Indigenous, Colonist, and Government Impacts on Nicaragua's Bosawas Reserve

ANTHONY STOCKS,* BENJAMIN McMAHAN,† AND PETER TABER†

*Department of Anthropology, Idaho State University, Box 8005, Pocatello, ID 83209, U.S.A., email astocks@isu.edu
†Department of Anthropology, University of Arizona, 1009 E. South Campus Drive, Tucson, AZ 85721-0030, U.S.A.

Abstract: *We studied the impacts of colonists, two groups of indigenous residents (Miskitu and Mayangna), and management by the Nicaraguan Ministry of Environment and Natural Resources (MARENA) on the forest of the Bosawas International Biosphere Reserve. Indigenous people and colonists subsist on the natural resources of the reserve, and MARENA is responsible for protecting the area from colonization and illicit exploitation. Using geostatistical procedures and Landsat images at three different time periods, we compared per capita deforestation and boundary stabilization in areas with colonists and areas with indigenous peoples. We also examined whether the Mayangna deforested less than the Miskitu and whether the Nicaraguan government has effectively defended the Bosawas boundary against the advance of the agricultural frontier. In addition, we analyzed the current distribution of land uses within the reserve and its contiguous indigenous areas with a supervised classification of current land cover. Indigenous demarcations protected the forest successfully, whereas the Bosawas boundary itself did not inhibit colonization and consequent deforestation. Indigenous farmers deforested significantly less per capita than colonists, and the two indigenous groups in Bosawas did not differ significantly in their effects on the forest. Our results show that indigenous common-property institutions and indigenous defense of homeland have been powerful factors in protecting the forests of Bosawas and that the difficult evolution of a nested cross-scale governance system in Bosawas—under pressure from indigenous peoples—is probably the key to the forest's survival thus far.*

Keywords: Bosawas, indigenous conservation, land-cover change, Mayangna, miskitu, Nicaragua, normalized burn ratio, remote sensing

Impactos de Indígenas, Colonizadores y Gobierno sobre la Reserva Bosawas de Nicaragua

Resumen: *Estudiamos los impactos de colonizadores, de dos grupos de indígenas residentes (Mismito y Mayangna) y del manejo por el Ministerio del Ambiente y Recursos Naturales de Nicaragua (MARENA) sobre el bosque en la Reserva de la Biosfera Internacional Bosawas. Los indígenas y colonizadores subsisten de los recursos naturales de la reserva, y MARENA es responsable de la protección del área contra la colonización y la explotación ilícita. Mediante procedimientos geoestadísticos e imágenes Landsat de tres períodos de tiempo diferentes, comparamos la deforestación per cápita y la estabilización de límites en áreas con colonizadores y áreas con indígenas. También examinamos si los Mayangna deforestan menos que los Miskito y si el gobierno nicaragüense ha defendido efectivamente el límite de Bosawas contra el avance de la frontera agrícola. Adicionalmente, analizamos la distribución actual de los usos de suelo dentro de la reserva y en las áreas indígenas circundantes mediante una clasificación supervisada de la cobertura de suelo actual. Las demarcaciones indígenas protegieron el bosque exitosamente, mientras que el límite de Bosawas por sí solo no inhibió la colonización y la deforestación consecuente. La deforestación per cápita de los campesinos indígenas fue significativamente menor que la de los colonizadores, y los dos grupos indígenas en Bosawas no difirieron significativamente en sus efectos sobre el bosque. Nuestros resultados muestran que las instituciones nativas de propiedad común y la defensa de la tierra natal han sido factores poderosos para la protección de los bosques de Bosawas y que la difícil evolución de un sistema de autoridad anidada en varias escalas en Bosawas—bajo presión de grupos indígenas—probablemente sea la clave para la supervivencia del bosque.*

Paper submitted May 24, 2006; revised manuscript accepted April 4, 2007.

Conservation Biology Volume 21, No. 6, 1495–1505

DOI: 10.1111/j.1523-1739.2007.00793.x

Palabras Clave: Bosawas, cambio de cobertura de suelo, conservación por indígenas, Mayangna, miskito, Nicaragua, percepción remota, tasa de quemas normalizada

Introduction

Background

Located in north-central Nicaragua, the Bosawas International Biosphere Reserve with its approximately 8000 km^2 "core zone" covers about 7% of Nicaragua (Fig. 1). During the Contra war against the Sandinistas (1980–1990), indigenous residents with historical land rights, the Miskitu and Mayangna (Sumu), were excluded from the area; it was occupied for nearly 10 years by combatants, and forest regeneration was general. In April of 1991 indigenous people were permitted to return to their home communities to rebuild. Later that year the new Chamorro government declared the area a "natural reserve" with the stated aim of protecting biodiversity and the resources necessary for indigenous subsistence. Meanwhile nonindigenous ex combatants were demanding land. Many were relocated along the southern and western boundary of the new reserve in various "development poles." The newly created reserve was interpreted by the ex combatants and their land-poor relatives in western Nicaragua as free land; encroachment on the reserve began immediately along the southwestern boundary and along the Bocay and Coco rivers, a movement that occasioned conflict with newly resettled indigenous communities along the same rivers (Kaimowitz 2002; Kaimowitz & Fauné 2003; Kaimowitz et al. 2003; Stocks 2003). Whereas the southern portion of the to-be-declared reserve held 167 colonist families in 1990, by 1996 there were 1,977 colonist families, approximately 10,000 people (The Nature Conservancy 1997*f*). The Nicaraguan Ministry of Environment and Natural Resources (MARENA) seemed powerless to halt the incursions. Physical presence of MARENA in the reserve became rare, partly because the colonists were armed and were not willing to negotiate withdrawal.

In 1994, faced with the advancing colonist frontier from the south and west, the indigenous residents of Bosawas began to organize resistance with the permission of MARENA and the support of The Nature Conservancy under a grant from the United States Agency for International Development. Eventually six indigenous civil societies were formed along historic ethnic and territorial divisions. These societies conducted self-studies and mapped, demarcated, and zoned six contiguous multicommunity territorial land claims (Fig. 1) (Stocks 1996, 2003; Stocks et al. 2000). The most politically contested of the territorial boundaries (the southern boundaries of Mayangna Sauni Bu [MSB] and Miskitu Indian Tasbaika Kum [MITK]) lay along the Coco and Bocay rivers and

