TROPICAL RESOURCES

The Bulletin of the Yale Tropical Resources Institute

2003 Volume 22

In this issue

TROPICAL RESOURCES INSTITUTE

Editor's Corner

A letter from the editors of *Tropical Resources:*

We are pleased to present you with this year's edition of *Tropical Resources: The Bulletin of the Tropical Resources Institute*. It has been our pleasure to work with the authors to produce the journal and publish some of our colleagues' finest work.

The breadth of the articles in this year's bulletin clearly shows the wide-ranging, interdisciplinary interests of TRI fellows. Topics range from restoration ecology to human-wildlife conflicts to transnational social movements from around the world.

This year the Tropical Resources Institute again underwent significant changes. We are happy to be working with our new Co-Program Director, Kim Awbrey, a F&ES graduate, who joins Amity Doolittle in running the TRI office. We also launched our new website **http://www.yale.edu/tri** which showcases all of the programs of TRI, and has an archive of abstracts from past TRI fellows. More changes are planned for next year when *Tropical Resources* will go digital. In an effort to live up to our school's environmental reputation we will be scaling back production of hard copies of the journal. They will be available for download through our website instead. At the same time we'll be able to email copies to more readers around the world.

This year's edition of *Tropical Resources* is sure to take you to some of the most interesting tropical places on earth. Enjoy!

Cheers,

Kevin Woods
TRI Co-Editor

Dani Simons
TRI Co-Editor

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May 2003

Dear Friends of TRI,

TRI has had a productive and exciting year. This issue of Tropica**l Resources: The Bulletin of the Yale Tropical Resources Institute** provides a mere glimpse of both the range and diversity of the new initiatives and expanding role we are seeking for TRI to play in the increasingly global scope of F&ES and Yale University. Last year, we explored the possibility of long-term in-country projects and field programs. With Woods Hole Research Center's Senior Scientists, Daniel Nepstad and David McGrath, TRI co-sponsored a seminar and two week field course "Conservation and Development in the Brazilian Amazon" with 12 FES graduate students and several Brazilian counterparts. The course is co-sponsored by NASA-LBA and we plan to make this an annual event for interdisciplinary training.

This year, major efforts were invested in fostering strong relationships with research organizations that could offer institutional, financial and intellectual support for F&ES students interested in conducting summer research projects. We initiated and continued a dialogue with eleven institutions. We have placed seven students in five of these institutions field programs: ICRAF (Africa), CIFOR (Belize), Chicago Field Museum (Peru), The Association for Interdisciplinary Research on Local Development and Conservation (El Salvador) and Woods Hole Research Center (Brazil).

Mark Wishnie now is full time Program Director of PRORENA, a reforestation project with native species based in Panama. Largely through Mark's efforts, the project received long-term external funding. Congratulations to Mark! We continue to coordinate PRORENA – TRI activities. Kim Awbrey, a FES graduate with ten years of NGO-based conservation work in Africa and Latin America now serves as Co-Program Director. Welcome Kim! Kim has been vital to our efforts and was instrumental in the design of new website that serves as a nexus for students and faculty doing tropical research at Yale and our partner institutions.

This year, we initiated an interdisciplinary guest lecture and film series on "Globalization and the Environment: International Agendas and Local Responses" led by TRI Co-Program Director, Amity Doolittle. The twelve speakers who spoke to our community addressed several key issues surrounding global environmental change and governance, while providing an interesting and critically importance lens on the rural, village, NGO and "grassroots" perspectives. Lectures, film series and discussions provided students with an interactive arena to discuss and debate issues. Moreover, this series broadened our interdisciplinary linkages among faculty and students at F&ES, Anthropology, Agrarian Studies, Public Health, and Yale Center for Genomics and Proteomics.

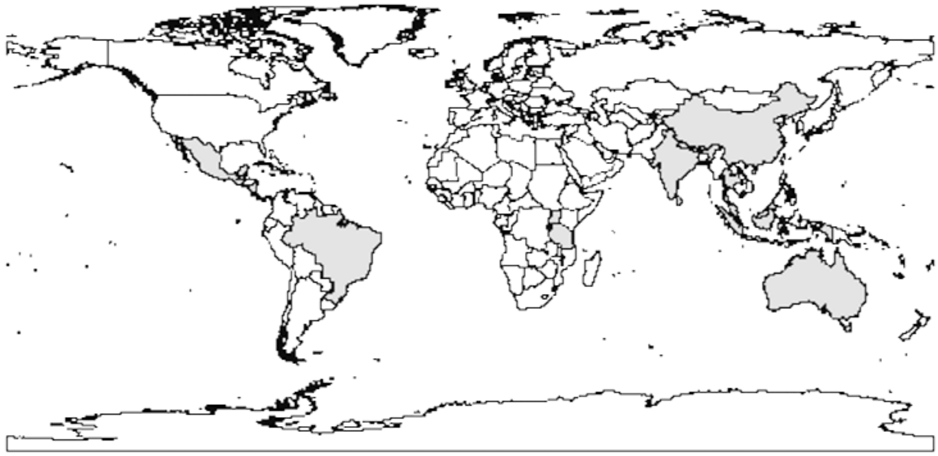
TRI serves to foster and encourage the dynamism of F&ES students' education and initiatives by supporting student workshops, symposium and travel to international conferences. Some examples of our support include:

- Four students attended the **Quito Social Forum** at the Free Trade Association of the Americas (FTAA) summit in Ecuador in November 2002. These students have written an article on the nature of local participation in global environmental governance for the TRI Bulletin.
- Two students attended the **Conservation and Community Workshop** in New Orleans at the American Anthropological Association meetings. As a result of the workshop we made our contacts with the Chicago Field Museum and are developing a proposal to bring a similar workshop to F&ES.
- We provided financial and intellectual support for the student interest group, Social and Community-Oriented Research in the Environment's (SCORE) symposium, P**articipatory Research: Issues and Methods of Action-Oriented Research.** TRI Program Directors met with SCORE on several occasions to facilitate the development of this symposium. Amity Doolittle presented her research on Community Mapping in Indonesia with my NASA-funded program.
- Yale's International Student Chapter of Tropical Foresters (ISTF) and its annual conference is a vibrant international forum. Our financial, intellectual, and institutional support for ISTF will continue. Proceedings of the 2002 ISTF Conference on **Illegal Logging** will be published as a special volume in the *Journal of Sustainable Forestry.* The 2003 conference **Ecosystem Services in the Tropics: Challenges to Marketing Forest Function** drew over 80 attendees and had 14 presenters.

During my second term at Yale F&ES and as Director of TRI, I sought to build on TRI's successes and also to extend and to invigorate the program. The passion, intellect, dedication and vision of the F&ES students provide the inspiration. For our readership, we are looking forward to your involvement in any capacity. TRI is eager to develop in new directions and to contribute our expertise toward applied interdisciplinary environmental problem-solving in the international arena. Our aim is to provide opportunities for students to develop their skills and experience. I commend the students and Program Directors for their efforts with this newsletter.

Sincerely yours,

Lisa M. Curran
Associate Professor of Tropical Ecology
Program Director Tropical Resources Institute



TRI 2002 Fellows

Australia: Hoang Dinh
Bhutan: Elizabeth Allison
Brazil: Margaret Francis, Ilmi Granoff, Alicia Pascasio
China: Geri Kantor
Columbia (San Andres): Emily Sprowls
Costa Rica: Heather Saida Coady, Quint Newcomer, Bryan Petit
Ecuador (Galapagos): Bob Powell
El Salvador: Elizabeth Shapiro
Guatemala: Boris Mendez Paiz
Hawaii: Nathaniel Carroll
India: Krithi Karanth, Rajyashree Narayanareddy
Indonesia: Yudi Iskandarsyah, Florence Miller, Kabir Peay
Malaysia: Betony Jones
Mexico: Laura Ruiz
Nepal: Soni Mulmi
Nicaragua: Richard Chavez
Panama: Michael Booth, April Connelly, Daniela Cusack
Sri Lanka: Naamal De Silva, Uromi Goodale
Tanzania: Abdalla Shah
Thailand: Kevin Coffey
Uganda: Rebecca Ashley, Kirsten Spainhower

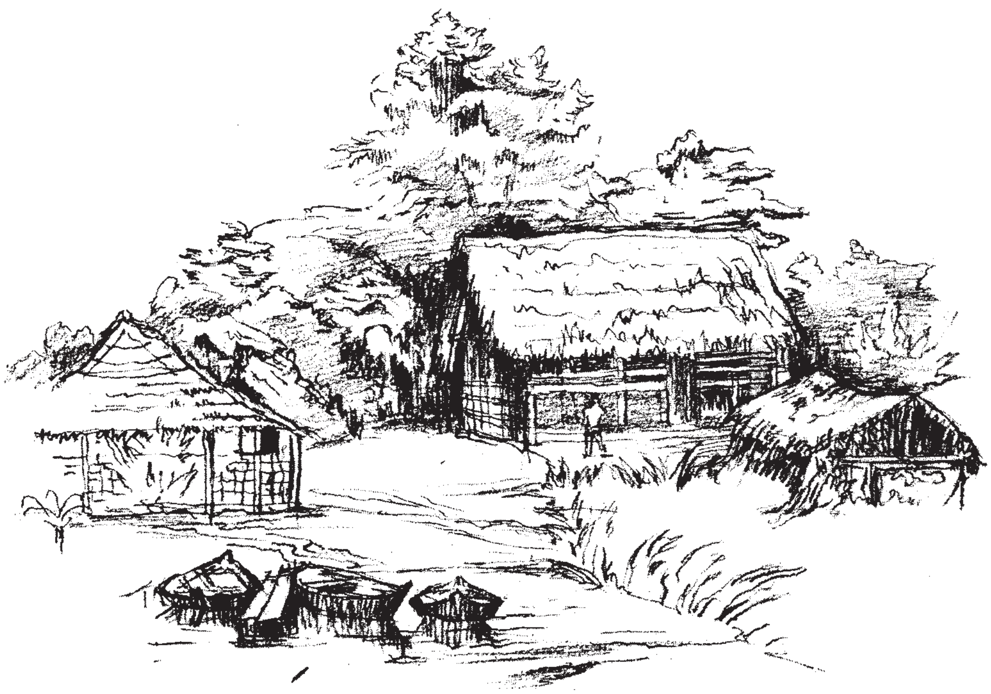
The Yale Tropical Resources Institute: Envisioning Synthesis and Synergy

Mission

The Mission of the Tropical Resources Institute is to provide a forum to support and connect the initiatives of the Yale community in developing applied research, partnerships and programs in the tropics. We support projects that aim to develop practical solutions to issues relating to conservation and management of tropical resources.

Vision

The problems surrounding the management of tropical resources are rapidly increasing in complexity, while demands on those resources are expanding exponentially. Emerging structures of global environmental governance and local conflicts over land use and environmental conservation require new strategies and leaders able to function across diversity of disciplines and sectors, and at local and global scales. The Tropical Resources Institute aims to build linkages across natural and social sciences and among government agencies, academia and practitioners, enabling the formation of successful partnerships and collaborations among researchers, activists and governments. The Tropical Resources Institute seeks to train students to be leaders in this new era, leveraging resources, knowledge and expertise among governments, scientists, NGOs and communities to provide the information and tools this new generation will require to equitably address the challenges ahead.



The village of Sacurí, Brazil,
sketched by Margaret Mee in T. Morrison, ed. 1988. *Margaret Mee: In Search of Flowers of the Amazon Forests*. Nonesuch Expeditions: Suffolk, England.

Survival, growth, and soil fertility of three exotic tree plantations in a tropical dry forest region of Panamá

David S. Howlett, MFSc 2002

Introduction

Tropical dry forests in Central America are one of the most endangered ecosystems in the lowland tropics (Allen 1988). At the time of the Spanish conquest, 550,000 square kilometers of this unique ecosystem extended from central Mexico to Panamá in strips along on the Pacific coast (Janzen 1988, Sorensen & Fedigan 1999). Presently, only 0.09% of these tropical dry forests are protected in any way (Janzen 1988). These forest types are easily cleared by fire in the dry season. This leads to the present 'open' state of this landscape, as normally closed canopy forests are replaced with pastures and grasslands, a loss of habitat for species adapted to these unique conditions. Remnant forests exist in fragments along this Pacific corridor. Forest regeneration has become difficult with such a heavy anthropogenic impact, including fires that 'restart' vegetative succession on an annual basis. Trees that do survive periodic fires face several more barriers to survival and regeneration, including a lack of pollinators and seed dispersal agents, and a harsh microclimate for seeds and seedlings. Temperature ranges are generally higher in this converted landscape, and increased solar radiation desiccates the soils at the surface. Soil fertility can also be a barrier to regeneration of dry forests, as decades to centuries of cropping and grazing take its toll on soil nutrients and structure (see Fisher 1995, Moran et al. 2000, Khurana & Singh 2001).

In recent years, there has been growing interest in the effect of tree plantations on the restoration of degraded lands, especially in the humid tropics (Fisher 1995, Brown & Lugo 1994, Lugo 1997, Ashton et al. 1998, Lamb 1998, Rhoades et al. 1998, Montagnini 2000, Lilienfein et al. 2001). Fewer studies have focused on restoration of degraded tropical dry forests (Bernhard-Reversat 1988, Islam et al. 1999, Khurana & Singh 2001). Fast growing exotic and native trees have been shown to improve soil fertility and ameliorate poor abiotic site conditions in some cases (Fisher 1995, Rhoades et al. 1998, Islam et al. 1999, Lilienfien et al. 2001). In Panamá's tropical dry forests, commonly used agrosilvopastoral systems have incorporated tree species that may have positive, although untested, effects on soil fertility (SAF 2001). The development of carefully managed agrosilvopastoral systems in dry forests could lead to improvement of the environmental conditions necessary for the regeneration of local native species. In agrosilvopastoral systems, farmers can grow crops in the establishment phase of a tree plantation, while utilizing the fodder produced by some trees in the dry season when short-rooting grasses are not abundant (Escalante 1985, Moreno 1986). It is the deep rooting ability of trees that allows them to access groundwater in the dry season, maintaining farm animals during a critical time of the year (Nepstad et al. 1994). Grazing animals also reduce weed competition with the plantation trees after the establishment phase. By establishment of plantations and suppression of fires, commercial agroforestry efforts could lead to the environmental improvement of vast areas of tropical dry forests. Private investors reap the benefits of growing crops, grazing animals and selling timber and poles, while at the same time intensifying land use on their property, and secondarily improving watershed, microclimatic and biodiversity aspects of the landscape.

The forest department in Panamá has issued guidelines for tree species adapted to each of the provinces (SAF 2001). Plantation tree species are selected for several benefits, including fodder for animals, firewood, poles for fences and lumber for construction. This study looked at three species widely planted in Panamá, Central America and worldwide. *Eucalyptus camaldulensis* Dehnh, or the Red Gum tree, is an exotic species from Australia known for its natural broad latitudinal range, and adaptation to arid climates and a variety of soil conditions (Escobar 1997, SAF 2001). *Pinus caribaea* var. *hondurensis* (Barret and Golfari) is a common plantation species found globally, yet native to Central America; its most southern range extends into northern Nicaragua. This species is known for its ability to thrive in low fertility soils with good drainage. *Acacia mangium* Wild is a commonly used multipurpose tree in lowland plantations in Central America and worldwide. A nitrogen fixer in the Legume family, this species produces high protein forage for animals. Cattle will even eat the fallen dry leaf litter on the ground. Overall, these three species are adapted to poor soils in arid regions. They provide the direct benefits of timber and firewood, while providing shade and fodder for grazing animals, particularly during the dry season.

The purpose of this study was to assess the survival and growth of these three species commonly used in agrosilvopastoral systems in Panamá's Coclé Province. This work also considered the effect these exotic plantation species may have on soil fertility, as compared to adjacent non-planted areas. This experiment compared the effects of five year old tree plantations on the soils. Differences in plantation soil fertility were compared to an adjacent open grassland area (control). Although tracking the soil fertility underneath the plantations since establishment would have been ideal to study changes in soil fertility, the method used in this study gives us a 'snapshot' of soil and tree growth characteristics for specific agroforestry systems in comparison to an unplanted control area.

Figure 1 Photograph of the unplanted control area, near Río Hato, Coclé, in Panamá.

Methods and materials

Site description

This study took place in the plantations of Reforestadora Rio Hato, located in the province of Coclé in the Republic of Panamá (north 08° 23', west 80° 07'). The experimental plots are approximately 116 kilometers west of Panamá City, along the Pan-American Highway near the small town of Rio Hato. This site is characterized as a seasonal dry tropical forest with an average rainfall of 900 to 1100 mm per year, falling mainly during the rainy season, June to November. This site is one of the driest places in Panamá (Jaramillo 1984), and an increasingly rare ecosystem in Central America (Janzen 1988). Dry grasslands with sparse cover of Chumico trees (*Curatella americana)* are a typical feature of these open areas (see Figure 1, Escalante 1985). Vegetative cover is most intact in the lower drainage areas surrounding this relatively flat site. The plots are less than two kilometers from the Pacific Ocean at an elevation of 30 to 40 m asl, on a <1% slope. The mean temperature is 27° C.

