotka-Volterra en la Amazonia. Paper presented at the 9th International Congress for Wildlife Conservation and Management in Amazonia and Latin America, May 2010, Santa Cruz, Bolivia. (18 July 2011; *www.ixcimfauna-bol.museonoelkempff.org/index.php*)

Bonney R, Cooper CB, Dickinson J, Kelling S, Phillips T, Rosenberg KV, Shirk J. 2009. Citizen science: A developing tool for expanding science knowledge and scientific literacy. BioScience 59: 977–984.

Campos-Rozo C, Ulloa A, eds. 2003. Fauna Socializada: Tendencias en el Manejo Participativo de la Fauna en America Latina. Fundación Natura.

Caughley G, Sinclair ARE. 1994. Wildlife Ecology and Management. Blackwell Scientific.

Congreso Internacional sobre Manejo de Fauna Silvestre. 2010. Congreso Internacional sobre Manejo de Fauna Silvestre–Inicio. (18 July 2011; *www.manejofaunasilvestre.org*)

Constantino PAL, Fortini LB, Kaxinawa FRS, Kaxinawa AM, Kaxinawa ES, Kaxinawa AP, Kaxinawa LS, Kaxinawa JM, Kaxinawa JP. 2008. Indigenous collaborative research for wildlife management in Amazonia: The case of the Kaxinawá, Acre, Brazil. Biological Conservation 141: 2718–2729.

Danielsen F, et al. 2009. Local participation in natural resource monitoring: A characterization of approaches. Conservation Biology 23: 31–42.

Eisenberg JF, Redford KH. 1999. Mammals of the Neotropics, vol. 3: The Central Neotropics: Ecuador, Peru, Bolivia, Brazil. University of Chicago Press.

Endo W, Peres CA, Salas E, Mori S, Sanchez-Vega J-L, Shepard GH, Pacheco V, Yu DW. 2010. Game vertebrate densities in hunted and nonhunted forest sites in Manu National Park, Peru. Biotropica 42: 251–261.

Ferraz G, Marinelli CE, Lovejoy TE. 2008. Biological monitoring in the Amazon: Recent progress and future needs. Biotropica 40: 7–10.

Fragoso JMV. 2004. A long-term study of white-lipped peccary (*Tayassu pecari*) population fluctuations in northern Amazonia: Anthropogenic versus "natural" causes. Pages 286–296 in Silvius KM, Bodmer RE, Fragoso JMV, eds. People in Nature: Wildlife Conservation and Management in South and Central America. Columbia University Press.

Fragoso JMV, Silvius KM, Villa-Lobos M. 2000. Wildlife Management at the Rio das Mortes Xavante Reserve, MT, Brazil: Integrating Indigenous Culture and Scientific Method for Conservation, vol. 4. World Wildlife Fund-Brazil.

Fragoso, JMV, Cunha M, Nascimento VLM. 2002. A Fauna Silvestre e as Práticas de Caça. PESACRE.

Fragoso, JMV, de Oliveira LF, Silvius KM, Read JM. 2010. The abundance and diversity of vertebrate frugivores at lanscape [sic] levels in Amazonia. Paper presented at the Fifth International Symposium on Frugivores and Seed Dispersal, 13–18 June 2010, Montpellier, France.

Hand E. 2010. Distributed computing: People power. Nature 466: 685–687.

Hill K, Padwe J. 2000. Sustainability of Aché hunting in the Mbaracayu Reserve, Paraguay. Pages 79–105 in Robinson J, Bennet E, eds. Hunting for Sustainability in Tropical Forests. Columbia University Press.

Hill K, Padwe J, Bejyvagi C, Bepurangi A, Jakugi F, Tykuarangi R, Tykuarangi T. 1997. Impact of hunting on large vertebrates in the Mbaracayu Reserve. Conservation Biology 11: 1339–1352.

Hill K, McMillan G, Fariña R. 2003. Hunting-related changes in game encounter rates from 1994 to 2001 in the Mbaracayu Reserve, Paraguay. Conservation Biology: 17: 1312–1323.

Holling CS, ed. 1978. Adaptive Environmental Assessment and Management. Wiley.

Ino C, Kudrenecky J, Townsend WR. 2001. Manejo de Fauna en la TCO Sirionó: El Recuento del Taitetú (Pecari tajacu). Publicacion del Proyecto de Investigación CIDOB-DFID No. 17. Centro de Estudios y Documentación Internacionales de Barcelona.

[IUCN] International Union for the Conservation of Nature. Red List of Threatened Species, 2010. IUCN. (27 December 2010; *www.iucnredlist.org/apps/redlist/search*)

Jorgenson JP. 1996. Métodos directos e indirectos para estimar el tamaño de las poblaciones de mamíferos. Pages 86–110 in Campos C, Ulloa A, Rubio H, eds. Manejo de Fauna con Comunidades Rurales. Utópica Ediciones.

Kubo H, Supryanto B. 2010. From fence-and-fine to participatory conservation: Mechanisms of transformation in conservation governance at the Gunung Halimun-Salak National Park, Indonesia. Biodiversity Conservation 19: 1785–1803.