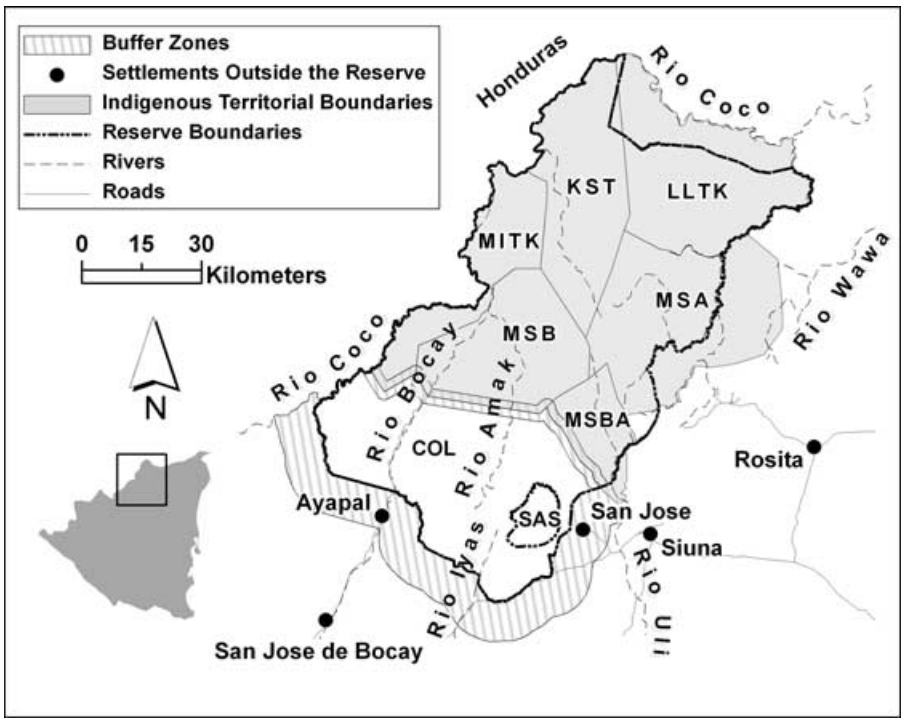

Figure 1. Territorial units in and near the Bosawas Bioreserve in northern Nicaragua: MSA, Mayangna Sauni As; MSB, Mayangna Sauni Bu; MSBA, Mayangna Sauni Bas; KST, Kipla Sait Tasbaika Kum; LLTK, Li Lamni Tasbaika Kum; MITK, Miskitu Tasbaika Kum; COL, area of mestizo colonization; SAS, Saslaya National Park.

Table 1. Mayagna and Miskitu estimated populations in or near the Bosawas Bioreserve in northern Nicaragua for dates ranging from 1994 to 2002.

Territory	Primary ethnicity	population (year of census)	Estimated population[a]			Official area (km^2)	GIS-defined area (km^2)
			1995	1996	2002		
Mayangna Sauni As (MSA)	Mayangna	3,405 (94)	3,524	3,648	4,641	1,635.47	1,542.44
Mayangna Sauni Bu (MSB)	Mayangna	1,886 (95)	1,886	1,952	2,400	1,032.04	1,030.74
Mayangna Sauni Bas aka Sikilta (SIK)	Mayangna	338 (95)	338	350	430	405.66	403.11
Miskitu Indian Tasbaika Kum (MITK)	Miskitu	3,454 (95)	3,454	3,575	4,394	690.55	694.99
Kipla Sait Tasbaika (KST)	Miskitu[b]	3,431 (96)	3,311	3,431	4,070	1,136.32	1,141.15
Total Mayangna			5,748	5,950	7,471	3,073.17	2,796.28
Total Miskitu			6,765	7,006	8,464	1,826.87	1,836.03
Total indigenous in Bosawas			12,513	12,956	15,935	4,900.04	4,812.32
Mestizo area		9,079 (96)	8,761	9,079	14,261[c]	2,170.5	2,170.50
Grand total Bosawas			21,184	22,035	30,196	7,070.54[d]	6,982.82
Li Lamni Territory[e]	Miskitu	9,103 (98)	8,180		10,446		1,379.9

[a] *Assumes 3.5%/year growth in indigenous territories (Buvollen & Buvollen 1994) and 17%/year in mestizo areas (The Nature Conservancy 1997f).*
[b] *The population is 6% Mayangna.*
[c] *Assumes documented 17% growth rate until 1998 when migration slowed to a stop and then 3.5% thereafter because we lacked better data. There is no more free land outside the indigenous territories.*
[d] *This area is different than the ~8000-km^2 Bosawas "nuclear" area because several indigenous territories have land both inside and outside the formal Bosawas boundary and the territory of Li Lamni Tasbaika Kum was not included in the analysis.*
[e] *Li Lamni was not included in the published study because the population does not live in the Bosawas Reserve.*

were rapidly being colonized from upstream. On these rivers six historic indigenous communities were left outside the demarcated boundary in a so-called conflict area because territorial leaders held no hope that newly established colonists could be removed. The boundary, however, was demarcated in coordination with a colonist organization that was seeking legitimacy for colonists in the reserve. The southwestern boundary of Mayangna Sauni Bas (MSBA) was also part of this negotiated demarcation. Since 1995 indigenous volunteer forest rangers have patrolled their boundaries with colonists, sometimes with funding from conservation organizations and sometimes without. Since 1999 these forest rangers have operated under the general authority of MARENA, although the official MARENA forest ranger has little presence in the reserve.

According to field interviews with colonists conducted by A.S. in 1998 and 2000, colonist immigration virtually halted in the contested southwestern part of the reserve after 1998. With approximately 50 ha claimed by each colonist family, there was no more land without moving the indigenous boundary, which was already demarcated, patrolled, and subject to an agreement. Table 1 presents the populations of colonists and indigenous peoples at the time of the first census and thereafter (The Nature Conservancy 1997*a*, 1997*b*, 1997*c*, 1997*d*, 1997*e*, 1997*f*).

On 24 May 2005 the Nicaraguan government awarded common property land titles in Bosawas and contiguous indigenous areas to the territorial organizations of five "ethnic" territories containing 86 indigenous Miskitu and Mayangna. (One title to the present MSBA was awarded under agrarian reform laws during the Sandinista period.) The titles cover approximately 80% of the 8000-km^2 reserve and assert government "codominion" only over areas designated by indigenous zoning maps as appropriate for conservation. This outcome was wholly unanticipated in the reserve's original design, which was ambiguous about the tenure status of indigenous people, but explicit about protecting their resources. Indeed, even after Bosawas became an international biosphere reserve in 1997, maps of the original reserve boundary presented the entire original reserve as core area, completely protected under Nicaraguan law, although over 25,000 indigenous people and colonists lived in this space. Indigenous territorial maps were only included among the reserve's official documents at the last moment because UNESCO insisted that they be recognized as a condition for official designation (A. Murrar, personal communication).