Adjacent soils were determined to be Ustic Haplustalfs, in the Alfisol order (Jaramillo 1984). The moisture regime is limiting for some plants during the dry season. The site is located on an ancient alluvial fan that is slowly eroding into the nearby Pacific Ocean.

This site has a unique history as a former military base and training center for US and Panamanian military troops. Shortly after the independence of Panamá in 1903, American forces seized the land from local peasants. Some time after this, an airstrip was constructed on the relatively flat site and military drills were carried out on the surrounding several hundred hectares towards the north. In 1962, the US military relinquished control to the Panamanian government that continued to operate the base. Soldiers used heavy machinery, including tanks, to practice maneuvers with live ammunition on adjacent lands. Historic aerial photographs from 1979 and 1993 show the areas of the current plantation with several dirt roads crossing portions of the base immediately east of the airstrip, where the current study took place. The site appeared in 1979 to be in scrub vegetation with sparse forest cover. After the 1989 U.S. invasion of Panamá, the training of troops at the base ceased. Only a few planes still utilize the southern end of the landing strip that spans the Pan-American Highway, across from the study site.

Reforestadora Rio Hato (Rio Hato Reforesters) is a company owned by Mr. Jacobo Sofer, a Panamá City businessman. Reforestadora Rio Hato acquired the land on the former Panamanian military base and in 1996 planted *Eucalyptus camaldulensis* (Dehnh), *Acacia mangium* (Wild), and *Pinus caribaea* var. *hondurensis* (Barret & Golfari) in 3x3-m spacing on a total of 27.5 ha (see photograph in Figure 2). Pre-planting procedures consisted of plowing the area to a depth of 15-20 cm and direct fertilization of the individual trees. No other fertilizer treatments were carried out. Corn was planted on the site during the first year of tree seedling growth. Weeds were controlled with monthly mechanical clearings. Trees that died during the first dry season were replaced and replanted after the first year only. In 1999, a pastoral system was implemented and cows and horses were introduced to reduce vegetation competing with the crop trees. The pine, eucalyptus and acacia stands received their first pruning during 2000 and 2001 as part of ongoing forest operations.

Figure 2 *Photograph of Acacia mangium plantation at Reforestadora Río Hato Coclé, in Panamá.*

Treatments

From the existing plantations in the summer of 2001, three treatment blocks and one control area were demarcated for study. Each block, with a surface area of approximately 3 ha, was mapped with a global positioning system (GPS). Twenty-five individual trees were chosen in a systematically randomized fashion in each block. Each selected tree became the center of a 6x6-m-sampling plot extending three m in each of the cardinal directions. Each plot consisted of nine trees total (6x6m = 36m^2 plots). Control area plots were the same size, representing similar site conditions on an adjacent area not planted. A portion of the control area was burned in the dry season of 2000-2001, while the rest was burned in the dry season of 1999-2000.

Silvicultural and soil fertility measures

Tree height, diameter at breast height (DBH), and survival was recorded for the 25 sampling plots within each of the three plantations. Sampling areas were also set up in the control areas and all woody vegetation (stems >2.5 cm) was recorded. These data were taken to access survival and growth of trees contributing to the leaf litter and eventually the soil. Samples of leaf litter (Oa, undecomposed detritus layer) were collected from a 20x20 cm PVC frame quadrats laid at a standard distance north and south from chosen trees (25 samples per 4 plots=100 samples). Leaf litter was dried at 60°C and weighed for comparison. Soil sample cores were taken in the soil underlying the removed leaf litter (25 samples per 4 plots=100 samples). Two ten-centimeter cores (0-10 cm depth) were collected 1.5 m north and south of the sampling area's center tree and composited for chemical analysis. Two 20 cm deep soil cores (0-20 cm depth) were taken from the even numbered sampling areas (12 per plot), dried and weighed for bulk density analysis.

Soil samples were air-dried and sieved. Several fertility factors were determined on the >2 mm portion of the samples. Soil pH was determined in a 1:2 soil to water solution. Concentrations of $[OH]^-$ ions were compared statistically for mean pH comparisons. Organic matter (%) was determined by loss on ignition. Total soil carbon and nitrogen were analyzed using a LEECO™ CHN analyzer. Cations (K, Ca and Mg) were extracted with BaCl and analyzed by atomic absorption spectroscopy. Texture analysis was performed using the Bouyoucos hydrometer method (Vogt & Tilley 2001).

Basal Area in all the study plots was calculated on a per hectare basis. Leaf litter measures (Kg/ha) were square root transformed for analysis, but are here reported untransformed. Estimates of volume per hectare were made using the formula: volume=1/3 basal area x height. Survival was calculated from the number of living trees per sampling area (out of possible 9 trees per 36 m^2 plot, given 3x3 m stem spacing). Soil fertility factors and silvicultural data were stored and arranged using Microsoft Excel™ software. SPSS™ statistical software was used to perform analysis of variance (ANOVA) on fertility factors, growth, and survival versus cover type. Tukey's post-hoc tests were conducted to compare means between cover types.

Results

Survival and growth in treatments

A. mangium and *P. caribaea* showed significantly greater survival (90.7% and 84.0%, respectively) than that of *E. camaldulensis* (75.9%) (see Table 1). *P. caribaea* had a higher basal area than any of the other treatments (19.2 m^2/ha) (see Table 1). The control area had lower mean basal area, 0.49 m^2/hectare, of which 66.7% was *Curatella americana*, the most common tree species in non-planted areas. Mean volumes of the plantation species did not vary statistically from each other (Table 1). The control area did have significantly less woody volume than the plantations, with 0.40 m^3/hectare. Tree height was associated with cover type, with *E. camaldulensis* taller than all plantation and control area species (Table 1).

cover/treatment	**survival** (%)	**basal area** (m2/ha)	**volume** (m3/ha)	**height** (meters)
Eucalyptus camaldulensis	75.9b	10.9b	38.2a	10.1a
Acacia mangium	90.7a	13.0b	33.5a	6.9b
Pinus caribaea	84.0b	19.2a	39.7a	6.0c
control area	n/a	0.47c	0.4b	1.2d

Table 1 *Mean survival and growth of agrosilvopastoral trees planted by Reforestadora Rio Hato. Means that are followed by different letters differ significantly from other cover types.*

Measures of soil fertility

ANOVA results indicate that variation in the mean soil fertility factors was significantly associated with cover type ($p<0.05$). The *P. caribaea* and control areas had slightly acidic, yet a relatively neutral pH of 5.8 and 6.0, respectively (see Table 2). *E. camaldulensis* and *A. mangium* soils had a pH of 5.5 and 5.4 respectively, with no differences between treatments. Table 2 shows the differences in leaf litter per hectare (square-root transformed) between the plantations and control area. *A. mangium* showed significantly greater production of leaf litter per hectare (176 kg/ha). Treatments with plantings did show significantly more leaf litter than the unplanted area. Organic matter (OM) and total carbon (%C) were highest in the *P. caribaea* and control area (Table 2). The

cover/treatment	pH	leaf litter	OM	C	N	K	Mg	Ca
		(kg/ha)	(%)	(%)	(%)	(cmol/kg)	(cmol/kg)	(cmol/kg)
Eucalyptus camaldulensis	5.50a	133.2b	1.06b	1.14ab	0.106b	0.247b	0.718b	1.66b
Acacia mangium	5.33a	176.1a	1.22b	1.09b	0.118b	0.321ab	0.679b	1.32b
Pinus caribaea	5.73a	86.8b	1.71a	1.21ab	0.153a	0.479a	1.271a	2.33a
control area	5.99a	15.8c	1.66a	1.30a	0.128ab	0.424a	1.302a	2.36a

Table 2 *Mean values for soil fertility factors are shown for each of the cover types. Means that are followed by different letters differ significantly from other cover types.*

control area had significantly higher carbon than the *A. mangium*, but no difference from the *E. camaldulensis* and *P. caribaea* treatments. Total nitrogen (N) was higher in the *P. caribaea* and control plots (Table 2). *P. caribaea* showed significantly higher nitrogen than the other cover types. The control area did not differ statistically from any of the N treatments. Table 2 also shows *E. camaldulensis* to have significantly lower potassium (K) than the other treatments, except the similarly low *A. mangium*. Levels of magnesium (Mg) and calcium (Ca) are higher in *P. caribaea* and in the control area, and lower in the other cover types (Table 2). Table 3 shows the differences in soil bulk densities (BD). *P. caribaea* and the control areas had high bulk densities of 1.5 g/cm^2 each, significantly higher than *E. camaldulensis* and *A. mangium* estimates. Texture analysis showed that the soils in the four treatments are similar, all sandy loams, with slightly more sand in the *P. caribaea* site (Table 3).

cover/treatment	sand	silt	clay	BD
	(%)	(%)	(%)	g/cm2
Eucalyptus camaldulensis	58.4	23.5	18	1.32b
Acacia mangium	59.7	24.8	15.5	1.34b
Pinus caribaea	67.4	16.5	19.1	1.48a
control area	61.3	19.9	18.8	1.48a

Table 3 *Mean values for soil physical properties are shown, including a texture breakdown by class and an estimate of bulk density. Means that are followed by different letters differ significantly from other cover types.*

Discussion

Survival and growth

Of the three tree species, *P. caribaea* and *A. mangium* have both survived well on sandy, unfertile soils for the past five years (Table 1). Martinez (1997) reports higher mean survival results for pine, but from trials carried out in Panama's more humid forests. Since countrywide survival estimates range from 51% to 100% for one to twelve year old *P. caribaea* stands (Martinez 1997), results reported here are reasonable when considering the dryer climate. Osorio (1997) reports lower survival (78%) for *A. mangium* on similar soils in a dry forest in the same Panamanian province, while estimates from other trials all over Panamá have a mean survival of 80%. Survival of *E. camaldulensis* on this site was much lower than the near 100% reported by Islam et al. (1999) from a tropical dry site in Bangladesh. Since trees in Rio Hato were replanted after the first year, these survival estimates reported here should be higher than for similar sites that did not replant.

P. caribaea has the most growth measured in basal area per hectare compared to *E. camaldulensis* and *A. mangium*. Basal area in *P. caribaea* is similar to what Martinez (1997) reported from other trials in Panamá. And *A. mangium* basal area growth is similar to that shown by Osorio (1997). While volume production over the five years did not vary between the plantations, others have found differences (NAS 1979). Researchers in Sabah, Malaysia found *A. mangium* to out-produce *P. caribaea* in volume on poor soils in a moist tropical forest. *A. mangium* volume growth in Rio Hato was less than that reported by Roshetko (2001). Perhaps on this dry site in Panamá, *P. caribaea* has an advantage in volume growth over *A. mangium*. According to Escobar (1997) these basal area results from *E. camaldulensis* would be categorized as intermediate, in terms of growth of this species all over Panamá. Tree height varied according to species in this treatment (Table 1). *E. camaldulensis* height, when compared to other data from Panamá, is also classified as medium in growth, (between 1.6 to 2.5 m annual increment) (Escobar 1997). The mean height attained for *A. mangium* is classified as medium in terms of annual growth according to Osorio (1997). Height of *P. caribaea* was less than that reported in a more humid La Yeguada, Panamá (Martinez 1997). These data do not show very high growth rates, as compared to other field trials completed by the Madeleña project in Panamá (Martinez 1997). Survival may be considered adequate here, as growing trees in one of the driest sites in Panamá presents a challenge.

Plantation effects on soil fertility

ANOVA results indicate that differences in soil fertility factors are related to cover type ($p<0.05$). The mean separation tests showed differences in fertility measures among treatments, except in pH. Although others have shown increased acidification in *P. caribaea* and *E. camaldulensis* plantations (Islam et al. 1999, Lilienfein et al. 2001), this study found lower but statistically similar pH in the different plots. *A. mangium* produced the most leaf litter of the plantation species, but this difference did not translate into improvements in soil chemistry, when compared to the control area. Nutrients in the *A. mangium* leaf litter may be locked up by mineralized resistant polyphenolic compounds in the falling leaf matter (Northup et al. 1998). *P. caribaea* and control areas showed similar trends of higher fertility in matter, carbon, nitrogen, organic matter, potassium, magnesium and calcium. In the control areas, the previous burns may have increased pH and nitrogen, as shown by Ellingson et al. (2000). The *P. caribaea* site has maintained similar soil fertility as the control area, while providing the added benefit of timber. The consistent incorporation of aboveground biomass by periodic fires serves to keep immediate fertility and pH higher in the control area than in the plantations. Since the control area is not grazed, there is less export of nutrients through biomass removal. Leaching of soil nutrients surely does occur, but may not be such a factor on this relatively flat site. Senescent, fallen pine needles may contribute more to soil nutrients than the leaf litter in other plantations. Nitrogen levels were highest in the *P. caribaea*, since drying, broken pine needles enhanced soil organic matter and nitrogen pools. Even though *P. caribaea* produced intermediate amounts of standing leaf litter, decomposed litter may have contributed to soil fertility. Higher leaf litter production in both the *E. camaldulensis* and *A. mangium* did correlate with high mineral soil nutrients found in the recently burned control area or in *P. caribaea*. This way, soil fertility in the control and *P. caribaea* area is the highest. *P. caribaea* plantations may not be taxing the local soils as much as the other plantations or, alternatively, *P. caribaea* may be improving the underlying soils. While the mechanism for higher fertility in the control area may be known (periodic fires), the reason for improvements and or maintenance of soil fertility in the *P. caribaea* area remains unclear (with fire suppression in the plantations). Soil types are sandy Alfisols, with relatively high bulk densities recorded for *P. caribaea* and the control area. Local managers at Reforestadora Rio Hato complained about compaction problems that were present at planting in 1996, yet they continued mechanical weed removals until 1999. Even though the whole plantation was plowed to a depth of 15-20 cm, bulk densities measured in the *P. caribaea* and control area are considered higher than necessary to inhibit some crop plant growth (Brady & Weil 1999), while bulk density was lower in *E. camaldulensis* and *A. mangium*. Explanations for this difference could consider increases in root growth, burrowing animals, and respiration of soil flora (Fisher 1995). Preferential grazing by cattle and horses may also contribute to higher bulk densities. A higher proportion of sand was found in the *P. caribaea* plantation soil samples, but all site texture estimates were in the range of sandy loam (Vogt & Tilley 2001). A greater proportion of sand in the *P. caribaea* plantation may help to maintain adequate drainage, which the pine requires (SAF 2001).

Although not quantified in this study, *P. caribaea* plantations in Rio Hato had a more diverse, well developed understory as compared to the other cover types. The *A. mangium* plantation was going through canopy closure, with intense shade in closed areas and a heavy cover of leaf litter. *E. camaldulensis* in this plantation provided very tall, diffuse shade, such that growth of a dense understory was inhibited by limited shallow soil moisture in the dry season. *P. caribaea*, alternatively, produces intense shade that is provided by a compact canopy structure that is closer to the ground. Since the *P. caribaea* has not closed canopy yet and the trees are still short, intense light and shade alternate on the ground to provide a balanced microclimate for understory growth. The variation in understory development may tell an interesting story of improvements made to soil fertility and physical structure. Parrotta (1995) reports how understory development is affected by the presence of birds and bats as seed dispersal agents. Grazing by cattle and horses would selectively eliminate the most palatable vegetation from all plantations. Nitrogen-fixing legumes were found in all the plantation understories. *P. caribaea* may be improving the soils, but may also be providing adequate environmental protection for soil improving species. The current plantation understory vegetation has survived the microclimatic extremes of the dry season and regular grazing from animals, benefiting from shade and mulch provided by the plantations. Ashton et al. (1997, 1998) demonstrated the usefulness of *P. caribaea* as a nurse tree for the planting of shade tolerant native trees in Sri Lanka. High bulk density soils in the *P. caribaea* plantation support a host of flora and fauna.

E. camaldulensis showed the poorest survival and growth on this site over five years, but did produce poles for fencing. Continued monitoring of soil chemistry changes may help to determine how *E. camaldulensis* may affect this site. *A. mangium* produced the most standing leaf litter in five years, but has yet to show improvements to the soil nutrients as compared to the unplanted control site. Studying the differences in phenolic makeup of pine and acacia leaf litter may help us to improve nutrient cycling in dry sites, so foresters can time the storage and release of litter nutrients in plantations. A key difference between *A. mangium* and the other species in the maintenance of agrosilvopastoral systems is that the acacia produces timber and fodder for grazing animals (which can be eaten fresh or dry). While benefits from the planting of all species was shown, this study demonstrates the particular usefulness of *P. caribaea* in the restoration of tropical dry forests in terms of survival through the dry seasons, growth in timber (measured in basal area), and effect on soil fertility as a significant improvement over the eucalyptus and acacia plantations.