Leeuwenberg F. 1997. Manejo da fauna cinegética na reserva indígena Xavante de Pimentel Barbosa, Mato Grosso, Brasil. Pages 233–238 in Villadares-Pádua C, Bodmer RE, eds. MCT-CNPq and Sociedade Civil Mamirauá.

Low B, Sundaresan SR, Fischhoff IR, Rubenstein DI. 2009. Partnering with local communities to identify conservation priorities for endangered Grevy's zebra. Biological Conservation 142: 1548–1555.

Neilson RP, Pitelka LF, Solomon AM, Nathan R, Midgley GF, Fragoso JMV, Lischke H, Thompson K. 2005. Forecasting regional to global plant migration in response to climate change: Challenges and directions. BioScience 55: 749–759.

Noss AJ, Cuéllar E. 2000. Indices de abundancia para fauna terrestre en el Chaco boliviano: Huellas en parcelas y en brechas barridas. Pages 73–82 in Cabrera R, Mercolli C, Rewquin R, eds. Manejo de Fauna Silvestre en Amazonía y Latinoamérica, CITES Paraguay, Fundación Moises Bertoni, University of Florida.

———. 2001. Community attitudes towards wildlife management in the Bolivian Chaco. Oryx 35: 292–300.

Noss, AJ, Painter MD. 2004. Community-based wildlife management in the Gran Chaco, Bolivia. Pages 59–75 in Silvius KM, Bodmer RE, Fragoso JMV, eds. People in Nature: Wildlife Conservation in South and Central America. Columbia University Press.

Noss AJ, Oetting I, Cuéllar RL. 2005. Hunter self-monitoring by the Isoseño-Guaraní in the Bolivian Chaco. Biodiversity and Conservation 14: 2679–2693.

Novaro AJ, Redford KH, Bodmer RE. 2000. Effect of hunting in source-sink systems in the Neotropics. Conservation Biology 14: 713–721.

[NSF] National Science Foundation. 2010. Dynamics of Coupled Natural and Human Systems (CNH). NSF. (18 July 2011; www.nsf.gov/funding/pgm_summ.jsp?pims_id=13681).

Nuñez-Iturri G, Olsson O, Howe HF. 2008. Hunting reduces recruitment of primate-dispersed trees in Amazonian Peru. Biological Conservation 141: 1536–1546.

Peres CA. 2000. Effects of subsistence hunting on vertebrate community structure in Amazonian forests. Conservation Biology 14: 240–253.

Peres CA, Nascimento HS. 2006. Impact of game hunting by the Kayapó of south-eastern Amazonia: Implications for wildlife conservation in tropical forest indigenous reserves. Biodiversity and Conservation 15: 2627–2653.

Prada M, Marinho-Filho J. 2004. Effects of fire on the abundance of Xenarthrans in Mato Grosso, Brazil. Austral Ecology 29: 568–573.

Rubio Torgler H, Ulloa A, Campos Rozo C, Jaramillo LP. 2000. Manejo de la Fauna de Caza: Una Construcción a Partir de lo Local: Métodos y Herramientas. La Silueta.

Skutsch MM, McCall MK, Karky B, Zahabu E, Peters-Guarin G. 2009. Case studies on measuring and assessing forest degradation: Community measurement of carbon stock change for REDD. Forest Resources Assessment Working Paper No. 156. Food and Agriculture Organization of the United Nations.

Terborgh J, Nunfiez-Iturri G, Pitman NCA, Cornejo Valverde FH, Alvarez P, Swamy V, Pringle EG, Paine CET. 2008. Tree recruitment in an empty forest. Ecology 89: 1757–1768.

Townsend WR. 1995. Living on the Edge: Sirionó Hunting and Fishing in Lowland Bolivia. PhD Dissertation, University of Florida, Gainesville.

———. 2000. The sustainability of subsistence hunting by the Sirionó Indians of Bolivia. Pages 267–281 in Robinson JG, Bennett EL, eds. Hunting for Sustainability in Tropical Forests. Columbia University Press.

———. 2004. Some techniques for increasing local stakeholder participation in wildlife management with rural communities. Pages 50–58 in Silvius KM, Bodmer RE, Fragoso JMV, eds. People in Nature: Wildlife Conservation in South and Central America. Columbia University Press.

Townsend WR, Borman R, Yiyoguaje E, Mendua L. 2005. Cofán Indians' monitoring of freshwater turtles in Zábalo, Ecuador. Biodiversity and Conservation 14: 2743–2755.

Ulloa A, Rubio-Torgler H, Campos-Rozo C. 1996. Trua Wuandra: Estrategias para el manejo de fauna con comunidades embera en el Parque Nacional Natural Utría, Chocó, Colombia. Buena Cemilla.

———. 2004. Conceptual basis for the selection of wildlife management strategies by the Embera people in Utria National Park, Choco, Colombia. Pages 11–36 in Silvius KM, Bodmer RE, Fragoso JMV, eds. People in Nature: Wildlife Conservation in South and Central America. Columbia University Press.

Walters CJ. 1986. Adaptive management of renewable resources. McMillan.

Zapata-Rios G, Urgilés C, Suárez E. 2009. Mammal hunting by the Shuar of the Ecuadorian Amazon: Is it sustainable? Oryx: 43: 375–385.

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