Consistent with its resistance to indigenous self-governance in the reserve, the government has dragged its feet in inscribing the titles in the national land registry, but the titles are nonetheless viewed by the Mayangna and Miskitu people as a step forward in a long struggle for land rights inside and outside the reserve (Stocks 2005). Thus, the present governance of the reserve is a product of grassroots pressure, not original design (Kaimowitz et al. 2003). It has evolved into a set of "nested" institutions in a "cross-scale" management system (Berkes & Folke 1998; Berkes 2004; Redford et al. 2006). The protected area also created conditions under which indigenous people could pursue their interests in defending a homeland free from the pressure of logging and mining interests, an important social impact highlighted by several recent works (Redford et al. 2006; West & Brockington 2006;

West et al. 2006; Wilkie et al. 2006). Their sense of historic ownership of a homeland is probably a key motive in defending their land claims, as predicted by several theorists of the development of effective common property institutions (Ostrom 1996; Ostrom et al. 1999; Dietz et al. 2003; Berkes 2004), and it is their relative legality within the reserve (i.e., their relationship with the government) that has empowered them to mobilize volunteer forest rangers for homeland defense.

Indigenous and Colonist Cultural Patterns in Bosawas

Information in this section is based on the territorial and colonist studies carried out between 1994 and 1997 (The Nature Conservancy 1997*a*, 1997*b*, 1997*c*, 1997*d*, 1997*e*, 1997*f*). Colonists and indigenous farmers in the Bosawas area are quite different in their ethnic identity and in their subsistence patterns. All claimants to Mayangna and Miskitu identity speak their respective languages. Because indigenous identity is stigmatized in western Nicaragua, few colonists in Bosawas—nearly all of whom stem from the Jinotega province—claim such identity or speak either of the two languages.

Neither indigenous people nor colonists have access to markets through roads, and their material level of wealth, as measured by inventories of possessions, is similar. All incomes average under $800/family/year. Nevertheless, they differ sharply in educational level. In 1996 82% of adult colonists were illiterate, compared with 39% among indigenous people.

A key cultural difference between indigenous and nonindigenous farmers lies in their property regimes. Indigenous people in Bosawas hold land in common, whereas colonists have adopted the model of private property, each holding to a parcel of land they hope to make their own legally. Common-property institutions are a proxy for indigenous identity in Nicaragua and generally in lowland Central and South America, whereas such institutions are rare in rural nonindigenous populations. There are some important concomitants to these differing property regimes, including settlement pattern, agricultural practice, and long-term livelihood strategy.

Colonist settlers tend to live and farm on their individual parcels, which are on average 50 ha, whereas indigenous people group together in communities closely knit through kinship and multiple reciprocal obligations. Although nucleated communities are not, per se, required by common-property regimes, they are part of being indigenous.

In 1996 only 1 in 10 indigenous families had cattle, nearly all of which were pastured within villages where they could be watched over, whereas colonists had an average of 1 cow/family that was pastured on their parcels. Because of the nucleated settlements, indigenous people farm outside the communities within a 2-hour radius to protect crops from village domestic animals, including numerous pigs.

Each indigenous family farms in an area of <15 ha, which is a mosaic of forest succession stages, because the land is cropped for a year or so and then allowed to go back to forest. In contrast, colonists affect land in an often irreversible trend that begins with an annual crop and ends in pasture. The goal of the colonist occupation is to develop as much pasture as possible. Many colonists cut forest and plant pasture annually as a livelihood strategy—even without cattle—so as to sell such "improvements" to the next wave of colonists. This way of converting labor to cash is the frontier equivalent of having a job. Such land speculation is almost unknown among indigenous residents of Bosawas.

Themes and Hypotheses

The northern part of Bosawas, occupied and demarcated by indigenous people, is 95% forest covered, and fauna thought for many years to be extinct north of Panama have been found there. In colonist-occupied areas many common faunal species, such as white-lipped peccaries (*Tayassu pecari*) and tapirs (*Tapirus bairdii*), seem to be extinct locally. Because of the spatial separation of the populations within the reserve, one can ask several interesting conservation questions. For example, does the indigenous demarcation along the colonist boundary really protect forest, in the sense that land cover in areas north of the most contested indigenous boundary can be distinguished from land cover south of it? Similarly, is forest cover in the colonist-occupied area within the reserve different from forest cover in older colonized areas outside the reserve? Are there significant per capita differences in the amount of deforestation by indigenous economies under common property institutions and colonist economies under private property regimes? Are the rural Miskitu—who are reputed to be more commercially active than the Mayangna (Dodds 1998)—harder on the forest than the Mayangna?

We used Landsat images at three different time periods and projections from census and socioeconomic data collected in the early years of the reserve to answer the above questions in a quantitative way that supplements much of the qualitative discussion about the nature of indigenous communities (e.g., Agrawal & Gibson 1999), whether indigenous people (and other poor rural traditional populations) do or do not make good conservation partners (e.g., Alcorn 1993; Redford & Stearman 1993; Colchester 2000; Schwartzman et al. 2000*a*, 2000*b*; Terborgh 2000; Borrini-Feyerabend 2002), whether indigenous peoples suffer economically and/or socially from the creation of protected areas (Brockington 2002; West & Brockington, 2006), and whether the state in a country like Nicaragua is capable of protecting its own protected areas with centralized institutions (Berkes 2004). We tried to answer the

call of many conservationists and social advocates for real cases that would allow one to determine the conditions under which successful partnerships between conservationists, governments, and indigenous peoples and the rural poor may actually work (e.g., Berkes 2004; Brockington et al. 2006; Redford et al. 2003, 2006; Wilkie et al. 2006). We think that studies such as ours help bridge the gap between social advocates and conservationists (e.g., Redford et al. 2006; West et al. 2006; Wilkie et al. 2006).

We tested four hypotheses: (1) the boundary separating the territories of MITK, MSB, and MSBA from the colonist area protects forest; (2) the Bosawas southern boundary protects forest; (3) indigenous populations and colonist populations differ significantly in their per capita impact on the forest; (4) Mayangna and Miskitu differ significantly in their per capita impacts on the forest.

Methods

We analyzed satellite data on land cover in Bosawas for three time periods: 1987 during the Contra War, when much of the forest affected earlier by evacuated populations underwent succession to tall secondary forest; 1995–1996, when the critical demarcations were made that separated contested areas of indigenous claims from the areas settled by colonists; and 2001–2002, when the resulting separation of claims had been in existence for 7 years. We divided the Bosawas region into different polygons in which land-cover change was examined independently (Fig. 1): paired strips of land 2 km north and south of the boundary separating MITK, MSB, and MSBA from colonists; a 10-km strip in the colonist-occupied "buffer zone" to the south of Bosawas; the area occupied by colonists within the reserve; five indigenous territories (Mayangna territories of Mayangna Sauni As [MSA], MSB, MSBA, and Miskitu territories of MITK, and Kipla Sait Tasbaika [KST]); and the original boundary of the Saslaya National Park. Li Lamni Tasbaika Kum was not included because almost all farming and ranching there is outside the reserve and the property regimes and ethnic makeup are variable. For current land-use analysis (supervised classification), we analyzed the vegetation cover for the entire reserve.