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References

Allen, W. 1988. Biocultural Restoration of a Tropical Dry Forest. *Bioscience* 38 (3)156-161.

Ashton, P.M.S., Gamage, S., Gunatileke, I.A.U.N. and C.V.S. Gunatileke. 1997. Restoration of Sri Lankan Rainforest: Using Caribbean *Pine Pinus caribeae* as a Nurse Tree for Establishing Late-successional tree species. *Journal of Applied Ecology* 34:915-925.

Ashton, P.M.S., Gamage, S., Gunatileke, I.A.U.N. and C.V.S. Gunatileke. 1998. Using Caribbean Pine to Establish a Mixed Plantation: Testing Effects of Pine Canopy Removal on Plantings of Rain Forest Tree Species. *Forest Ecology and Management* 106:211-222.

Bernhard-Reversat, F. 1988. Soil Mineralization Under a Eucalyptus Plantation and a Natural Acacia Forest in Senegal. *Forest Ecology and Management* 23:233-244.

Brady, N.C. and R.R. Weil. 1999. *The Nature and Properties of Soils.* Prentice Hall, New Jersey.

Brown, S. and A.E. Lugo. 1994. Rehabilitation of Tropical Lands: A Key to Sustaining Development. *Restoration Ecology* 2(2): 97-111.

Ellingson, L.J., Kaufman, J.B., Cummings, D.L., Sanford, R.L. and V.J. Jaramillo. 2000. Soil N Dynamics Associated with Deforestation, Biomass Burning, and Pasture Conversion in a Mexican Tropical Dry forest. *Forest Ecology and Management* 137:41-51.

Escalante, E. 1985. Promising Agroforestry Systems in Venezuela. *Agroforestry Systems* 3:209-221.

Escobar, F.G. 1997. *Eucalyptus camaldulensis*: Descripción Botánica y Ecológica. Resultados de 10 Anos de Investigación Silvicuiltural del Proyecto Madeleña en Panamá. L.A. Ugalde Arias (ed.), CATIE, Costa Rica.

Fisher, R.F. 1995. Amelioration of Degraded Rain Forest Soils by Plantations of Native Trees. *American Journal of Soil Science Society* 59: 544-549.

Islam, K.R., Kamaluddin, M., Bhuiyan, M.K. and A. Badruddin. 1999. Comparative Performance of Exotic and Indigenous Forest Species for Tropical Semievergreen Degraded Forest Land Reforestation in Chittagong, Bangladesh. *Land Degradation and Development* 10:241-249.

Janzen, Dan H. 1988. Guanacaste National Park: Tropical Ecological and Biocultural Restoration. In *Rehabilitating Damaged Ecosystems,* John Cairns (ed.). Vol.II.CRC press, Boca Raton.

Jaramillo, S.E. 1984. *Estudio General de los Suelos de la Finca COAPRHA*. Instituto de Investigación Agropecuaria de Panamá (IDIAP), Sub-Programa de Reconocimiento y Clasificación de Suelos, Panamá.

Khurana, E. and J.S. Singh. 2001. Ecology of Seed and Seedling Growth for Conservation and Restoration of Tropical Dry Forests. *Environmental Conservation* 28(1): 39-52.

Lamb, D. 1998. Large Scale Ecological Restoration of Tropical Forest Lands: The Potential Role of Timber Plantations. *Restoration Ecology* 6(3):271-279.

Lilienfein, J., Wilcke, W., Thomas, R., Vilela, L., doCarmo Lima, S. and W. Zech. 2001. Effects of *Pinus* caribaea Forests on the C, N, P, and S Status of Brazilian Savanna Oxisols. *Forest Ecology and Management* 147: 171-182.

Lugo, A.L. 1997. The Apparent Paradox of Reestablishing Species Richness on Degraded Lands with Tree Monocultures. *Forest Ecology and Management* 99:9-19.

Martínez, R. 1997. *Pinus caribaea*: Descripción Botánica y Ecológica. Resultados de 10 Anos de Investigación Silvicuiltural del Proyecto Madeleña en Panamá. L.A Ugalde Arias, (ed.), CATIE, Costa Rica.

Montagnini, F. 2000. Accumulation in Aboveground Biomass and Soil Storage of Mineral Nutrients in Pure and Mixed Plantations in a Humid Tropical Lowland. *Forest Ecology and Management* 134: 257-270.

Moran, E.F., Brondizio, E.S., Tucker, J.M., Silva-Forsberg, M.C., McCracken, S. and I. Falesi. 2000. Effects of Soil Fertility and Land use on forest succession in Amazonia. *Forest Ecology and Management* 139:93-108.

Moreno, Albert. 1986. Estructura y función del sistema agroforestal Gliricidia sepium -bovino-gramíneas. Finca La Pacifica (Guanacaste, Costa Rica). In Sistemas Agroforestales, Organización Para Estudios Tropicales y CATIE. San Jose, Costa Rica.

National Academy of Sciences (NAS). 1979. *Tropical Legumes: Resources for the Future*. National Academy of Sciences, Washington, D.C.

Nepstad, D.C., Decarvalho, C.R., Davidson. E.A., Jipp, P.H., Lefebvre, P.A., Negreiros, G.H., Dasilva, E.D., Stone, T.A., Trumbore, S.E. and S. Vieira. 1994. The Role of Deep Roots in the Hydrological and Carbon Cycles of Amazonian Forests and Pastures. *Nature* 372 (6507): 666-669.

Northup, R.R., Dahlgren, R.A., McColl, J.G. and N.V. Breemen. 1998. Polyphenols as Regulators of Plant-Litter-Soil Interactions in Northern California's Pygmy Forest: a Positive Feedback? *Biogeochemistry* 42(1-2):189-220.

Osorio, R. V. 1997. *Acacia mangium*: Descripción Botánica y Ecológica. Resultados de 10 Anos de Investigación Silvicuiltural del Proyecto Madeleña en Panamá. L.A. Ugalde Arias, (ed.), CATIE, Costa Rica.

Parrota, J.A. 1995. Influence of Overstory Composition on Understory Colonization by Native Species in Plantations on a Degraded Tropical Site. *Journal of Vegetation Science* 6(5):627-636.

Rhoades, C.C., Eckert, G.E. and D.C. Coleman. 1998. Effects of Pasture trees on Soil Nitrogen and Organic Matter: Implications for Tropical Montane Forest Restoration. *Restoration Ecology* 6(3): 262-270.

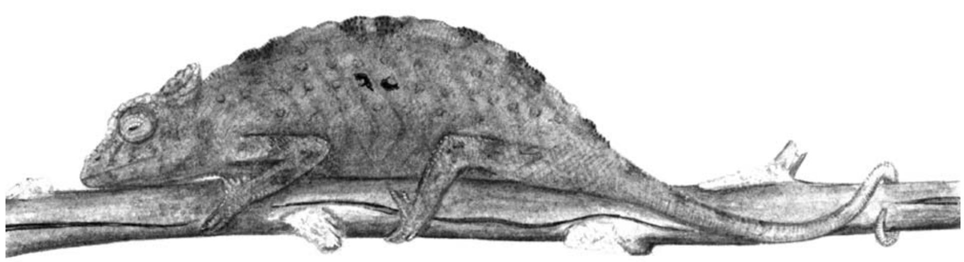
Rico-Gray, V., Chaemas, A. and S. Mandujano. 1991. Uses of Tropical deciduous forest species by the Yucatecan Maya. *Agroforestry Systems* 14: 149-161.

Roshetko, J.M. 2001. *Agroforestry Species and Technologies*. Winrock International, Taiwan.

Servicio de Administración Forestal (SAF). 2001. Guía Técnica Para la Reforestación en Panamá. Autoridad Nacional del Ambiente, Panamá City, Panamá.

Sorenson, T.C. and L.M. Fedigan. 1999. Distribution of three monkey species longa gradient of regenerating tropical dry forest. *Biological Conservation* 92 (2) 227-240.

Vogt, D.J. and J.P. Tilley. 2001. *Laboratory Procedures for Soil and Plant Analysis*. Yale University School of Forestry and Environmental Studies (FES 531b), New Haven, CT



Chamaeleon ituriensis
Watercolor by James Chapin
Congo Expedition 1909-1915
American Museum of Natural History Library

Recruitment of woody regeneration on experimental and private timber plantations in Costa Rica

Daniela Cusack, MESc 2003

Introduction

In the early 1990s, the total area of deforested and degraded tropical land worldwide (2 billion ha) surpassed the area of mature tropical forests (1.8 billion ha) (Lugo 1997). In Costa Rica alone, over 50% the natural forests have been cleared for agriculture and grazing (FAO 2000), yet the productivity of lands cleared for agricultural expansion and grazing is often short-lived.

On pasturelands in advanced stages of degradation, native forests regenerate slowly or not at all (Ashton et al. 2001). Moderately to severely degraded pasturelands tend to be colonized quickly by invasive grasses and ferns (Kuusipalo et al. 1995). The competitive advantage of grasses, combined with degraded soils and lack of nutrients, can prevent the initiation of tree seedlings (Kuusipalo et al. 1995, Parrotta 1992). Forest regeneration on abandoned pasturelands is desirable in order to restore soil fertility, reduce erosion and restore biological productivity (Montagnini 2001, Parrotta 1992).

Establishment of one woody species in a grassland can shade out grasses, increase nutrient status of topsoils (through litterfall), and facilitate the influx of other, more site-sensitive tree species (Grubb 1995). Various studies have demonstrated that planting native or exotic species can increase biodiversity by promoting regeneration of native woody species in plantation understories (Ashton et al. 2001, Carnevale & Montagnini 2002, Guariguata et al. 1995, Haggar et al. 1997, Keenan et al. 1997, Keenan et al. 1999, Lugo 1997, Parrotta et al. 1997, Powers et al. 1997).

Despite widespread success of forest restoration projects, such projects are often expensive, and therefore unrealistic for wide-scale application in developing countries (Parrotta et al. 1997). An economically viable solution is to use fast-growing timber species to ameliorate site conditions, as described above, and promote natural forest successional processes. This approach has the advantage that timber species can later be harvested, providing an economic incentive to reforest abandoned pasturelands.

This study examined the potential of six native timber species for restoring diversity of understory woody species in tropical ecosystems. Similar past studies of understory regeneration on neotropical plantations have been conducted exclusively on experimental plantations (Carnevale & Montagnini 2002, Guariguata et al. 1995, Montagnini 2000, Powers et al. 1997). This research sought to determine whether trends in understory regeneration on experimental plantations hold true on private commercial plantations of the same timber species.

Study site

Three plantation sites were used for this research. All sites were native species plantations established between 1992 and 1993 on the Caribbean lowlands of Costa Rica. The study sites are located at 10°12' to 10°47' North latitude and 84°09' to 83°45' West longitude. Mean annual temperature is 24°C. Mean annual precipitation is 3500-5000 mm, and in no month is precipitation less than 50 mm. Elevation is between 30 and 200 m asl. The overall topography is flat to undulating terrain. In general, soils belong to the Ultisol and Inceptisol orders. There are various limitations of the soil, such as slow or impeded drainage, and very low to medium fertility. These limitations restrict land uses to permanent crops and reforestation (Piotto et al. 2002).

The first site used in this study was an experimental plantation at La Selva Biological Station (7.5 ha). The second and third sites were native species plantations on private farms belonging to Vicente Paniagua (16 ha) and Isidro Quesada (20 ha). Both private plantations were established with technical advice from a local non-governmental organization, FUNDECOR (Foundation for the Development of the Central Mountain Range), as part of a government reforestation initiative. Each plantation was composed of adjacent plots (1-5 ha each) of various species. Six species were used in this study, each of which was present at every site. Species used were *Calophyllum brasiliense* Cambess, *Hieronyma alchorneoides* Allemao, *Terminalia amazonia* (J.F. Gmel.) Exell, *Virola koschnyi* Warb., *Vochysia ferruginea* Mart., and *Vochysia guatemalensis* Sprague. Abandoned pastures adjacent to each site were used as controls.

La Selva experimental plantations were arranged in randomized blocks of timber species. On the two private plantations, the six timber species were planted in plots adjacent to each other and adjacent to abandoned pastures. This arrangement created a mosaic of patches, which was used in this study as a block design. At each site four subplots of 4m x 4m were established for each of the six timber species plots. In total, twelve subplots were established for each species and the control pastures at each site totaling 1,344 m^2 surveyed.

All plantations were 9-10 years old at the time of this study. All had low-intensity management, with little or no cleaning, clearing or pruning since the third year. Some cleaning did occur on private plantations, but none had occurred for at least three years prior to the study. Plantations also had similar thinning regimes, although final spacing varied from 4m x 4m to 4m x 8m. The La Selva plantation was 100 m from continuous forest, the Paniagua plantation was 1.3 km from continuous forest, and the Quesada plantation was 2.5 km from continuous forest. None of the sites were connected to each other by continuous forest, however, and can be considered independent replicates. The important factors which varied between the three sites were exact distance to continuous forest, final spacing of planted trees, and undulation of terrain. The block design of the experiment was expected to account for the major differences between sites.

Methods

Evaluation of understory woody regeneration

Understory woody regeneration was surveyed in each of the subplots. Only woody species were recorded. Abundance and species richness in each subplot were recorded. Regenerating woody individuals were identified to genus or species in the field, and specimens were taken for confirmation of identification at the La Selva Biological Station herbarium. Woody species diversity was calculated using the Simpson Index and the Shannon-Weiner Index for understories of the six timber species.

Statistical analysis

All data were analyzed using the SAS program General Linear Model. A Poisson transformation was applied to all abundance data,because data was count-data of stem occurrence in plots. This transformation helped normalize the distribution and means of errors. The model used tested for significant differences in understory abundance between control sites and planted sites. A second model was run using only data from the six treatments, disregarding the pasture sites since regeneration in these was equal to zero. Tukey tests were also conducted for comparisons of total regeneration and regeneration by height class among the six timber species ($p=0.05$). Data from all three sites were analyzed both pooled together and separately by site.

Results

Understory abundance in private farms and at La Selva

When comparing planted plots to control plots, all plots with planted species had significantly higher abundance of regenerating individuals than control plots ($p<0.0001$). Because all control plots had 0 regneration, these plots were not used for the subsequent analysis.

Figure 1 shows the total abundance of regenerating individuals in treatments across the three different sites. *C. brasiliense* and *V. guatemalensis* had the greatest abundance of regenerating individuals at La Selva. At the Paniagua plantation, *T. amazonia* followed by *V. guatemalensis* had the highest abundance of regeneration. At the Quesada site, *V. ferruginea* followed by *T. amazonia* and *C. brasiliense* had the greatest understory abundance.

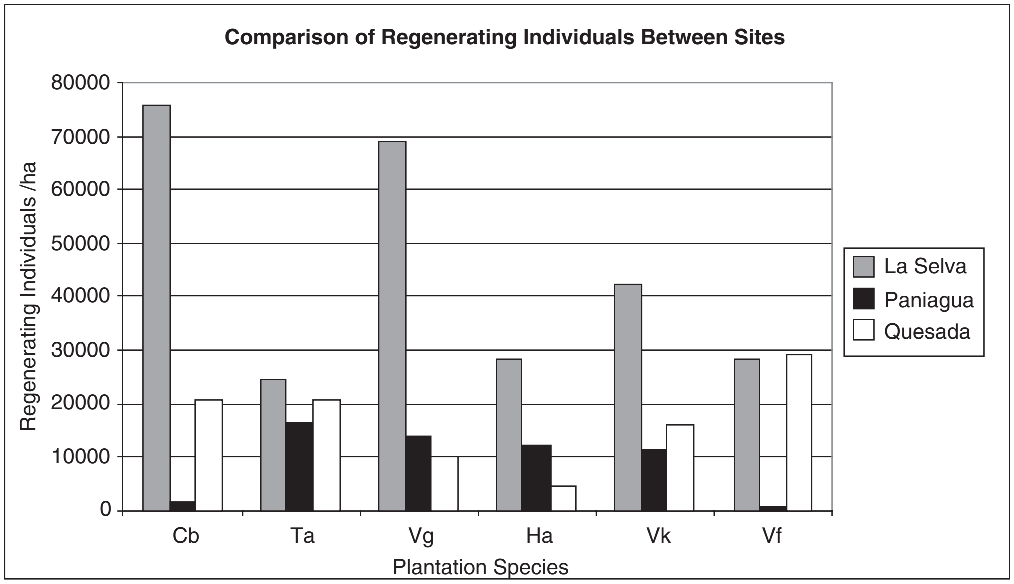


Figure 1 *Understory woody regeneration under six timber species. Cb:* ***Calophyllum brasiliense****, Ta:* ***Terminalia amazonia****, Vg:* ***Vochysia guatemalensis****, Ha:* ***Hierronyma alchorneoides****, Vk:* ***Virola Koschnyi****, Vf:* ***Voshysia ferruginea****.*

Across all three sites, there was no significant difference for total abundance of regenerating individuals among the 6 treatments, unless the interaction effect of site and planted species was accounted for in the model. The interaction between site and plantation species was significant ($p<0.0001$). Once the interaction was accounted for, site had a highly significant association with regeneration ($p<0.0001$), and planted species had a somewhat less significant association with ($p<0.02$) total regeneration. This implies that site was more important than planted species for understory regeneration, although planted species did influence recruitment to varying degrees within sites.