Imagery

We conducted land-cover change and vegetation classification analyses with two Landsat scenes (path 16, row 50–51: TM5 for 1987 and 1995–1996 and ETM7+ for 2001–2002). We used imagery acquired during the wet winter season to minimize phenological variation. In the infrequent instances where sufficient cloud-free imagery was not available for the same date for both scenes, we used the nearest possible image date. The north and south scenes for each time period were put into a mosaic form to facilitate processing, and pixels containing cloud cover were masked and excluded from analysis with a maximum likelihood classification and hand digitization.

Land-cover Comparisons

Our first goal was to identify and quantify areas of deforestation in the Bosawas region. Although many vegetation indices were considered, the normalized burn ratio (NBR) provided the clearest delineation of known areas of disturbance and was the index used in all subsequent analyses (see Key & Benson (2004) for relevant background). The formula for the NBR with Landsat TM data was near infrared (B4)—middle infrared (B7)/near infrared (B4) + middle infrared (B7). The NBR values can range between −1 (no vegetation) to 1 (maximum vegetation). In our analysis, pixels typically ranged from approximately 0.2 to 0.8.

The natural land-cover regime in northern Nicaragua is moist subtropical rainforest, consisting of a wide variety of species, little or no bare ground visible from space, and a canopy height ranging from approximately 10 to 30 m. Areas of known primary forest displayed consistent NBR values in all images. These observations facilitated a coarse classification into "disturbed" and "intact" primary forest classes around an NBR threshold that varied depending on the image. We reclassified the imagery into binary grids of change or no-change between time periods with a threshold based on the NBR values of known primary forest regions and known regions of cultural disturbance. We calculated land-cover change area as a percentage of the total cloud-free area and used the total area of each analytical polygon to determine the projected total (square kilometers) of deforested area in each region. We then used chi-square goodness-of-fit tests to compare per capita deforestation (hectares) in indigenously controlled regions against that in colonist-controlled regions, treating the proportions of intact and disturbed forest in the indigenous region as an expected ratio for comparison with that in the colonized regions.

To determine the significance of differences in NBR values between indigenous and colonist-controlled regions in and around the Bosawas reserve, we generated equal numbers of random points in each polygon ($n = 500$ per territory). We then compared the NBR values at each of the sample points for the time period when the indigenous demarcations were established (1995–1996) and the time period after which these demarcations could be assumed to be protected by the indigenous groups (2001–2002). We performed independent-sample t tests to compare the mean NBR values of indigenous versus colonist-controlled regions and one-way analysis of variance (ANOVA) with least significant difference post hoc comparisons to compare the mean NBR values among Mayangna, Miskitu, and colonist-controlled regions. We used an independent-sample t test to compare the mean

NBR values of the 2-km buffer regions north and south of the indigenous demarcations separating MITK, MSB, and MSBA from the colonist-controlled region.

Field-Data Collection and Supervised Classification

We used field data collected during summer 2004 in the countryside surrounding the city of Siuna and the community of San Jose de Bocay to construct and validate the vegetation-classification model. These data included positional information; attribute data regarding land-cover class and approximate patch size and homogeneity; and ethnographic notes concerning land-cover species composition and typical crop-rotation cycles. Given the long-term persistence of land-cover changes, the gap between the validation of the model and the data we analyzed was not considered a problem.

In the field we used a seven-category classification scheme, based on the relative nonvisibility of bare soil, observable species composition, and canopy height: primary forest, secondary forest, *guamil* (a term for fallow fields), pasture, monoculture agricultural plots of staple crops (i.e., rice, beans, or corn), rivers, and settlements. These seven classes were based on similar classifications used in previous analyses (Smith 1998, 2001), ethnographic information obtained before and during collection of field data collection, and the spectral dissimilarity of the classes. The data were recorded as points or transects in numerous homogeneous patches of each of the seven classes.

We used the 2004 sample points to generate maximum likelihood supervised classifications for the 2001 southern ($n = 373$) and 2002 northern ($n = 372$) scenes and to validate the model ($n = 201$). We calculated the relative proportion of each vegetation class for each polygon in the analysis and used a 2×2 chi-square analysis to gauge whether the proportion of regions classified as intact primary forest differed significantly between indigenous- and colonist-controlled regions of Bosawas.

Results

Impact of Territorial Boundaries

The 2-km buffer region within the indigenous territories experienced proportionally less cumulative land-cover change (0.09% in 1987, 1.0% in 1995–1996, and 2.3% in 2001–2002) than the 2-km buffer region within the colonist-occupied region (0.06% in 1987, 2.0% in 1995–1996, and 6.7% in 2001–2002), and the results of the t test showed that the buffer region within the indigenous-controlled area had a significantly higher NBR value compared with the buffer region within the colonist-controlled region (t test: $\alpha = 0.05$, $p < 0.0001$, mean difference = 0.0154).

Impact of the Bosawas Boundary

Within the first 10 km of the colonized buffer region south of the Bosawas reserve, the proportions of disturbance increased from 9.1% in 1987 to 14.4% in 1995–1996 and to 28.0% in 2001–2002, whereas the disturbances in the colonist area of Bosawas disturbance increased approximately 2.5%, approximately 6.6%, and approximately 16.4%, respectively. There was still a significant difference in the two areas in the 1995 images, but that difference had disappeared by 2002, and area occupied by colonists within the reserve showed the most dramatic increases in proportion of disturbed and fragmented forest areas (Fig. 2).

Colonist and Indigenous Deforestation per Capita

Indigenous territories in Bosawas had significantly less net vegetation loss/capita associated with agricultural and pastoral conversion, settlement, and logging than the colonist-inhabited portion of the Bosawas reserve (Table 2). Over the 15 years covered by the satellite images in indigenous territories 0.24 ha/capita and 0.15 ha/capita were deforested in 1995 and 2002, respectively. In contrast, in the colonist area, deforestation rose from 1.65 ha/capita in 1995 to 2.50 ha/capita in 2002, over 16 times the indigenous ratio. The chi-square goodness-of-fit analyses for the two later periods for both 1995–1996 ($\chi^2 = 17.17$, $p < 0.0001$, $n = 6358$) and 2001–2002 ($\chi^2 = 399.51$, $p < 0.0001$, $n = 5699$) demonstrated significant increases in per capita deforestation in colonist regions compared with the expected proportions of deforestation in the indigenous regions. Compared with the control and standard of the indigenous regions, the increased proportion of disturbed forest in colonist regions was statistically significant. Mean NBR values increased significantly in regions under indigenous control compared with regions under colonist control for 1995–1996 ($\alpha = 0.05$, $p < 0.0001$, mean difference = 0.073) and 2001–2002 ($\alpha = 0.05$, $p < 0.0001$, mean difference = 0.0670). Indigenous subsistence practices in Bosawas tended to be much easier on the forest than colonist subsistence practices.

Miskitu versus Mayangna Deforestation per Capita

Taken only as a percentage of the territorial area deforested, the proportion of disturbed areas was higher in Miskitu-controlled regions than in the Mayangna-controlled region, and the Mayangna-controlled regions had a slightly higher mean NBR value compared with the Miskitu-controlled regions (ANOVA: $\alpha = 0.05$, $p < 0.005$, mean difference = 0.0087) and significantly higher mean NBR value compared with colonist-controlled regions (ANOVA: $\alpha = 0.05$, $p < 0.0005$, mean difference = 0.0764) during the 1995–1996 period. In addition, the Miskitu-controlled regions had a mean NBR that was significantly higher than that of the colonist-controlled

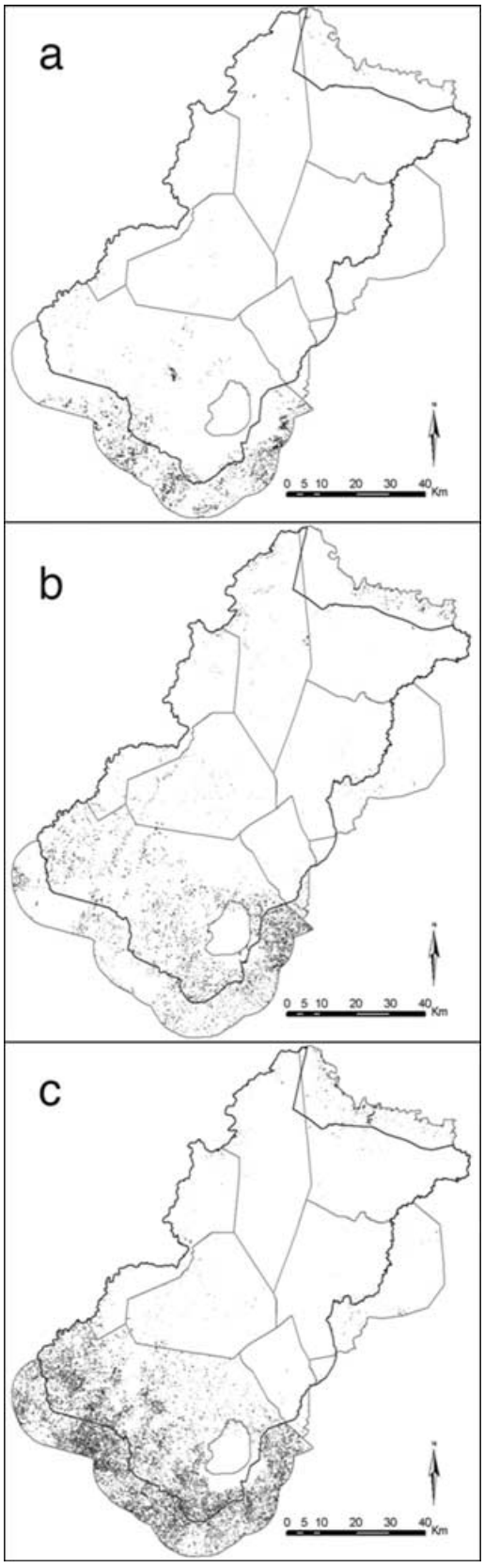

Figure 2. Deforestation in (a) 1987, (b) 1995/1996, and (c) total cumulative change by 2001/2002 in or near the Bosawas Bioreserve in northern Nicaragua.

regions (ANOVA: $\alpha = 0.05$, $p < 0.0005$, mean difference = 0.0678). These patterns persisted during 2001–2002. The mean NBR value for Mayangna regions was significantly higher than for either Miskitu (ANOVA: $\alpha = 0.05$, $p < 0.0001$, mean difference = 0.0083) or colonist regions (ANOVA: $\alpha = 0.05$, $p < 0.0001$, mean difference = 0.0710). However, when deforestation was converted to per capita deforestation to account for population differences, neither the 1995–1996 ($\chi^2 = 0.28$, $p = 0.591$, $n = 6358$) nor the 2001–2002 ($\chi^2 = 0.01$, $p = 0.929$, $n = 5699$) time period was significantly different. Miskitu in Bosawas did not differ significantly from Mayangna in their visible deforestation per capita.

Supervised Classification Results (Current Land Use and Vegetative Cover)

After consideration of the resolution of the imagery being used (25-m^2 pixels) and the spectral similarity of two pairs of the classes (secondary forest versus guamil and agriculture versus pasture) we aggregated the pairs of similar classes into single classes. Thus, the initial seven classes were reduced to the following five classes: primary forest, secondary forest/guamil, agriculture/pasture, rivers, and settlements. This simplified the vegetation classification scheme and better represented the biological diversity of the region within the technological and operational limitations of the satellite platform and image analysis software. The resulting five-class maximum-likelihood supervised classification had an overall accuracy of 86.07% ($\kappa = 0.823$) (Table 3), compared with 76.1%, ($\kappa = 0.709$) for the seven-class scheme.

The proportions of the various vegetation classifications in the 2001–2002 image also corroborated some of the patterns described in the previous land-cover change analyses (Table 4). The percentage of the indigenous territories within Bosawas classified as primary forest was approximately 88%, and when the secondary forest/guamil class was included in this statistic, the proportion increased to nearly 96%. In the much smaller colonist-controlled regions of Bosawas, overall forest coverage was approximately 85%, but only 59% of this region was classified as primary forest. During 2001 and 2002, there was a significant increase in the observed level of deforestation in the colonist region compared with the indigenous region (expected level) ($\chi^2 = 756.2$, $p < 0.0001$, $n = 6439$).

Discussion

Measured by forest cover on the indigenous side of the most contested territorial demarcation in Bosawas, indigenous people have been successful in defending their homelands. Brazilian indigenous lands are also sharply distinguishable from colonist lands in satellite images (Schwartzman et al. 2000*b*; Nepstad et al. 2006).

Table 2. Deforestation in and around Bosawas Reserve.