Understory abundance within each site

Within the La Selva experimental plantations, *V. guatemalensis* and *C. brasiliense* had significantly higher total mean number of regenerating individuals than other species. At the Paniagua plantation, *T. amazonia* had significantly greater total understory regeneration than other species. At the Quesada plantation, *V. ferruginea* had significantly higher total abundance of regeneration than other species (Figure 1), all ($p \leq 0.05$).

Understory species diversity

Virola koschnyi had the greatest number of species, and one of the highest values of diversity under the Simpson Index (Table 1). *Terminalia amazonia* had a higher Shannon-Wiener Index however, indicating that rare species were more prominent in plantations of *T. amazonia* than *V. koschnyi*. Similarly, *Vochysia guatemalensis* had a higher number of species than *Calophyllum brasiliense*, yet *C. brasiliense* ranked higher in both diversity indices. Interestingly, *Hieronyma alchorneoides,* which had the fewest number of species, had a relatively high Simpson Index of diversity, and a mid-range Shannon-Weiner Index, indicating the abundance of individuals was well distributed across species, and that rare species were relatively important. Understories were dominated by shrub species of the families Melas-

Treatment	Number of Individuals/192m²	Number of Species/192m²	Simpson Index	Shannon-Wiener Index
Calophyllum brasiliense	542	53	0.93	1.36
Terminalia amazonia	393	57	0.93	1.4
Vochysia guatemalensis	603	55	0.88	1.2
Hieronyma alchorneoides	288	48	0.92	1.33
Virola koschnyi	444	60	0.93	1.39
Vochysia ferrugniea	374	49	0.88	1.21
Control	0	0	0	0

Table 1 *Simpson and Shannon-Wiener diversity indices for plantations species. Data from the three sites is included.*

tomataceae, Piperaceae and/or Rubiaceae. However, 13% of the regeneration across all sites was natural regeneration from seed of the planted timber species.

Discussion

Previous studies of understory regeneration in the humid lowlands of the Neotropics have typically compared understory regeneration on plantations at a single site within a biological reserve (Carnevale & Montagnini 2002, Guariguata et al. 1995, Montagnini 2000, Powers et al. 1997). The present research attempted to examine trends across three sites planted with the same six timber species. The strongest trend found across all sites, corroborated by previous studies, was the success of plantations at recruiting understory regeneration in comparison to abandoned pasturelands. Among plantations in the present research site, planted species was significantly correlated to understory regeneration. Although the effect of planted species on understory regeneration was significant, individual species' performance was most influenced by the plantation site. The interaction effect of site and planted species was more significant than the influence of the planted species alone, and equal to that of site.

Unlike previous studies conducted at a single site, no single timber species emerged as the most successful for recruiting understory regeneration among the three sites of this research. Results from the experimental plantations, nearest to continuous forest and on uniformly flat terrain, did not match results from private plantations. Private plantations at two sites also exhibited different trends in species performance. Therefore, experimental plantations such as those at La Selva Biological Station cannot necessarily predict patterns of regeneration elsewhere, even at similar sites within the humid lowland tropics.

Despite the lack of an overarching trend, there was at least one species that was most successful for recruiting understory regeneration at each site. At La Selva, *Vochysia guatemalensis* and *Calophyllum brasiliense* had the greatest abundance of understory regeneration, both for total numbers and by height classes. At La Selva, differences in soil and slope were systematically blocked out in the original experimental design. In the two private farms, the original plantation design was not fully randomized with respect to slope and soil characteristics. The thinning regime at La Selva was also probably more precise and more evenly applied than in the two farms.

At the Paniagua plantations *Terminalia amazonia* was the most successful species for total understory regeneration and in the three height class. At the Quesada plantations *Vochysia ferruginea* was the most successful species overall and in two of the height classes. At both farmers' sites, plantations of each timber species were scattered across irregularly undulating terrain (although plots used in this research were randomized). One explanation for the variation in plantation understory abundance between sites is this irregularity of planting and terrain at the two farms. At the Paniagua plantation, *T. amazonia* was planted on flatter, better drained soils than some of the other species. *T. amazonia* also had an intermediate spacing regime relative to plantations of other species at the site. At the Quesada plantation, slope and spacing were more uniform than at the Paniagua plantation. However, plots of *C. brasiliense* and *V. guatemalensis,* which were most successful at La Selva, were uniformly located on sites with poorer drainage than other species at the Quesada plantation. Differences in slope, soil drainage, and incident light (due to spacing) might explain the lack of trends in understory regeneration among plantations across sites.

The present research highlights the importance of site conditions and thinning regimes for promoting understory regeneration of woody species on tropical plantations. While planted plots species had greater understory diversity than unplanted pastures, success of particular timber species at recruiting understory regeneration was strongly associated with site. A closer examination of the interaction between site conditions (such as soil and terrain), planted species and understory regeneration would improve our understanding of forest successional processes on plantations across sites in the humid lowland tropics.

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References

Ashton, M., Gunatilleke, C., Singhakumara, B. and I. Gunatilleke. 2001. Restoration pathways for rain forest in southwest Sri Lanka: a review of concepts and models. *For. Ecol. Manage.* 525: 1-23.

Carnevale, N. and F. Montagnini. 2002. Facilitating regeneration of secondary forests with the use of mixed and pure plantations of indigenous tree species. *For. Ecol. Manage.* 163: 217-227.

Grubb, P.J. 1995. Mineral nutrients and soil fertility in tropical rainforests. Pp. 308-330 In *Tropical Forests: Management and Ecology*, A. E. Lugo and C. Lowe (eds.), Springer-Verlag, New York.

Guariguata, M., Rheingans, R. and F. Montagnini. 1995. Early woody invasion under tree plantations in Costa Rica: Implications for forest restoration. *Restoration Ecol.* 3: 52-260.

Haggar, J., Wightman, K. and R. Fisher. 1997. The potential of plantations to foster woody regeneration within a deforested landscape in lowland Costa Rica. *For. Ecol. Manage.* 99:55-64.

Keenan, R., Lamb, K., Parrotta, J. and J. Kikkawa. 1999. Ecosystem management in tropical timber plantations: satisfying economic, conservation, and social objectives. *J. Sustainable For.* 9, 117-134.

Keenan, R., Lamb, D., Woldring, O., Irvine, T.. and R. Jensen. 1997. Restoration of plant biodiversity beneath tropical tree plantations in northern Australia. *For. Ecol. Manage.* 99: 117-131.

Kuusipalo, J., Goran, A., Jafarsidik, Y., Otsamo, A., Tuomela, K. and R. Vuokko. 1995. Restoration of natural vegetation in degraded *Imperata cylindrica* grassland: understory development in forest plantations. *J. Veg. Sci.* 6: 205-210.

Lugo, A.E. 1997. The apparent paradox of reestablishing species richness on degraded lands with tree monocultures. *For. Ecol. Manage.* 99: 9-19.

Montagnini, F. 2000. Strategies for the recovery of biodiversity in deforested landscapes. Pp. 310-319 In *Forests and Society: the role of research*, Krishnapullay, B., Soepadmo, E., Arshad, M., Wong, A., Appanah, S., Wan Chik, S., Manokaran, N., Tong, H. and Choon, K. (eds.). IUFRO World Congress, Aug. 6-12, 2000. Sub-plenary Sessions, Volume 1. International Union of Forestry Research Organizations. Kuala Lumpur, Malaysia..

Montagnini, F. 2001. Strategies for the recovery of degraded ecosystems: experiences from Latin America. *Interciencia* 26: 498-503.

Parrotta, J., Turnbull, J. and N. Jones. 1997. Catalyzing native forest regeneration on degraded tropical lands. *For. Ecol. Manage.* 99: 1-7.

Parrotta, J. 1992. The role of plantation forests in rehabilitating degraded tropical ecosystems. *Agriculture,Ecosystems and Environment* 41, 115-133.

Piotto, D., Montagnini, F., Ugalde, L. and M. Kanninen. 2003. Performance of forest plantations in small and medium-sized farms in the Atlantic lowlands of Costa Rica. *For. Ecol. Manage.*, in press.

Powers, J.S., Haggar, J.P. and R.F. Fisher. 1997. The effect of overstory composition on understory woody regeneration and species richness in seven year old plantations in Costa Rica. *For. Ecol. Manage.* 99: 43-54.

From James Castner, 1990. *Rainforests: A Guide to Research and Tourist Facilities at Selected Tropical Forest Sites in Central and South America*. Gainesville, Florida: Feline Press.

Implications of a strong El Niño-associated drought across three lowland mixed dipterocarp forest types on dipterocarp seedling survivorship in Indonesian Borneo

Kabir Peay, MESc 2003

Introduction

Rare or extreme events are often disproportionately important in the historical development of ecosystems (Gaines & Denny 1993). In both the neo- and paleo-tropics extreme drought events associated with the El Niño Southern Oscillation (ENSO) act as important phenological cues (Wright et al. 1999, Curran & Leighton 2000, Curran & Webb 2000). Although ENSO events have occurred for at least 200,000 years (Tudhope et al. 2001) recent studies suggest that their frequency and intensity may be increasing (Salafsky 1998, Timmerman et al. 1999). Land use and land-cover change have exacerbated the local effects of ENSO, leading to large-scale wildfires and forest decline in both Indonesian Borneo and the Amazon (Jipp et al. 1998, Cochrane et al. 1999, Curran et al. 1999, Siegert et al. 2001).

Trees of the family Dipterocarpaceae dominate the canopy of lowland Bornean forests. In lowland forests at the Gunung Palung National Park (GPNP), Dipterocarpaceae account for 61% of the basal area in alluvium, 63% in sandstone and 79% in lowland granite (from Figure 2 in Curran & Leighton 2000), and can commonly account for approximately 50% of basal area and 80% of emergent trees in other Bornean lowland forests (Ashton 1992, Fatawi & Mori 2000). Ashton (1992) has suggested that supra-annual drought is an important bottleneck for seedling establishment and strongly influences species composition and habitat associations in Bornean mixed-dipterocarp forests (MDF). Thus, increasing drought frequency and intensity could precipitate large-scale changes in the dipterocarp community composition of even undisturbed Bornean forests (see also Curran 1999).

Although distinct habitat associations between sympatric dipterocarps have been well documented within the GPNP (Curran & Leighton 2000; Paoli unpublished data), the mechanisms maintaining these distinct communities are still poorly understood. While Ashton (1992) suggested drought affects community composition, annual monitoring of soil moisture content in Gunung Palung National Park from May 2000 to August 2001 showed no significant differences in soil moisture status between three distinct dipterocarp communities (Paoli, unpublished data). Due to their infrequent nature, extreme drought events, especially on ENSO cycles, are difficult to observe and thus, understudied in ecology. Here we were able to document the relationships between canopy structure and soil moisture content in three distinct dipterocarp communtities occuring on alluvium, sandstone and lowland granite soils during a relatively severe ENSO associated drought. The results are interpreted in light of their possible significance in causing differential seedling mortality and thus, altering forest community composition.

Methodology

This study was conducted in the Gunung Palung National Park (GPNP; 90,000 ha; 1°00'-1°20' S, 109°-110°25' E) in the province of West Kalimantan (146,760 km^2; Indonesian Borneo; Figure 1). Measurements were taken from July 7-9 near the end of a 14-day drought event during the 2002-2003 ENSO. Soil moisture and canopy structure measurements were obtained in a total

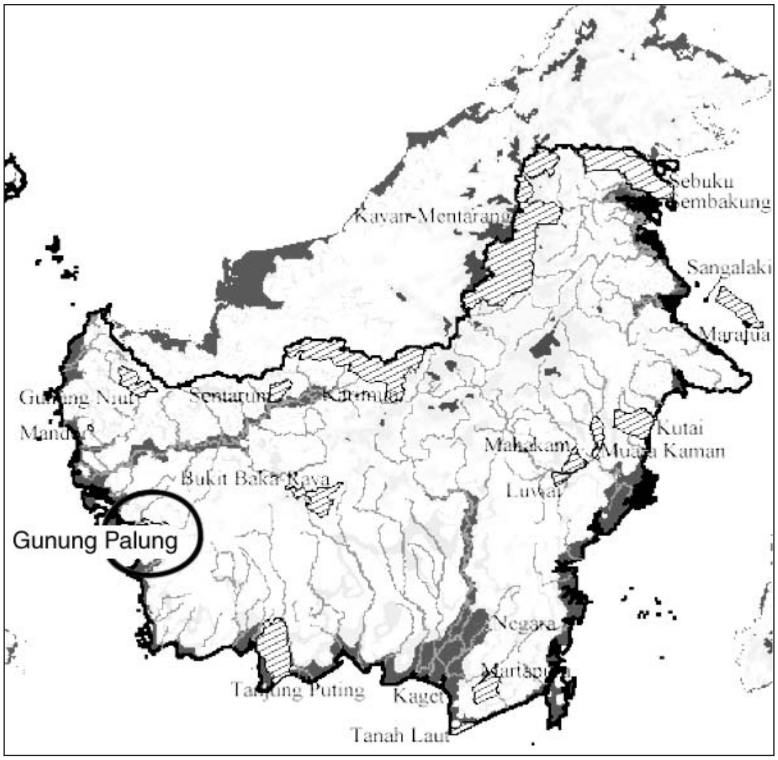

Figure 1 *National Parks of Indonesian Borneo (Gunung Palung).*

of 29 plots 30 m x 30 m (0.07 ha) located on three distinct soil types: alluvial bench (n = 10), sandstone (n = 8), and lowland granite (n = 11).

Based on annual plot measurements mean diameter at breast height (DBH) across plots was 27.9 ± 1.4 cm in alluvial bench (A), 25.4 ± 1.4 cm in sandstone (S) and 26.5 ± 1.1 cm in granite (G). Mean number of stems (dbh ≥ 10 cm) per plot did not differ significantly: 37.4 ± 2.1 (A), 40.25 ± 1.7 (S) and 41.6 ± 1.6 (G) nor did mean basal area per plot: 3.71 ± 0.33 m2 (A); 3.78 ± 0.31 m^2 (S); and 3.78 ± 0.32 m^2 (G). Litterfall (mg ha^{-1} $yr.^{-1}$) was 4.5 ± 0.17 (A), 4.0 ± 0.22 (S) and 3.9 ± 0.08 (G).

Soil moisture was estimated by measuring soil conductivity with a Dynamax Theta-Probe©. Based on soil conductivity, dielectric content of the soil was converted to volumetric water content (m^3/m^3) on a linear calibration curve. Measurements were made at three standardized locations within each plot: the center, northwest, and southeast litter traps. Because variability in soil moisture content measurement is reduced in mineral versus organic soil, we removed the top layer of organic soil and exposed the mineral layer before probe insertion. The organic layer was generally < 5 cm in depth.

Canopy structure was estimated using digital hemispherical photographs (Figure 2a and 2b). Hemispherical photographs were taken in each plot using a Nikon 990 digital camera equipped with a fisheye lens and affixed to a self-leveling mount (Delta-T Devices) with LED lights to mark the compass bearing of the photo. Due to time constraints, only one sample was taken at the center of each plot. For each photograph, we ensured that the mount was level and LED positioned facing magnetic north. Time, date, plot location, and JPG file name were recorded for each photograph and later downloaded to Hemiview software (Delta-T Devices). Photos were oriented in Hemiview (v. 2.1) and the longitude and latitude of Gunung Palung National Park used to calibrate calculated indices of canopy structure and solar radiation.

Statistical analysis was conducted using SAS (v 8.02) and SYSTAT (v 10). An Analysis of Variance (ANOVA) model was built using plot data on soil moisture, canopy structure, and soil type as well as annual plot level data on basal area, relative growth rate, number of stems and litterfall.

Results

Average soil moisture content across the three soil types was 0.23 ± 0.01 m^3/m^3 (A); 0.18 ± 0.012 m^3/m^3 (S); and 0.14 ± 0.014 m^3/m^3 (G) (Figure 3). Differences between least squares means were significant for all soil type comparisons of mean soil moisture content ($p < 0.01$). Leaf Area Index (LAI), measured as 50% of the leaf area per unit ground area, was 3.1 ± 0.12 (A); 3.2 ± 0.17 (G); and 2.9 ± 0.14 (S). Percent visible sky, a measure of canopy openness, was 6.1 ± 0.3%

Figure 2a *Hemispherical photograph of canopy.*

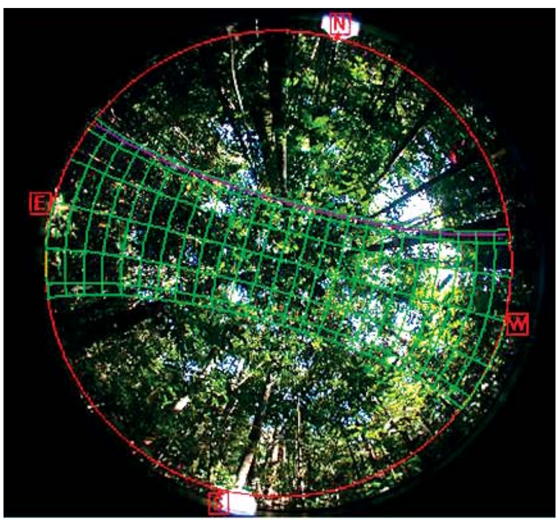

Figure 2b *Hemispherical photograph from Sandstone AT-3 (top) and with Granite AT-9 (bottom) with solar trajectory imposed (Annual = Green, Daily for July 8 = Pink).*

(A); 6.3 ± 0.2% (G); and 5.4 ± 0.3% (S). Residuals were normally distributed and Tukey's pairwise comparisons indicated that there were no significant differences between canopy structure measures between soil types ($p > 0.10$).

ANOVA results indicated that soil type was the best predictor of soil moisture levels ($r^2 = 0.55$, f_2, 14.96, $p < 0.0001$). If soil type was included in the ANOVA model, no other measured parameters were significant predictors of soil moisture content. If soil type was excluded from the model, litterfall was the next best predictor of soil moisture content ($r^2 = 0.25$, f_1, 8.69, $p = 0.0067$). None of the measures of canopy structure calculated from hemispherical photographs, percent visible sky ($p = 0.49$) and leaf area index ($p = 0.86$), were significant predictors of soil moisture content.

Discussion

Our measurements, made during a drought associated with the onset of an ENSO event, suggest that differences in soil moisture content may not be observed in typical or average years, but do develop during extreme droughts. These extreme droughts are experienced differentially by soil substrate (Granite > sandstone > alluvium) and thus, the communities found on these substrates. The lack of differences between gross canopy structure, (i.e., leaf area index and percent visible sky), suggest that these results are due to inherent differences in soil substrate quality rather than differences in the degree of exposure. However, the positive correlation between litterfall and soil moisture levels ($r^2 = 0.25$) suggests that soil insulation may play a role in our results.

Interestingly, some of the vegetation and stand demographic indicators that might be thought to influence soil moisture content, number of stems and basal area, were unimportant as predictors of soil moisture status. While this does suggest that our results were not simply an artifact of plot stocking, it does not rule out the possibility that observed differences in soil moisture content were caused by differential species-specific abilities at removing water from the soil matrix, rather than inherent soil properties. These results require further investigation. Moreover, the lack of correlation between soil moisture content and relative growth rate, an indicator of site quality, suggests that soil moisture limitation over a two-week period is not generally a limiting factor for stem growth (> 1 cm dbh). Rather, it suggests that occasional drought events

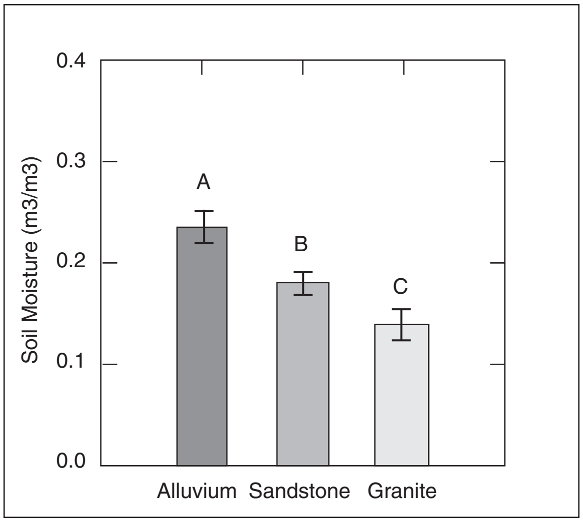

Figure 3 *Mean soil moisture content by soil type (bars ± SE). Letters indicate grouping by statistical significance.*

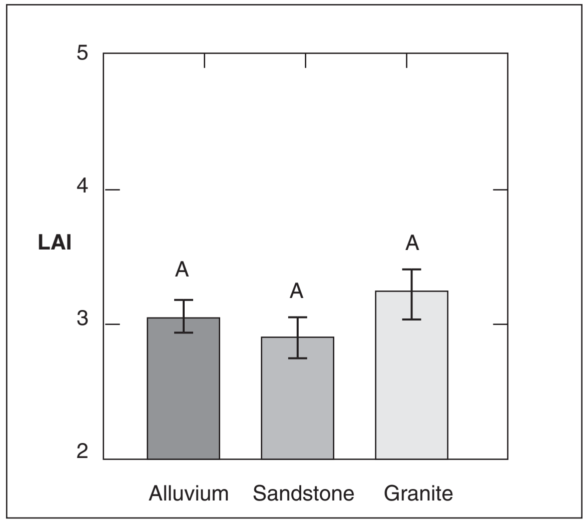

Figure 4 *Mean leaf area index by soil type (bars ± SE). Letters indicate grouping by statistical significance.*

are important sources of mortality for establishing shallowly-rooted seedlings and possibly adults as well.

While vertebrate seed predation has been established as a critical first barrier to dipterocarp seedling establishment (Curran & Leighton 2000, Curran & Webb 2000) drought induced mortality seems to be the primary for bottleneck for seedling recruitment. Canopy dipterocarp seedlings may be suppressed in the understory for decades (Delissio et al. 2002) which means that they will have likely experience strong ENSO-associated droughts. Droughts have been shown to cause significant increases in seedling mortality (Ito et al. 2000, Hammermil & Newbery, in review). These extreme droughts may represent one of the major recruitment bottlenecks that would create or maintain distinctive floral community assemblages on alluvium, sandstone and granite substrate habitats.

While mast fruiting may have evolved to minimize seed predation, ENSO events have been occurring on the order of 200,000 years (Tudhope et al. 2001) and it is interesting to speculate about what evolutionary adaptations may have evolved to cope with drought stress.

Our results suggest that the distinct dipterocarp species complements found on alluvial, sandstone, and granite soils may represent the tradeoffs in resistance to drought and nutrient use efficiency (Paoli, unpublished data). Additional field research is required to confirm the relationships and quantify the postulated drought mechanism for affecting dipterocarp community composition suggested by our results. While we have observed differences in soil moisture content, these differences require testing for ecologically significant shifts in seedling mortality.

Future research should attempt to establish soil moisture retention curves for each of the three soil types and also perform direct tests of drought tolerance in the dipterocarp seedlings for species from each soil type. Also, long-term patterns of rainfall (17 years) within the GPNP site must be examined for the length and frequency of drought events to place our measurements in context and to determine whether such two-week periods without rainfall are increasing. Quantifying the numbers of such severe drought events and the periodicity would assist in assessing the relative evolutionary and anthropogenic significance of the 2002 event.

If drought tolerance is a recruitment barrier for dipterocarp species, as our results suggest, synergies between current logging practices and global climate change may induce greater than expected shifts in the tree communities of Bornean rainforests. The massive fires in Indonesian Borneo during the 1998 ENSO have been linked to changes in land use and land cover (Siegert et al. 2001, Page et al. 2002) through changes to forest structure (Cochrane et al. 1999). GPNP and the surrounding 10 km matrix buffer has lost considerable forest cover since 1988 (Curran et al., in press). Our results suggest that even if degraded forests are spared from wildfire, changes in environmental conditions may lead to long-term changes in community composition.

Acknowledgments

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References

Ashton, P. S.1992. The structure and dynamics of tropical rain forest in relation to tree species richness.Pp. 53-64 In *The Ecology and Silviculture of Mixed-Species Forests*, M. J. Kelty,B. Larson and C. Oliver (ed.) Boston, Kulwer Academic Publishers.

Cochrane, M., Alencar, A., Shulze, M.D., Souza Jr., C.M., Nepstad, D., Lefebvre, P. and E. A. Davidson. 1999. Positive feedbacks in the fire dynamic of closed canopy tropical forests. *Science* 284:1832-1835.

Curran, L., Caniago, M.I., Paoli, G.D., Astianti, D., Kusneti, M., Leighton, M., Nirarita, C.E. and H. Haeruman.1999. Impact of El Nino and logging on canopy tree recruitment in Borneo. *Science* 286:2184-2188.

Curran, L. M. and M. Leighton. 2000. Vertebrate responses to spatiotemporal variation in seed production of mast-fruiting dipterocarpaceae. *Ecological Monographs* 70:101-128.

Curran, L. M. and C. O. Webb. 2000. Experimental test of the spatiotemporal scale scale of seed predation in mast fruiting dipterocarpaceae. *Ecological Monographs* 70:129.

Delissio, L. J., Primack, R.B., Hall, P. and H. S. Lee. 2002. A decade of canopy-tree seedling survival and growth in two Bornean rain forests: Persistence and recovery from suppression. *Journal of Tropical Ecology* 18:645-658.

Fatawi, M. and T. Mori. 2000. Description of Forests and Forestry in East Kalimantan. Pp. 3-12 In *Rainforest Ecosystems of East Kalimantan: El Nino, Drought, Fire and Human Impacts*, S. Ohta (ed.). Springer, New York.

Gaines, S.and M. Denny. 1993. The largest, smallest, highest, lowest, longest and shortest: extremes in ecology. *Ecology* 74:1677-1692.

Hammermil, A. and Newbery. (In review). Effect of drought on trees in lowland Dipterocarp forest at Danum, Sabah, Malaysia.

Ito, S., Nishiyama, Y. and W. Kustiawan. 2000. Responses of Dipterocarp seedlings to drought stress. Pp. 143-151. In *Rainforest Ecosystems of East Kalimantan: El Nino, Drought, Fire and Human Impacts*. S. Ohta (ed.). Springer, New York.

Jipp, P. H., Nepstad, D. and C. R. D. Carvalho. 1998. Deep soil moisture storage and transpiration in forests and pastures of seasonally dry amazonia. *Climatic Change* 39:395-412.

Page, S. E., Siegert, F., Rieley, J.O., Boehm, H.D.V., Jaya, A. and S. Limin. 2002. The amount of carbon released from peat and forest fires in Indonesia during 1997. *Nature* 420:61-65.

Paoli, G. 2001. *The role of growth-strategy trade-offs in structuring the community composition of rain forest canopy trees in a heterogeneous environment*. University of Michigan, Ann Arbor.

Salafsky, N. 1998. Drought in the Rain Forest, Part II: An Update Based on the 1994 ENSO Event. *Climatic Change* 39:601-603.

Siegert, F., Rueckert, G., Hinrichs, G. and A. Hoffman. 2001. Increased fire impacts in logged over forests during El Nino driven fires. *Nature* 414: 437.

Timmerman, A., Oberhuber, J., Bacher, A., Esch, M., Latif, M. and E. Roeckner.1999. Increased El Nino frequency in a climate model forced by future greenhouse warming. *Nature* 395:694-697.

Tudhope, A. W., Chilcott, C.P. and M. T. McCulloch. 2001. Variability in the El Nino-Southern Oscillation through a glacial-interglacial cycle. *Science* 291:1511-1517.

Wright, J. S., Carrasco, C., Calderon, O. and S. Paton. 1999. The El Nino southern oscillation, variable fruit production, and famine in a tropical forest. *Ecology* 80:1632.

Heliconia uaupensis on Rio Uauprés, Brazil, sketched by Margaret Mee in T. Morrison, ed. 1988. *Margaret Mee: In Search of Flowers of the Amazon Forests.* Nonesuch Expeditions: Suffolk, England.

Species choices for forest plantations with incentives in the southern lowlands of Guatemala: Assessment of past trends and present scenario

Boris Mendez Paiz, MFSc 2003

Background and introduction

Guatemala's forest sector

Guatemala is moderately forested with around 35% forest cover. The forest cover area in 2000 was 2.85 million hectares with an estimated rate of decline between 1.7% and 2.5% annually; the rate of deforestation has been estimated by different sources, ranging from 54,000 to 80,000 ha/year (Schmithulsen & Spinnler 1996, FAO 2002, INAB 2000-2001, PAFG 2001).

Wood is an important source of fuel in Guatemala. A high proportion of the population especially in rural areas use fuelwood as their primary source of energy (for the period 1995-1999, fuelwood use accounted for 97% of the total wood volume). Guatemala produces moderate quantities of sawn-wood, a small proportion of that production is exported. The commercial data for forest products in 2000 reported a negative balance of $140,000,000 mainly due to import of paper and paperboard products (FAO 2002).

Incentives as a forest policy tool

Most Latin American countries today provide incentives for private investment in forestry. The rationale to provide subsidies to plantations are summarize by Keipi (1997) as follows:

1. Modify the social bias against forestry investments among farmers who have traditionally considered forests as an obstacle to agricultural development.
2. Increase the rates of return on investments that may have a relatively low private profitability but offer external benefits for society as a whole.
3. Reduce risk and uncertainty that arise particularly from the long time period of reforestation returns.
4. Reduce cash flow problems during the often long periods required to recover planting and operational costs through harvest income.
5. Establish a critical mass of plantations needed for the initial building of competitive forest industries.

Forest incentives for plantations in Guatemala

In 1974, the Government of Guatemala launched the Forest Tax Incentives program to promote forest plantations through income tax reduction, provided the users invest the money in the establishment of forest plantations. By 1996, 20,000 hectares were planted at an annual rate of 1000 hectares and with a total investment of US$33.8 million (Instituto Nacional de Bosques 2000-2001).

In 1996 the current forest law was approved, which created a new Forest Service. The law replaced the income tax reduction program with a grant program. 1 % of the government's total budget was set aside with the specific purpose of promoting the cultivation of forests through plantations and management of natural forests (INAB 1997, CATIE 1994).

The change allowed an expansion of the range of potential beneficiaries, including small holders, local government (municipalities), associations of producers and individual landowners. As a result the average of new forests established yearly in the first four years under the new program increased five times in relation with the previous period and it is expected to continue growing (INAB 2000-

2001). During the first four years of the new grant program 21,500 hectares have been planted. The main species planted, for example *Tectona grandis, Gmelina arborea, Eucalyptus spp.* are all exotic species. Currently there is a growing interest to plant native hardwood species and pine species.

Plantations with incentives in the southern lowlands of Guatemala

For administrative purposes the country is divided into nine regions by the Forest Service. Region number nine includes the Pacific or Southern Coast of Guatemala. This is the most important region in terms of agricultural production, and as a result the region has lost almost all of its original forest cover. Plantations could be a suitable land use option in this region, considering the favorable soil and climatic conditions that enhance fast timber production; availability of adequate infrastructure to promote industry; labor availability; and proximity to the capital of the country (main national market) and to seaports.

Incentives could promote the expansion of forest cover in the Southern Coast of Guatemala in such a way that it could play an important role in regional economy, contributing significantly to diversify exports, providing new employment. The aim of my research is to describe the tendencies of forest plantations established in the Southern Coast of Guatemala through new forest incentives during its 4 initial years, between 1996 and 2000, as a means of understanding the effectiveness of this policy tool for this region. Research of this type study is crucial to help facilitate the economic growth of the region based on plantation forestry.

Site description: the southern coastal lowlands

The Guatemalan Forest Service designed a methodology to assess the potential of land for forestry use throughout the country. As part of this methodology, the territory is divided into "natural regions" integrating different criteria that include geology, topographic, climatic and edaphic factors and the influence that these factors have on the productive capacity of the land (INAB website: Guatemalan Forest Service 2002). My research was carried out in two of the seven natural regions of Guatemala: the "Lands of the Pacific Coastal Plain" and the "Piedmont Volcanic Lands".

The Lands of the Pacific Coastal Plain cover a strip that goes eastward from the border with Mexico to the border with El Salvador and northward from the Pacific Ocean to a northern limit defined by beginning of an undulating landscape. Its characteristics include gentle slopes and geology composed by quaternary alluviums. The predominant land uses are perennial agricultural crops such as sugar cane, rubber, African palm and pastures for cattle grazing. The altitude range is 0-250 m asl.

The Piedmont Volcanic Lands are a strip parallel to the Pacific Coastal Plain with elevations ranging from around 200-1200 m asl. This region represents a transition zone between the southern lowlands and the highlands located on the Sierra Madre chain. Its geology includes pyroclastic materials from the quaternary. The climate of this zone is defined by high amounts of precipitation and cooler temperatures as compared with the Pacific Coastal Plain, but warmer than those of the highlands. A large part of this zone has permanent agricultural crops such as coffee, rubber and cardamom.

The Southern Lowlands of Guatemala fall into two of the Holdridge System of Life Zones (De la Cruz 1982). The first is wet subtropical forest (warm) that matches the natural region of the Pacific Coastal Plain with an average rainfall between 1200 and 2000 mm/year and average temperature of 27°C. The second life zone is very humid subtropical forest (warm) with average precipitation ranging from 2,100 to 4,300 mm/year and average temperature ranging from 21 to 25°C.