Territory	*1987 deforested (km^2)*	*1995/1996*		*2001/2002*	
		deforested (km^2)	*deforestation per capita (ha)*	*deforested (km^2)*	*deforestation per capita (ha)*
Mayangna Sauni As (MSA)	0.29	3.76	0.11	4.83	0.1
Mayangna Sauni Bu (MSB)	0.35	5.62	0.3	4.98	0.21
Mayangna Sauni Bas aka Sikilta (SIK)	0.21	2.7	0.8	3.03	0.7
Miskitu Indian Tasbaika Kum (MITK)	1.26	9.52	0.28	7.77	0.18
Kipla Sait Tasbaika (KST)	1.51	9.69	0.29	3.64	0.09
Total Mayangna	0.84	11.98	0.21	12.25	0.16
Total Miskitu	2.78	18.8	0.28	11.5	0.14
Total indigenous	3.62	30.45	0.24	24.19	0.15
Mestizo area Bosawas	17.09	144.44	1.65	356.98	2.5
Total Bosawas	20.71	174.89		381.17	
Li Lamni territory	2.85	13.66	0.17	20.88	0.2
External mestizo 10-km buffer region	97.22	183.77	n/a	357.19	n/a
2-km buffer—indigenous	0.11	1.61	n/a	3.62	n/a
2-km buffer—mestizo	0.08	3	n/a	10.18	n/a

Based on the satellite images of forest disturbance in areas of small farmers with private property compared with patterns of disturbance around nucleated communities, it is obvious that forest fragmentation is a concomitant of private property in these circumstances. In the indigenous communities there were high levels of disturbance in the communities themselves and a mosaic of forest types in the work areas. Beyond these areas were great reserves of intact forest, distant from communities. It was difficult to quantify the amount of fragmentation, but it was easy to distinguish qualitatively from photographs (Fig. 3).

There are several possible reasons why colonists in southwestern Bosawas tend to respect the indigenous territorial boundaries. The unique methodology used in establishing the indigenous boundaries in this part of the reserve permitted demarcation without violence. When the lines were demarcated, an agreement was forged by indigenous territorial leaders with each individual colonist who found his or her property along the proposed line. Colonists were invited to propose where they wanted the line. Often they wanted the line close to their own northern boundary to protect their water sources. The outcome was a "social line" or boundary to which colonists agreed. Thus, the straight lines shown on our maps are actually convoluted, running around, for example, pastures and crops. The Bosawas boundary is much more permeable. The increasing similarity of colonist areas inside the reserve to those outside indicates that state controls have not been effective in protecting the reserve from the advance of the agricultural frontier. Indigenous protection efforts have been much more fruitful.

That indigenous per capita deforestation declined between 1995 and 2002 is interesting, but unexplained. To understand the reasons for these anomalous data, a new on-the-ground demographic and socioeconomic study of the reserve is needed so that a comparison of the current situation with the original baseline data from the mid-1990s can be made.

Some argue that the prevalence of intact forest cover in indigenous areas is not a proxy for ecological health (e.g., Redford 1992; Robinson & Bennett 2000), and satellite data do not reveal damage from hunting or certain kinds of selective logging. Recent studies of Bosawas hunting patterns (Gros et al., unpublished data; St. Louis Zoo, unpublished data) indicate that the hunting patterns

Table 3. Error matrix for maximum likelihood supervised classification of land-cover classes in or near Bosawas Bioreserve in northern Nicaragua.*

	Primary forest (%)	*Rivers (%)*	*Secondary forest/ guamil (%)*	*Agriculture pasture (%)*	*Settlement (%)*
Unclassified	0.0	0.0	3.9	10.8	25.0
Primary forest	98.4	0.0	9.8	0.0	0.0
Rivers	0.0	1.0	0.0	0.0	0.0
Secondary forest/guamil	1.6	0.0	78.4	10.8	0.0
Agriculture pasture	0.0	0.0	7.8	78.4	0.0
Settlement	0.0	0.0	0.0	0.0	75.0

**The columns in the error matrix represent groundtruthed observations made in Nicaragua during the field season of summer 2004. The rows represent the predicted classes of the maximum likelihood classification model output. Overall accuracy = (173/201) = 86.07%, Kappa coefficient = 0.8217.*

Table 4. Mayangna and Miskitu territories classified with supervised classification in or near the Bosawas Bioreserve, northern Nicaragua.*

Territory	*Primary forest (%)*	*Secondary forest/ guamil (%)*	*Agriculture/ pasture (%)*	*Settlement (%)*
Mayangna Sauni As (MSA)	94.46	4.37	0.59	0.59
Mayangna Sauni Bu (MSB)	91.73	5.97	0.61	1.69
Mayangna Sauni Bas aka Sikilta (SIK)	84.41	10.67	2.04	2.85
Miskitu Indian Tasbaika Kum (MITK)	88.77	8.49	1.41	1.33
Kipla Sait Tasbaika (KST)	94.15	4.74	0.52	0.60
Total Mayangna	92.64	5.46	0.70	1.18
Total Miskitu	92.08	6.18	0.86	0.88
Total indigenous	92.40	5.77	0.77	1.06
Saslaya National Park	87.36	10.21	1.93	0.30
Bosawas mestizo area	60.79	26.20	9.12	2.94
10-km buffer region	31.79	43.27	20.20	2.65

**The major rivers category was excluded from this table because it accounted for a very small proportion of the area of all territories. Overall accuracy = 86.07%, kappa = 0.8217.*

of indigenous peoples have not created an empty-forest syndrome, although there are signs of population decrease in tapirs, white-lipped peccaries, spider monkeys (*Ateles geoffroyi*), and green macaws (*Ara ambigua*) as measured by tracks, camera traps, transect observations, and reported hunting encounters. In a few Mayangna communities hunting may account for 48% of the biomass consumed, and the territorial managers (who are the primary recipients of the hunting data) will probably need to make adjustment on hunting seasons and hunting areas. There are encouraging signs that they are doing so

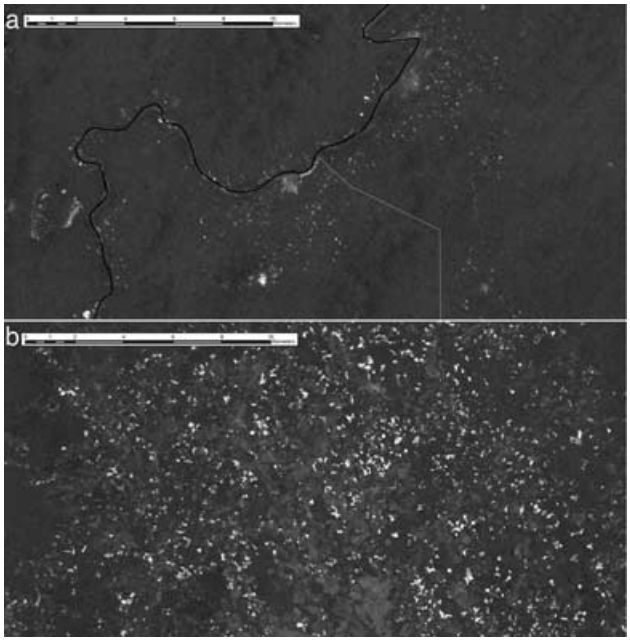

Figure 3. Northern Nicaraguan (a) indigenous and (b) colonist patterns of land conversion (white patches) in the southern portion of the Bosawas Bioreserve, and outside of the reserve, respectively. Scale bar includes a total of 10 km with 2-km division marks.