Methodology

The field phase of this research was conducted in Guatemala. Information was collected from the files of the Forest Service, located in Guatemala City, including a review of the statistics compiled in the annual reports of the Forest Service. Interviews were conducted with forest service officers in charge of the Forest Incentives Program, as well as those from the Seed Bank and other programs linked to Forest Incentives and Forest Management.

To identify the species preferences and the performance of plantations during their initial stages I conducted a set of visits to projects with incentives in the Southern Coast. There I interviewed landowners, forestry professionals and Forest Service officials. From a list of 60 approved and running projects of plantations with incentives in the Region, the researcher visited twelve. Focus was placed on looking for a representative sample which included all of the main species as well as different levels of success with plantations and different ownership regimes.

Results

Forest law

The Guatemalan forest law, approved on December of 1996 established the current Forest Incentives Program. The Program was defined for twenty years, starting in 1997 and provides support to landowners for the first six years of plantations. The incentive will be awarded to the owners of land with potential for forest production. Landowners must plant a minimum of two hectares. The costs per hectare are determined by the Forest Service every year and vary depending on the region of the country and the species considered. National goals for the period of the program (20 years from 1997 to 2016) are to establish 285,000 ha of new plantations and to incorporate sustainable management of 650,000 ha of natural forest.

After completing the first four years of the program a total of 19,500 ha has been planted (an average of 4875 ha/year) and 21,000 ha of natural forest incorporated into some form of management with incentives (an average of 5250 ha/ year). There are several reasons why this is a smaller area than hoped; these reasons include:

1. There are insufficient funds to support the program. The proposed allocation of 1% of the national budget for forest plantations has never been entirely used for forest incentives.
2. At the beginning of the program, interest by the landowners was rather low; but it continues to grow.
3. Apparently the forest incentives do not cover the total cost to a landowner of starting a plantation. Even though it is possible to get loans to invest in plantations, most of landowners are afraid to pay high rate of interest (18% as an average for loans) even for such a short period of one year. Paper work to get a loan is not easy.
4. Political instability in the country had affected the image of the Forest Service (Paiz, pers. comm. 2002).

Regional priorities

The criteria to define priority regions was set by the Forest Service in the Forest Incentives annual program five year plan (INAB-PAFG 2001). These criteria are given below:

1. Factors affecting the establishment and growth of plantations: surfaces with suitable forest productive lands and suitable to be planted
2. Climatic conditions: looking at those sites with the highest average rainfall and the shortest dry season.
3. Factors affecting management, marketing and sale of timber: surfaces with already established plantations, distance to main markets, distance to ports, accessibility, road density.

In this context, the priority zones are provinces of Peten, Izabal (both located in the northern lowlands of the country), Alta Verapaz and Baja Verapaz (located mainly in the highlands but with some parts in the northern lowlands) and the Pacific coast provinces of Escuintla, Retalhuleu and Suchitepequez, located in the southern lowlands of Guatemala. The latter, constitutes the region number nine, which is the area assessed in this research as shown in Figure 1.

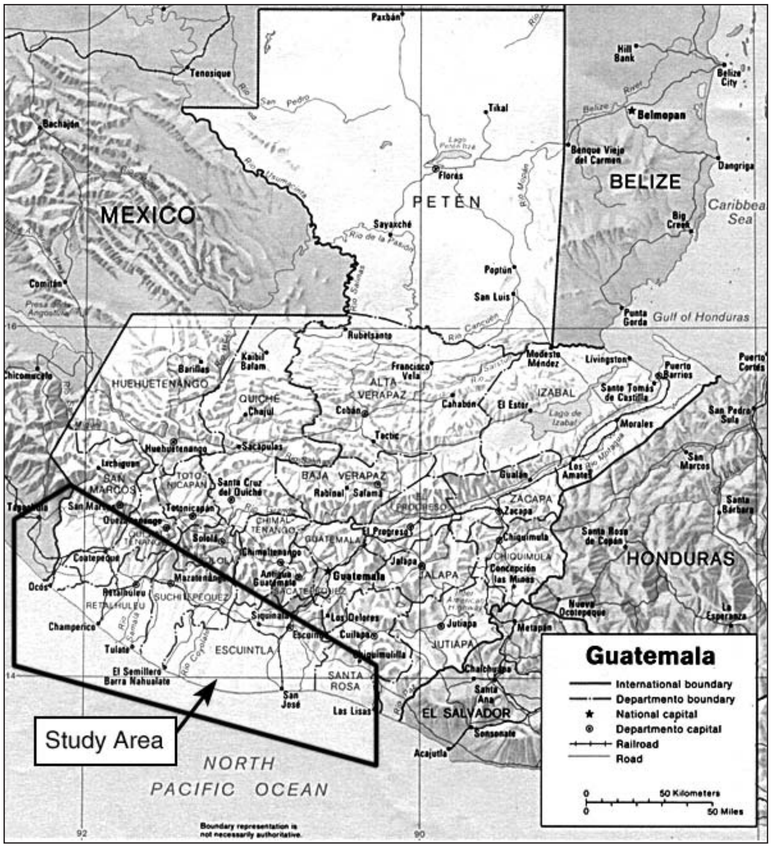

Figure 1 *Map of Guatemala and study site.*

Funding allocation of forest incentives

The Forest Service allocates 80% of the incentives budget to finance the establishment and management of new forests through plantations. The remaining 20% is devoted to finance the management of natural forests. The Forest Service annually allocates 50% of the incentives within these categories for smallholders (properties with less than 15 hectares) and the remaining 50% for projects with larger areas. A total of 12,400 Quetzals (Guatemala's currency) equivalent to approximately US $1,600 is provided per ha as incentive during the establishing period (six years) of plantation. The highest amount is given the first year (40% of total); the amount per year decreases every year.

The rotation period is calculated for each species as a means to allocate resources for different species of plantation trees. The longer the rotation period, the larger the number of years paid as an incentive. The rotation periods are given in Table 1 for the species currently promoted in the southern lowlands. Landowners receive the grants at the end of the current year, based on an assessment of plantations by technical staff of the forest service. Most of landowners finance the balance of the expenses of the plantation without support from banks.

One cost reduction option chosen especially by big landowners is to allow peasants to cultivate crops in alleys between tree rows (usually corn). The landowner gives use-rights to the land for two or three years without charging the farmers any rent; in exchange farmers take care both of corn and tree plants (weeding, fertilizing). Since labor is one of the biggest expenses for tree plantations establishment, this practice allows landowners to avoid loans from a bank or other sources for laborers.

The amount of money given by the state as incentives for plantations has remained the same since the start of the program even though the cost to landowners has risen dramatically in the last three years. One large cost for the landowner

Species	Estimated Rotation Period for Final harvest in years	Number of years benefited with incentives
Roseodendron sp.	More than 20	6
Tectona grandis	More than 20	6
Gmelina arborea	10-15	3
Acrocarpus fraxinifolius	10-15	3
Eucalyptus spp.	6 – 8	1

Table 1 *Estimated rotation period by the Forest Service for different species in the southern lowlands of Guatemala.*

is the fee for a professional foresters to provide technical advice. In order to receive forest incentives, landowners must submit documents that prove ownership of the land along with two technical documents: a management plan for plantations and a technical assessment of the suitability of the land for forest use. Although it is mandatory for landowners to hire a forester to prepare these technical documents, it is not obligatory to keep him on during the implementation of projects, which in many cases had lead to serious mistakes being committed in the management of plantations. The role of the forester is critical since they act as linkages between the state (through the Forest Service) and beneficiaries from the incentives (landowners or companies). The professional foresters usually take between 10-15% of the grant for any project, subject of negotiation between them and landowners. Additionally the Forest Service takes another 10% of the grant to cover the administrative duties involved with projects. Some incentive grant recipients suggest a periodic revision of the incentives to compensate for the raising costs of establishment for plantations is warranted.

	Plantations		Management of natural forests	
	# Projects	**Surface (ha)**	**# Projects**	**Surface (ha)**
Total				
Small (< 15 ha)	19	128.7	2	13.35
Large	35	1,327	4	2,918.70
Total	54	1,455.70	6	2932

Table 2 *Summary of plantations by type of incentives and size of properties for the southern lowlands of Guatemala during the first 4 years of the program (1997-2000).*

Plantations established through incentives in the southern lowlands

Region 9 includes the whole territory of the departamentos (administrative divisions of the country) of Escuintla, Suchitepequez, and Retalhuleu as well as the lower elevation municipios (counties) of the departamentos of Quetzaltenango and San Marcos (see Figure 1). This region covers almost all the Pacific lowlands of the country.

Plantations represented 90% of the number of projects approved for the Region, covering only 33% of the land area included for incentives. Thus, managed natural forests represented 10% of the number of projects, covering 67% of the areas covered by incentive programs. Yet plantation projects received 98% of the total amount of money granted by government during this period for the region. Small holders (landowners with less than 15 ha per project) received only 9% of the funds provided during this period in the region, large property owners received 91% (see Table 2).

At the national level, plantations established through the incentive program for the same period of analysis covered 18,129 ha; the southern lowlands contributed with 8% of the national plantations.

Species Selection

Any tree species was eligible for use in plantations during the initial four years of the program. Now the Forest Service is restricting incentives to a limited number of species in order to gain economies of scale to make plantations more attractive for industrial investments in the future. Priorities species are those with an already established market, proper performance in the field and with enough silvicultural information to support their management. Proposed priority species for the southern lowlands include: *Cibistax donnells-smithii, Tectona grandis, Gmelina arborea* and *Pinus caribaea*. Hardwoods species which require more silvicultural study before being listed as priority species include: *Cedrella* spp, *Swietenia* spp, *Pseudobombax ellipticum, Cordia dodecandra, Pithecolobium arborea, Genipa americana* and *Shyzolobium parahyba*. See Table 3 for a summary of species selection for plantations.

#	Scientifc Name	Common Name	Origin[1]	Hectares Planted	Number of Projects
1	*Eucalyptus camaldulensis* Dehnh	Eucalipto	Exotic	455.2	22
2	*Tectona grandis* L.f.	Teca	Exotic	201.3	22
3	*Acrocarpus fraxinifolius* Arn	Cedro de India	Exotic	175.8	11
4	*Pinus oocarpa* Schiede	Pino colorado	Exotic	118.9	3
5	*Roseodendron donnell-smithii* (Rose) Miranda[2]	Palo blanco	Native	106	13
6	*Cupressus lusitanica* Miller	Cipres	Native	84.2	5
7	*Euclyptus torelliana* F. Muell.	Eucalipto	Exotic	66.5	5
8	*Gmelina arborea* Roxb	Melina	Exotic	60.9	7
9	*Swietenia humilis* Zuccarini	Caoba	Native	45.5	8
10	*Cedrela mexicana* M. Roem[3]	Cedro	Native	27.5	8
11	*Tabebuia rosea* (Bertol.) DC.	Matilisguate	Native	26.9	5
12	*Terminalia oblonga* (R. et P.) Steud	Volador	Native	17.5	3
13	*Juglans spp.*	Nogal	Native	16	1
14	*Pinus caribaea* Morelet	Pino caribe	Exotic	14.3	1
15	*Pinus maximinoi* H.E. Moore	Pino candelillo	Native	14	1
16	*Sickingia salvadorensis* Standl.	Puntero	Native	6.6	2
17	*Abies guatemalensis* Rehder	Pinabete	Native	5	1
18	*Pterocarpus spp.*	Fabaceae	Native	4.3	1
19	*Ocotea spp.*	Canoj	Exotic	4	1
20	*Aspidosmerma megalocarpon* Muell- Arg.	----	Native	4	1
21	*Caesalpinea velutina* (Britt.&Rose) Standl.	Chaperno	Exotic	0.9	1
			Total	**1455.3**	**122**

Table 3. *Forest plantations established through the Program of Forest Incentives in the southern coast of Guatemala from 1996 to 2000.*

References *Farjon & Styles 1997, Mabberley 1997, Royal Botanic Gardens, Kew 1997, Standley, et al. 1946, field notes 2002.*

Notes:

1 'Exotics' are species planted outside their natural distribution range, although some of these species are found under natural conditions in other ecological or geographical regions of Guatemala.

2 This is the technical name reported by Standley et al. (1946). The Forest Service gives this species the name of *Cibystax Donnell-smithii* (Rose) Seibert. After Standley, Mabberley (1997) considered the genus Roseodendron as Tabebuia.

3 According to Standley (1946), the Central American trees often have been referred to as *Cedrela odorata,* a species of the West Indies and South America, but unknown in Central America.

Seed supply

With some exceptions, in the past, afforestation projects in Guatemala have not been large. The awareness of the importance of quality of the propagation material (seeds and seedlings) for afforestation projects in the country is emerging slowly. With the start of the new forest incentives policy in 1996-97 the demands for forest seed grew exponentially and surpassed the supply capacity of Forest Service seed bank

(BANSEFOR) and the nurseries supported by the Forest Service. In the forest region where I conducted my research, it is evident that an important number of landowners are acquiring seedlings and seeds from private suppliers and not only from the BANEFOR and other Forest Service supported nurseries. In the future it would be valuable to develop quality control protocols to assure that the landowners are provided with high quality seeds

Conclusions

1. The Forest Law (1996) and its derived regulations provide the legal framework for incentives in Guatemala.

2. Plantations established in the Southern Lowlands of Guatemala vary in terms of surface and species choices; most of the plantations medium size (15-90 ha) and all the projects are younger than 5 years. The main species planted during first four years of the program in the region include: *Eucalyptus camaldulensis*, *Acrocarpus fraxinifolius*, *Tectona grandis*, *Gmelina arborea*, *Pinus oocarpa* and *Roseodendron donnell-smithii*; only the latter is native of the region. The first two species are considered inappropriate for plantations due to an ill-defined market and lack of technology to process the wood. The latter four species are now the priority to be planted with incentives.

3. Two types of landowners were identified: those with a strong commitment for sustainable management, viewing the incentives as an important support to establish a new economic activity, and those who are interested in taking advantage of the governmental subsidy, without a clear vision and commitment to long-term forest management.

4. Both the landowners with forest incentives projects and the Forest Service are recognizing the importance of the forest techncian in overseeing the forestry plan.

5. The different seeds banks in Guatemala, including the Forest Service, have supplied the seed for projects, but their supply is insufficient. An increasing amount is coming from abroad.

Policy recommendations

1. Research is needed to test the performance of promising species in the southern lowlands of Guatemala. It could be useful to generate site index curves for these species as a basis for management measures. Mixed species settings and the potential of agroforestry schemes could be explored as alternatives to improve plantations with incentives.

2. It is necessary that the Forest Service strictly enforce regulations for forest incentives. The amount of incentives should remain the same as a way to improve efficiency.

3. The Forest Service must address the supply of high quality seed (both physically and genetically) as a key element when evaluating new and ongoing projects. Closer supervision of all the seed and seedling producers is also required.

4. Forestry professionals must be hired permanently by those projects above 15 hectares as a way to assure a proper advisory and supervision of plantations. Ideally only professionals with a degree in Forestry should be authorized to perform the role foresters.

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References

CATIE. 1994. Revista Forestal Centroamericana 1994. No.7, Año 3, Febrero-Abril. El sector forestal en America Central: el punto de vista oficial, Pp. 29-30.

De La Cruz, J. 1982. Clasificacion de zonas de vida de Guatemala a nivel de reconocimiento. Ministerio de Agricultura, Ganaderia y Alimentacion 42p

Farjon, A. and B.T. Styles. 1997. *Flora Neotropica, Monograph 75, Pinus (Pinaceae)*. Organization for Flora Neotropica, The New York Botanical Garden, New York.

Food and Agricultural Organization of the United Nations (FAO). At http://www.fao.org/forestry/fo/country-menu.jsp?geo_ id= 174&lang_id=1.

Guatemalan National Institute of Statistics. At http://www.segeplan.gob.gt/ine/index.htm

Inter American Development Bank (IADB). 2000. Social Protection for Equity and Growth. Washington, D.C.: Inter American Development Bank.

Instituto Nacional de Bosques (INAB). 2002. Guatemalan Forest Service. At http://www.inab.gob.gt/clasificacion de tierras por capacidad de uso on December 2.

INAB. 2000-2001. Guatemala Forestal, Numero 8, Ano IV. Incentivos para el Desarrollo del Sector Forestal de Guatemala. Guatemala City, Instituto Nacional de Bosques.

INAB. 1998. Normativas de la Ley Forestal: Reglamento de la Ley Forestal, Reglamento de Transito de Productos forestales, Reglamento de Incentivos Fiscales. 25 p.

INAB. 1997. Ley Forestal, Decreto Legislativo Numero 101-96. Ministerio de Agri- cultura, Ganaderia y Alimentacion. 27p.

INAB. No date. Programa de Incentivos Forestales. 2 p.

INAB. No date. Guatemalan Forest Service. Promotional Brochure of the Forest Incentives Program. 2 p.

INAB-PAFG. 2001. Plan Estrategico del Programa de Incentivos Forestales para el quinquenio 2001-2005. Unpublished. 37 p.

Inversiones y Desarrollo de Centroamerica, S.A. 1999. Diagnostico del Cluster Forestal de Guatemala. 52 p.

Keipi, K. 1997. Financing forest plantations in Latin America: Government incentives. At: http://www.fao.org/docrep/w3247e/w3247e0b.htm

Lopez, S. 2002. Personal communication

Mabberley, D.J. 1997. *The Plant-book, a portable dictionary of the vascular plants.* Second edition. Cambridge Univ. press. 858 p.

Ministerio de Agricultura, Ganaderia y Alimentacion.1997. Instituto Nacional de Bosques. Programa Emergente de Incentivos Forestales (PINFOR).

Paiz, M. 2002. Personal communication.

Paiz, M. (No date). Reforestacion y manejo de bosques naturales por incentivos forestales en Guatemala. 4 p.

Plan de Accion Forestal para Guatemala. 2001. Boletin Informativo Mayo-Agosto. FAO.

Royal Botanic Gardens, Kew. 1997. Index Kewensis 2.0 Release on CD-ROM. Oxford University Press.

Schmithulsen, F and F. Spinnler. 1996. Forestry and Deforestation – Country Profile: Guatemala, Population. National Council for Science and the Environment.

Standley, P.C. and J. Steyermark. 1946. *Flora of Guatemala*. Chicago Natural History Museum. Fieldiana Botany v. 24, 13 part.

US International Development Agency (USAID) Guatemala. At http://www.usaid.gov/country/lac/gt/

VELA, L. 2002. Personal communication.

World Bank Website. At http://wbln0018. worldbank.org/external/lac/lac.nsf

Biodiversity research in Blyde River Canyon Nature Reserve: a floristic survey with geo-referenced specimens and its implications for natural resource management

Sarah A. Canham, MESc 2002

Introduction

The Blyde River Canyon Nature Reserve encompasses more than 26,000 hectares of striking landscape along the Drakensberg Escarpment, in Mpumalanga Province, South Africa (see Figure 1). The changes in altitude throughout the reserve result in a diversity of habitat and vegetation types, from grasslands to indigenous forest. As a result, the area has been identified as an important center of endemism in South Africa, with 54 species found nowhere else on Earth. The goal of this project was to use global positioning systems (GPS) to begin intensive quantitative analyses of the vegetation present on the reserve. Spatial distribution of species populations and their ecological relationships within vegetation types were analyzed as well. The data obtained will provide a background of the area's natural history, and assist in future conservation and resource management efforts within the reserve.

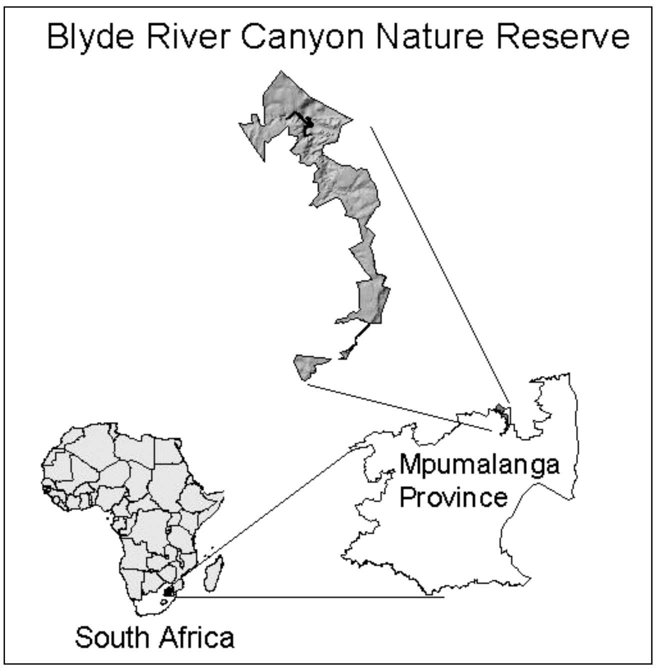

Figure 1 *Study site location.*

Study site

The Blyde River Canyon Nature Reserve is situated along the northern end of the Drakensberg Escarpment, a ridge of quartzite and sandstone that extends for 50 km north-south through the reserve and rises more than 1800 m above the plains, or lowveld, below. The Blyde, Treur, and Ohrigstad Rivers cut through the sedimentary rock, creating the third deepest canyon in the world. Most of the reserve is characterized by flatter areas of North Eastern Mountain Sourveld-type grasslands (meaning, outside of the growing season, the grasses are considered unpalatable for livestock.) The sloped areas of the reserve, along the rocky edge of the escarpment, feature dense, indigenous Afromontane forest (Acocks 1975) (see Figure 2).

Elevations in the reserve can rise as high as 1800 m above sea level, and can be as low as 580 m on the canyon floor and in the lowveld areas (Bronkhorst 2001). Rainfall amounts vary along the escarpment, from 560 mm/year in the northern sections (situated at lower altitudes) to 2700 mm/year in the southern sections. Mean daily temperatures vary as well, from 17-26°C in the northern areas to 10-18°C in the south.

The reserve is classified as being within the Wolkberg Center of Plant Endemism (WCPE), which is characterized by quartzite rock formations such as those comprising the escarpment (White 1984) (Geology influences plant distribution and thus is used to help ascertain boundaries of the Centers of Endemism.) The Blyde River Canyon Nature Reserve comprises only 4.7% of the WPCE, yet contains 54 of the 97 taxa considered endemic or near-endemic to the Center (Lötter et al. 2001). Commercial tree plantations surround most of the reserve, causing establishment of exotic *Pinus* and *Eucalyptus* species within its boundaries. Disturbed areas such as roads and scenic overlooks may also experience invasive species, though this has not been measured quantitatively.

Figure 2 *The layers of sedimentary rock can be seen in this view of the Three Rondavels, a popular tourist attraction in the reserve. In the background is Mariepskop, at a height of 1700m.*

Major families represented on the reserve include Asteraceae, Euphorbiaceae, Fabaceae, and Rubiaceae, with Poaceae (grasses) having the highest number at 178 taxa. There are 414 tree species, with the specific number of shrubs and herbs not yet defined.

Methods

During this first season of quantitative vegetative analyses, the goal was to link plant species populations with their exact locations, using GPS (global positioning systems) to record latitude and longitude. This data had been lacking within the reserve, and was necessary in order to perform more sophisticated and comprehensive analyses (Canham & Beck 2001). Using aerial photographs and topographic maps, and later ground-truthing, areas representative of vegetation types were delineated. These sites were sampled using 50 m grids, in which the presence and abundance of all tree, shrub, herb, and grass species were noted. Several specimens of each species present were identified, collected and preserved using standard herbarium techniques. Attached to each grid square was a real-time coordinate, obtained using rented Omnistar satellite access and Trimble Pro XRS receivers. All information, from genus to soil type, was recorded using the data dictionary option of the receivers (see Figure 3). The submeter accuracy of the Trimble units allowed the creation of precise population maps in Pathfinder GPS software provided with the receivers.

Figure 3 *Recording coordinates in the Cullis section of the reserve, using a Trimble Pro XRS GPS unit. Typical grasses indicative of sourveld vegetation types can be seen, as well as a **Pinus** plantation abutting the reserve edge.*

Results

During the six-week project, over 60 plant taxa and/or populations were geo-referenced in eight different habitats. Several herbarium specimens were made for each taxa, so herbaria in Mpumalanga as well as at Northern Illinois University could have copies for identification and study. No new taxa were discovered, but the efforts made prompted further concentration on improving the database of information regarding the flora of the reserve. Financial support and man power is lacking within the Mpumalanga Parks Board, the authority in charge of the reserve.

As a result, I began to add and merge lists of flora from various collectors, as well as check for multiple entries, misspellings, and outdated names. As of May 2002, 1661 plant taxa were found within the Blyde River Canyon Nature Reserve, including approximately 500 taxa that I personally added to the database. This taxa count comprised 126 species of fern/fern allies, 90 bryophytes, 8 gymnosperms, 425 monocots, and 1012 dicot species. Only 39 exotic species were recorded from the reserve, consisting of 1 fern species, 1 gymnosperm, 10 monocots, and 27 dicot species. Most importantly, the reserve's unique topography has resulted in a high number of endemic or near-endemic plant species found within its bounds (for example, see Figure 4). As stated previously, 54 species exist on the reserve and nowhere else on Earth. This is further evidenced by some taxa having species names of 'laetans,' or Latin for 'joyful,' a translation of the Afrikaans word 'blyde' (Lötter 2001). *Protea laetans* L.E. Davidson, *Ozoroa laetans* Retief, and *Rhoicissus laetans* Retief are all endemic to the Blyde River Canyon Nature Reserve. Lastly, 75 species listed by the IUCN as threatened or endangered are found on the reserve as well (Lötter pers. comm.).

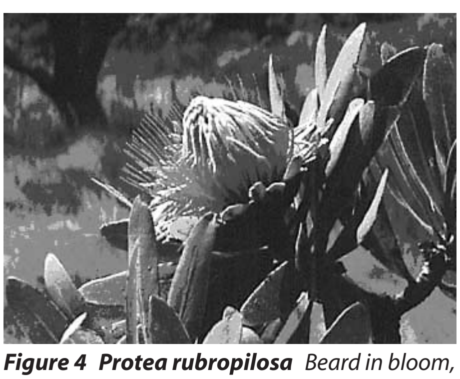

Figure 4 Protea rubropilosa *Beard in bloom, at 1650m above sea level. The species is endemic to the Blyde River Canyon NR.*

Discussion

The Blyde River Canyon Nature Reserve is an important part of the conservation movement within Mpumalanga Province and South Africa as a whole. Southern Africa is considered a "hotspot" for biodiversity, and Mpumalanga plays a role in that by supporting 21% of the region's plant taxa, on only 3% of its surface area (Lötter et al. 2001). The high ratio of endemic to naturalized or exotic plant species in the designated Centres of Plant Endemism within the province proves the value of protecting the area. As Mpumalanga is known as the "forestry province" of South Africa—due to the large-scale commercial forestry it supports—it becomes more necessary to document and catalogue species native to the region. Afforestation with exotic timber species has already resulted in plantations covering over 20% of the Wolkberg Centre of Plant Endemism, which includes a portion of Mpumalanga Province. Yet, areas such as the Blyde River Canyon Nature Reserve are providing protection for endemic species like *Protea*. The use of GPS units to track the populations of such taxa may show that they have a wider or even smaller range than previously thought, which may impact how conservation efforts are carried out. Data acquired from GPS units and associated software could assist in future analyses of ecology, as it relates to vegetative structure. Continued maintenance of an accurate database allows for a variety of statistical applications regarding the flora of the reserve. This first season of research within the Blyde River Canyon Nature Reserve emphasized the importance of endemic species, and how collection of data can help to promote further conservation efforts within the reserve, and beyond to the province and country as well.

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References

Acocks, John P. H. 1975. Veld types of South Africa. *Mem. Bot. Surv. S. Afr.* 40: 1-128.

Bronkhorst, Frick. Protected area management plan for Blyde River Canyon Nature Reserve.

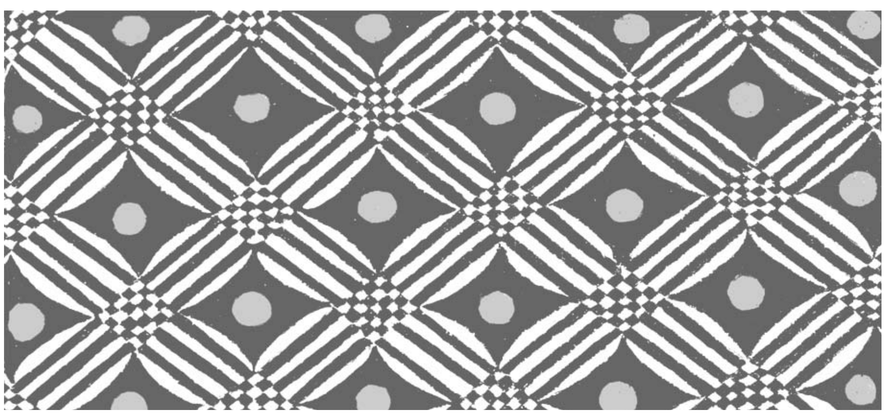
Personal memo. 15 March 2001.

Canham, Sarah A. & Hans T. Beck. Biodiversity research in the Blyde River Canyon Provincial Park, Mpumalanga Province, South Africa: a floristic survey with geo-referenced specimens. Proposal for academic research. 15 February 2001.

Lötter, Mervyn C. Notes on the botanical diversity of Blyde River Canyon Nature Reserve. Personal memo. 6 August 2001.

Lötter, M.C., Burrows, J. & A. Emery. 2001. Phytochoria: centres and regions of endemism.

White, F. 1984. The vegetation of Africa: a descriptive memoir to accompany the UNESCO/AETFAT/UNSO vegetation map of Africa. United Nations International..



Okondo's village, mural painting
Watercolor by James Chapin
Congo Expedition 1909-1915
American Museum of Natural History Library

The capacity of invaded forest to sustain Hawaiian birds: Volcanoes National Park, Hawaii

Nathaniel Carroll, MFS 2003

Introduction

Invasive alien species (IAS) encroachment is one of the greatest threats to Hawaii's native ecosystems (Wilcove 1998). More than 90% of Hawaii's native species are threatened by invasive species (Staples & Crowie 2001, Elmqvist 2000). Accordingly, IAS are also one of the most urgent challenges facing the Hawaiian Islands' natural resource managers (Loope et al. 2001). As an expanding human population and their consumption creates an increasingly fragmented mosaic of land use, we must examine the capacity of disturbed habitats to support biodiversity (Daily et al. 2001).

The process of plant and animal invasion is as complex and variable as the characteristics of the invading organism and host ecosystem. Determining the impacts of IAS and their underlying mechanisms is critical to effective management of native lands and to the preservation of endemic wildlife. While much research has been conducted on the role of predators and diseases in the decline of Hawaiian birds, more information is needed on how invasive plants contribute to the problem (Loope et al. 2001, Vitousek et al. 1997).

This study aims to understand the impacts of invasive plants on avian communities, specifically to detect the change in bird density and the life history characteristics that are affected by the invasion of an ornamental ginger (Kahili ginger, Zingiberaceae: *Hedychium gardnerianum*). With this information we may better gauge the capacity of native Hawaiian forest invaded by Kahili ginger, to sustain endemic Hawaiian bird life and the effects of ginger removal.

It is hypothesized that Kahili ginger invasion will reduce avian density for birds that feed in the understory, while other species less dependent on native fruiting plants in the shrub layer and understory will remain unaffected or possibly be augmented. With specific information on species affected and by what mechanisms, we may better manage Hawaiian forests for bird diversity and forecast the impact of Kahili ginger on the avifaunas of other Pacific islands.

Study species

Kahili Ginger

Many invasive plants tend to favor disturbed sites, but occasionally an alien species thrives in pristine habitat (Elton 1958). These species present an important challenge for the preservation of native flora and fauna. Some plant families such as Zingiberaceae have proven to be effective invaders of Hawaiian native forest (Smith 1985). The ability of non-native, shade-tolerant plants to invade undisturbed forest makes them a particularly significant factor in initial disturbance of intact forest.

Kahili ginger forms monospecific (composed of a single species) understory stands in native forests; likely disrupting native plant regeneration (Warschauer 2002). Its native range is the lower slopes of the Himalayas, India, but it was introduced to almost all the Hawaiian Islands by horticulturalists as an ornamental plant. Ginger was first recorded in the park in the early 1900s, but kept in check (along with native understory plants) by feral pigs. In the early 1970's feral pigs were fenced out of the park and ginger was able to grow unchecked (Zimmer 2002). Its potential range of invasion in Hawaii is great, including essentially all wet habitats below 1,700 m asl. (Smith 1985). Kahili ginger can invade both disturbed and undisturbed areas in Hawaii and is able to establish and thrive in sites with 100% canopy cover, and forms vast, dense colonies, possibly suppressing recruitment of native trees and causing displacement of native shrubs. The ginger propagates by stolons (underground branches that produce new plants), through seeds dispersed by frugivorous birds, and by human plantings. Complete eradication of Kahili ginger stands is difficult and usually requires a combination of mechanical removal and an herbicide called Escort® (DuPont™) sprayed on root stumps.

Forest Birds

Research on avian habitat selection has shown that vegetative composition and structure is a good predictor of the diversity and distribution of bird species (MacArthur & MacArthur 1961). Researchers have gained insight into the nature of the correlation between habitat structure and species distribution by studying life history traits and foraging patterns (Robinson & Holmes 1982, Cody 1981). Lloyd et al. (1998) found the invasion of mesquite in Arizona grassland to increase the abundance of some bird species while depressing abundances of others based on life history characteristics such as feeding habits and nesting preference. The current ranges of most Hawaiian forest birds appear closely tied to the distribution of forests dominated by native tree species. It is unclear whether this association is due to feeding specialization on native plants, or if other factors, such as disease or predators, restrict native birds from disturbed habitats (Jacobi & Atkinson 1995).