(J. Polisar, personal communication). Unlike the indigenous people reported by Bennett and Robinson (2000), most Mayangna and Miskitu people rely far more on domestic production of protein than they do on hunting, and they spatially separate activities in ways that preserve habitat. Most hunting in the territories studied by St. Louis Zoo personnel occurs in the work areas, where there is a higher density of white-tailed deer (*Odocoileus virginianus)*, collared peccaries (*T. tajacu*), and pacas (*Cuniculus paca*) than in the areas formally designated on indigenous maps as hunting sinks. In addition, in 1999 the indigenous territories of Bosawas formalized a shared "Waula Conservation Zone" in the heart of the reserve, effectively an indigenous park that protects both flora and fauna.

The amount of secondary forest in the colonist polygon is somewhat surprising and remains unexplained until further fieldwork can be done. MARENA, although unable to physically protect the reserve, has steadfastly refused to consider legalization of colonist tenure or to build new roads into the colonist area and has prevented bank credit for farming or ranching in the reserve. It may be that these policies are working and that some colonists are actually leaving the reserve and allowing forests to take over again. Over the long run, such policies may prove effective.

Our finding that Miskitu and Mayangna territories are similar in their per capita deforestation, whereas they are reportedly dissimilar in their commercial orientation, requires explanation. The major commercial product of the Miskitu along the Coco River is the bean crop, which is sold to markets downstream. The major Mayangna source of cash in northern Bosawas tends to be from panning for gold and the sale of pigs, neither of which require much deforestation. The fact that Miskitu cash cropping does not seem to require deforestation might be explained by the fact that beans are planted principally on muddy river banks when the water level drops during the dry season. The net effect probably does not show up on satellite images except as included in the category of rivers.

Before and during the Contra War, the Saslaya National Park appears to have been heavily settled by colonists in its southern region. Nevertheless, there was much more forest in the park in 2002 than in 1987. In addition, the land-cover change analysis and the vegetative cover analysis both revealed that the park had nearly twice the forested space than it is allotted by statute. There is much forested land to the south of the park that remains free of agricultural colonization, apparently because in the absence of physical demarcation in the 1990s, local populations had to decide for themselves where the boundaries ought to be. The cause of this grassroots manifestation of conservation deserves study on its own.

Conclusion

Colonist and indigenous land uses exhibited marked difference in levels and types of disturbance to the forests. In addition, all differences between indigenous and colonist-controlled regions were statistically significant. The distinction of Miskitu versus Mayangna was much less transparent because although there may be more activity in Miskitu regions, similar proportions of change and forest cover persisted on a per capita basis. Forest connectivity was difficult to gauge and quantify, but the difference between indigenous settlements, with nucleated villages and intensively used nearby agricultural areas, and colonist areas, with forest disturbance spread all over the landscape, seems important. Indigenous communities, even with relatively high populations, maintain large areas of intact forest nearby, and these forests seem to have maintained faunal diversity for the most part.

It seems that the Nicaraguan government has not proved effective in halting colonization of Bosawas. Our results show that the ability of the state to defend the biosphere it created is extremely weak. In contrast, indigenous people in Bosawas—with the collaboration, or at least permission, of the state—have been able to maintain the integrity of demarcated indigenous territories without violence. That the indigenous people see themselves as defending a homeland is important. They have held the belief, even from the beginning of their mapping project, that they would somehow be able to legalize their territorial claims, even when Nicaragua lacked legislation to recognize those claims. This belief or hope, we argue, has been a significant factor that has kept a measure of protection for the land even when funding for supporting voluntary forest rangers was irregular.

The question of indigenous people as conservation partners will have to be researched on a case-by-case basis until the factors that lead to conservation are determined in a number of cases. In this case it seems that the conservation effort has been successful and that indigenous people have been much more protective of the flora and fauna than the government or the colonists, who have illegally occupied parts of it. The future of the indigenous areas, however, depends on continuing devolution of power to indigenous territories, economic development to provide "green" jobs in the reserve, and the collaboration of the government with indigenous organizations and with other organizations that can provide scientific information to territorial authorities on which management decisions can be based (e.g., Brosius & Russell 2003; Berkes 2004; West & Brockington 2006). The model of shared responsibility at various social and political scales in Bosawas evolved through a great deal of grassroots pressure from the indigenous people who took it upon themselves to protect their homeland when it was faced with disaster. Such a model has not yet been systematized by MARENA for future conservation activities in Nicaragua. We predict, based on the Bosawas history and outcome so far, that the success of other Nicaraguan conservation efforts—such as the Atlantic Biological Corridor—will depend on MARENA's ability to do so because the most biodiverse areas in Nicaragua are entirely occupied by a number of indigenous territorial-level claims that remain unrecognized by the government.

Acknowledgments

The satellite imagery research on which this paper is based was funded by the Humanities and Social Sciences Research Council at Idaho State University and by The Nature Conservancy in Nicaragua through its Parks in Peril program in Bosawas. Earlier research in the 1990s on demography and the social and economic patterns of colonists and indigenous people was funded by the U.S. Agency for International Development through a grant to The Nature Conservancy and by Idaho State University. We thank profoundly all organizations and especially the Miskitu, Mayangna, and colonist people who provided information, field assistance, and shelter during that earlier period. The opinions voiced are our own and do not represent either The Nature Conservancy or Idaho State University.

Literature Cited

Agrawal, A., and C. C. Gibson. 1999. Enchantment and disenchantment: the role of community in natural resource conservation. World Development **27:**629–649.

Alcorn, J. B. 1993. Indigenous peoples and conservation. Conservation Biology **7:**424–426.

Bennett, E. L., and J. G. Robinson. 2000. Hunting of wildlife in tropical forests: implications for biodiversity and forest peoples. Environmental department papers, no. 76. The World Bank, Washington, D.C.

Berkes, F. 2004. Rethinking community-based conservation. Conservation Biology **18:**621–630.

Berkes, F., and C. Folke, editors. 1998. Linking social and ecological systems: management practices and social mechanisms for building resilience. Cambridge University Press, Cambridge, United Kingdom.

Borrini-Feyerabend, G. 2002. Indigenous and local communities and protected areas: rethinking the relationship. Parks **12:**5–15.

Brockington, D. 2002. Fortress conservation: the Mkomazi game preserve, Tanzania. James Curry, Oxford, United Kingdom.

Brockington, D., J. Igoe, and K. Schmidt-Soltau. 2006. Conservation, human rights, and poverty reduction. Conservation Biology **20:**250–252.

Buvollen, H. P., and H. A. Buvollen. 1994. Demografía de la RAAN. Wani (Journal of the Nicaraguan Caribbean) **15:**5–19.

Colchester, M. 2000. Self-determination or environmental determinism for indigenous peoples in tropical forest conservation. Conservation Biology **14:**1365–1367.

Dietz, T., E. Ostrom, and P. C. Stern. 2003. The struggle to govern the commons. Science **302:**1907–1911.

Dodds, D. J. 1998. Lobster in the rain forest: the political ecology of Miskito wage labor and agricultural deforestation. Journal of Political Ecology **5:**83–108.

Kaimowitz, D. 2002. Resources, abundance and competition in the Bosawas biosphere reserve, Nicaragua. Pages 171–194 in R. Matthew, M. Halle, and J. Switzer, editors. Conserving the peace: resources, livelihoods and security. World Conservation Union, Geneva.

Kaimowitz, D., and A. Fauné. 2003. Contras and comandantes: armed movements and forest conservation in Nicaragua's Bosawas biosphere reserve. Pages 23–47 in S. Price, editor. War and tropical forests: conservation in areas of armed conflict. Haworth Press, New York.

Kaimowitz, D., A. Faune, and R. Mendoza. 2003. Your biosphere is my backyard—the story of Bosawas in Nicaragua. Policy Matters **12:**6–15.

Key, C. H., and N. C. Benson. 2004. Ground measure of severity, the composite burn index; and remote sensing of severity, the normalized burn ratio. FIREMON Landscape Assessment documents. National Park Service-U.S. Geological Survey National Burn Severity Mapping Project. U.S. Geological Survey, Washington, D.C. Available from http://burnseverity.cr.usgs.gov/methodology.asp (accessed February 2007).

Nepstad, D. S., et al. 2006. Inhibition of Amazon deforestation and fire by parks and indigenous lands. Conservation Biology **20:**65–73.

Ostrom, E. 1996. Governing the commons: the evolution of institutions for collective action. Cambridge University Press, New York.

Ostrom, E., J. Burger, C. B. Field, R. B. Norgaard, and D. Policansky. 1999. Revisiting the commons: local lessons, global challenges. Science **284:**278–282.

Reford, K. H. 1992. The empty forest. BioScience **42:**412–422.

Redford, K. H., and A. M. Stearman. 1993. Forest-dwelling native Amazonians and the conservation of biodiversity: interests in common or in collision? Conservation Biology **7:**248–255.

Redford, K., et al. 2003. Mapping the conservation landscape. Conservation Biology **17:**116–131.

Redford, K. H., J. G. Robinson, and W. M. Adams. 2006. Parks as shibboleths. Conservation Biology **20:**1–2.

Robinson, J. G., and E. L. Bennett. 2000. Hunting for sustainability in tropical forests. Columbia University Press, New York.

Schwartzman, S., A. Moreira, and D. Nepstad. 2000*a*. Rethinking tropical forest conservation: perils in parks. Conservation Biology **14:**1351–1357.

Schwartzman, S., D. Nepstad, and A. Moreiera. 2000*b*. Arguing tropical forest conservation: people versus parks. Conservation Biology **14:**1370–1374.

Smith J. H. 1998. Land cover changes in the Bosawas region of Nicaragua: 1986–1995/96. Ph.D. dissertation. University of Georgia, Athens.

Smith, J. 2001. Land cover assessment of indigenous communities in the Bosawas region of Nicaragua. Human Ecology **29:**339–347.

Stocks, A. 1996. The Bosawas natural resource reserve and the Mayangna of Nicaragua. Pages 1–31 in K. H. Redford and J. A. Mansour, editors. Traditional peoples and biodiversity conservation in large tropical landscapes. Island Press, Washington, D.C.

Stocks, A. 2003. Mapping dreams in Nicaragua's Bosawas biosphere reserve. Human Organization **62:**65–78.

Stocks, A. 2005. Too much for too few: problems of indigenous land rights in Latin America. Annual Review of Anthropology **16:**85–105.

Stocks, A., J. Beauvais, and L. Jarquín. 2000. El activismo ecológico en Nicaragua: demarcacion y legalizacíon de tierras indígenas en Bosawas. Wani (Journal of the Nicaraguan Caribbean) **25:**6–21.

Terborgh, J. 2000. The fate of tropical forests: a matter of stewardship. Conservation Biology **14:**1358–1361.

The Nature Conservancy. 1997*a*. Mayangna Sauni As: tradición oral de la historia y estudio socioeconómico de las comunidades Mayangna de la cuenca del Río Wapuk. Impresiones Modernas, Managua.

The Nature Conservancy. 1997*b*. Mayangna Sauni Bu: documentación del reclamo historico de las comunidades Mayangna de la cuenca del Río Bocay. Impresiones Modernas, Managua.

The Nature Conservancy. 1997*c* Sikilta (Mayangna Sauni Bas): historia y situación actual de los Mayangna Balna del Uliwas. Impresiones Modernas, Managua.

The Nature Conservancy. 1997*d*. Kipla Sait Tasbaika: tradición oral y estudio socioeconómico de las comunidades indígenas del sector raudales. Impresiones Modernas, Managua.

The Nature Conservancy. 1997*e*. Miskitu indian tasbaika kum: historia y situación actual de las comunidades Miskitu del alto Coco. Impresiones Modernas, Managua.

The Nature Conservancy. 1997*f*. Población mestiza en el suroeste de la reserva Bosawas: estudio socioeconómico. The Nature Conservancy, Managua.

West, P., and D. Brockington. 2006. An anthropological perspective on some unexpected consequences of protected areas. Conservation Biology **20:**609–616.

West, P., J. Igoe, and D. Brockington. 2006. Parks and peoples: the social impact of protected areas. Annual Reviews, Anthropology **35:**251–277.

Wilkie, D. S., G. A. Morelli, J. Demmer, M. Stakey, P. Telfer, and M. Steil. 2006. Parks and people: assessing the human welfare effects of establishing protected areas for biodiversity conservation. Conservation Biology **20:**247–249.