The abundance and composition of birds may react differently to plant invasion depending on the bird species' feeding habits (guilds) (Lloyd et al. 1998). Some guilds may be negatively affected (i.e., decreased density) while others may respond positively (increased density) or not at all. This assumes that density is positively correlated with habitat quality, which is best determined with demographic data but out of the scope of this pilot study (Van Horne 1983). Successful guilds are often able to utilize the new vegetation as a resource, and, in some cases, even aid the invasion by dispersing seeds (Vitousek & Walker 1989). Thus, alterations in forest plant composition can have varying degrees of impact on local bird populations, with some bird species coping with plant invasion more easily than others. Understanding the habitat requirements of both resistant and vulnerable bird species will aid in preserve design, restoration efforts, compatible land use and corridor design; all are critical elements in adapting environmental management to the problem of invasive alien species (Glover 1999).

This study focuses on three forest birds common to the Kilauea summit area: the Omao (*Myadestes obscurus*), the Apapane (*Himatione sanguinea*) and the Japanese white-eye (*Zosterops japonicus*). Other bird species, such as I'iwi (*Vestiaria coccinea*) and Amakihi (*Hemignathus virens virens*) were recorded during surveys, but were not observed in sufficient numbers to calculate accurate density estimates.

Site Description

Hawaii Volcanoes National Park is located on the southeast side of the island of Hawaii, and includes portions of the Mauna Loa and Kilauea volcanoes. The altitudinal range of the park is from sea level to 4,170 m, although much of the wet forest and the research station are at approximately 1,500 m. The weather is dominated by northeast trade winds and the windward slope mid-slope receives a mean annual rainfall of 381 cm. Five major ecological zones have been identified within the park, from rainforest to desert scrub.

The wet montane forest at the summit of Kilauea Volcano is dominated by Ohia (*Metrosideros polymorpha*), the most widespread canopy tree in Hawaii, and contains sites of Kahili ginger invasion and areas of complete ginger eradication. A total of four plots were included in this study: two plots, Ginger 1 and Ginger 2, contained greater than 90% ginger invasion and are 35 ha and 25 ha, respectively. Two other plots, No Ginger 1 (36 ha) and No Ginger 2 (42 ha), were placed in forest from which ginger was removed (see Figure 1). The understory of these plots was composed of native vegetation, primarily: Hapu'u (*Cibotium glaucum*), Ohelo (*Vaccinium calycinum*), Pilo (*Coprosma* spp.), Kolea (*Myrsine lessertiana*) and Uluhe (*Dicranopteris linearis*). The four sites share topographic, vegetative and climatic characteristics. All plots are placed in closed canopy Ohia forest growing on 1790 volcanic substrate (Wolf & Morris 1996), between 1300 m to 1400 m with a general west facing aspect.

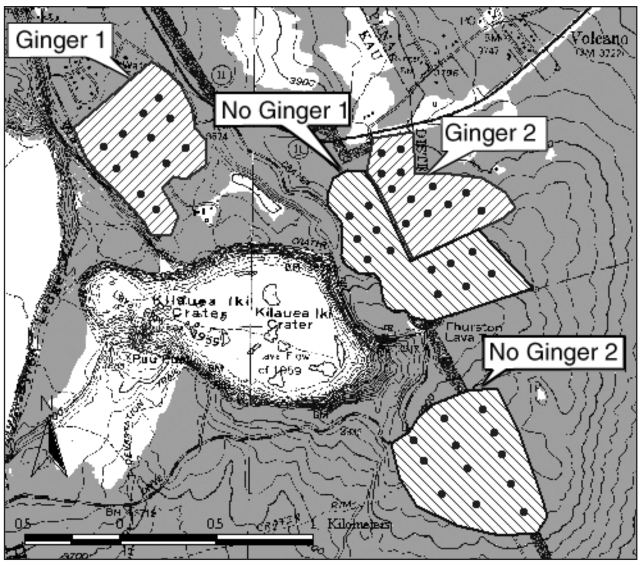


Figure 1 *Kilauea region study plots.*

Methods

Fieldwork was conducted during June and July of 2002. Twelve sampling stations were placed in each of the four plots. All 48 stations were sampled once a week for six weeks, totaling 288 station observations.

The Variable Circular Plot (VCP) method (Buckland et al. 2001, Reynolds et al. 1980) was used to estimate bird density at each station. This distance sampling method takes into account the distance between the observed bird and the observer at a fixed point in the center of the plot. From these distance data, estimated by the observer, a detection function is calculated using Distance 4.0© software that assesses the probability of detecting a bird at a given distance (Thomas et al. 2002). Accurate estimates of forest bird density can be derived from the function model (Camp 2002, Nelson & Fancy 1999, Fancy 1997).

Counts took place between sunrise and noon, the period of highest bird activity. Counts consisted of standing in the center of a station for eight minutes recording all birds seen or heard and their estimated distance from the observer. Eight minutes is considered to be an appropriate length of time in the closed canopy forest of Hawaii after which birds are more likely to be counted twice (Reynolds 1980). In addition, at each station condition baseline data was collected on: percent cloud cover, rain intensity (0-4), wind (0-5) and gust (0-5).

To select sampling stations within plots, a random starting point was chosen from along the boarders of each plot (Buckland et al. 2001) by numbering the perimeter and rolling a dice. From each starting point, transects were drawn systematically to fill plots entirely. Along each transect, sampling stations were placed every 150 m, to ensure sampling independence. Based on past experience, Omao were expected to have the largest detection distance of roughly 70 m and any larger estimates would likely be truncated in analysis (Woodward 2002). Omao estimated detection radius (EDR) in this study was determined to be 55.43 m. Apapane EDR was 18.8 m and Japanese White-eye was 17.95 m. All stations were at least 75 m from the edge of a plot.

At each station, vegetation data were collected according to protocols described by Ralph et al. 1993 and BBIRD (http://pica.wru.umt.edu/BBIRD/). The data were collected within a circular plot of radius 12.6 m measured around the observation point. Measurements included: tree data (canopy height, canopy density, Ohia DBH, Ilex DBH, and snag DBH), Understory data (tree fern [Hapu'u] abundance, ginger percentage, and native and non-native shrub abundance), and bloom and fruit data (percent Ohia bloom, ginger bloom abundance, and fruit abundance). Latitude and longitude were also recorded for each station with a Magellan GPS receiver.

SAS® and MINITAB® statistical softwares were used to run one-way analysis of variance tests with Tukey's comparison of means, t-tests, and power analyses.

Results

Birds

Density per station and plot was calculated and compared for the three species of bird: Omao, Apapane, and Japanese white-eye. A comparison of density per station among plots shows a distinctly higher density of Japanese white-eye in Ginger-invaded forest than Ginger-removed forest (Figure 2). A one-way Analysis of Variance (ANOVA) with Tukey's comparison of means confirms a significantly higher density of Japanese white-eye in Ginger plots ($F(3,44) = 10.09$, $p < 0.0001$).

A one-way ANOVA with Tukey's comparison of means of Omao density among plots demonstrates a lower density of Omao in Ginger 1 than any other plot, including Ginger 2 ($F(3,44) = 7.62$, $p < 0.0002$) (Figure 3).

Apapane density among plots revealed a different pattern, a significantly higher density of Apapane in Ginger 1 and No Ginger 2 than any other plot ($F(3,44) = 24.35$, $p=0.0001$), but not equal to each other (Figure 4).

Vegetation

Abundance of native fruit plants as well as the quantity of fruit was calculated for each plot (Figure 5). No significant difference in the mean number of fruiting plants among plots was detected ($t[4] = 1.94$; $p = 0.12$, 95% CI = [-7.4, 41.8]). However, a significant difference in the mean number of fruit between treatment plots was documented ($t[5] = 3.61$; $p = 0.015$, 95% CI = [546, 3253]). Fruiting plants included: Ohelo, Olapa, Pilo, Kolea, Ilex, Manono and a few ginger (not quite fruiting yet).

No significant difference was found in canopy height and percent canopy cover among plots. Estimated basal area, calculated for the dominant

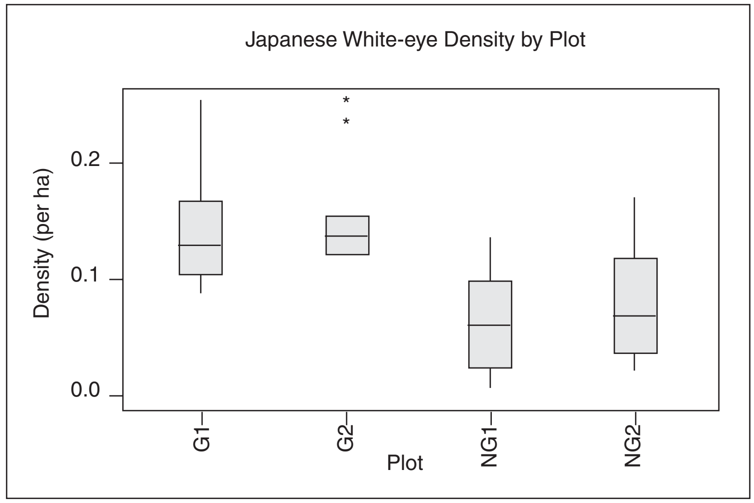


Figure 2 *Japanese White-Eye density by plot.*

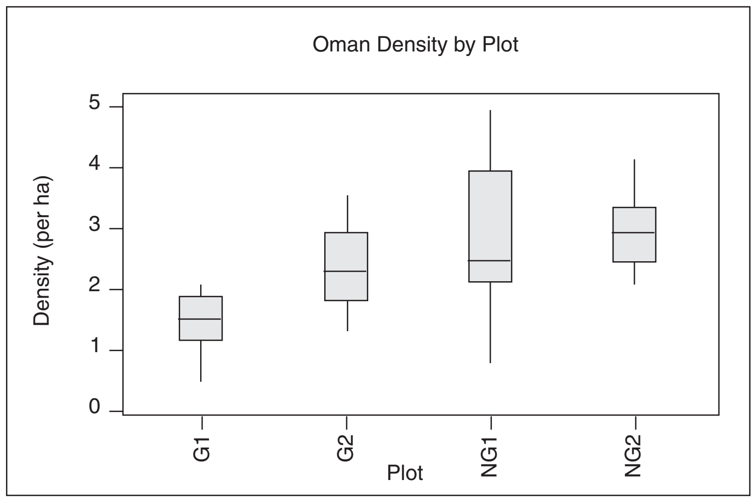


Figure 3 *Omao density by plot.*

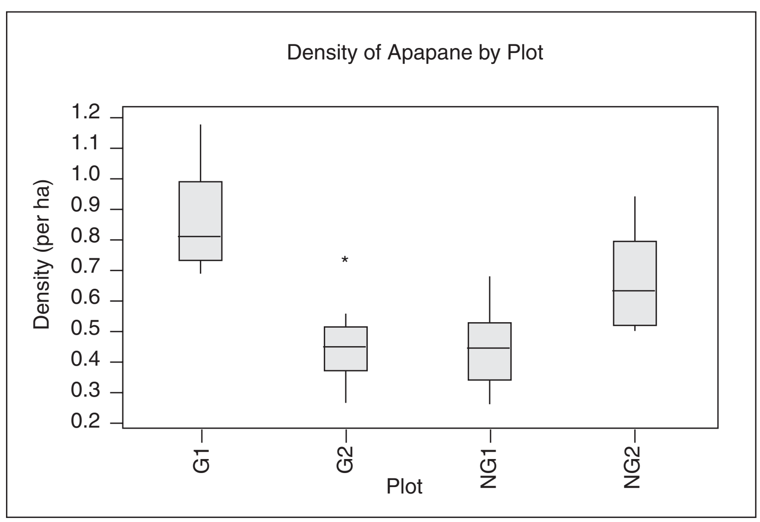


Figure 4 *Apapane density by plot.*

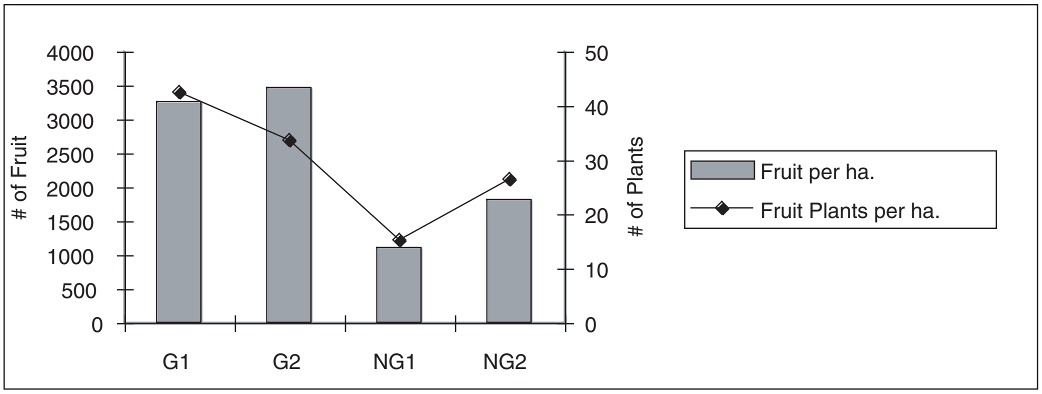


Figure 5 Understory fruit plant and fruit abundance.

tree species, Ohia, and the next most common tree species, *Ilex*, did not differ significantly among plots (ANOVA, Tukey: Ohia: $p = 0.064$ and *Ilex*: $p = 0.026$). Dead snag abundance and distribution of DBH also did not vary significantly among plots (ANOVA, Tukey: $p = 0.122$). Ohia bloom was surveyed twice during the study, at the start and the halfway point. The average percent of canopy in bloom shows higher number of flowers in bloom in the Ginger 1 and No Ginger 2 plots (Figure 6).

Discussion

These results suggest a relationship between ginger invasion and Japanese white-eye density, whereas the correlation is not as clear with Omao, and even unconnected to the Apapane.

Japanese white-eyes are an alien species that feed primarily on insects and nectar (Van Riper 2000). White-eyes were observed collecting nectar at ginger flowers (in peak bloom by the end of the study) several times during the study, though not often enough to influence density. If the significant increase in vegetative biomass caused by ginger invasion was accompanied by a rise in invertebrate abundance, and thus white-eye food source; this would provide a possible explanation for the observed pattern. For example, abundance of an alien insect (*Sophonia rufofoascia*) was found to be 5 to 19 times greater in nearby forest invaded by the non-native plant *Myrica faya* (Lenz & Taylor 2001). Invertebrates may be attracted to the flowers heads and rotting inflorescences found on mature ginger stalks, resulting in greater resource availability to white-eyes in ginger invaded forest.

The mechanisms behind of the pattern of Omao density, lower density in Ginger 1 than all others, is less clear than that for Japanese white-eye. A careful examination of the distribution of Omao density samples in plots Ginger 2 and No Ginger 1 shows that plot Ginger 2's three highest samples are in a corner surrounded nearly 270 degrees by plot No Ginger 1 (Figure 1). This edge effect where the ginger-removed plot is nearly surrounded the ginger invaded plot may erroneously inflate the density estimate of Omao in the enveloped corner – as passing birds would likely cut through the corner to reach other suitable habitat.

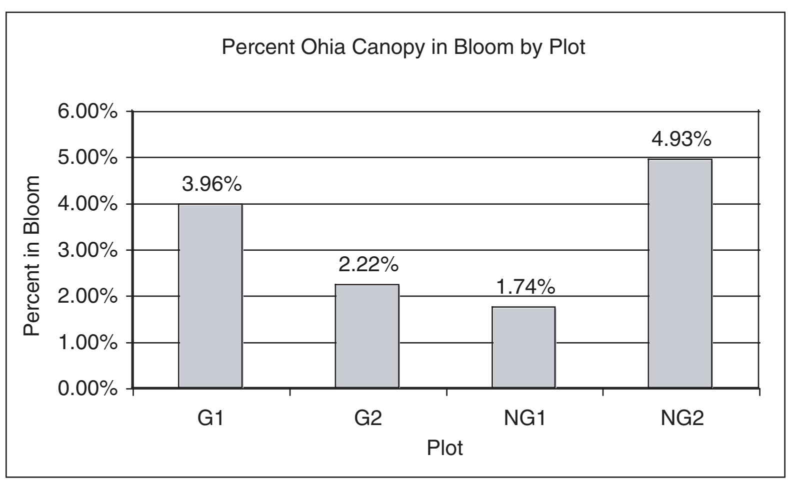


Figure 6 Percent Ohia canopy in bloom by plot.

Surprisingly, there is greater fruit abundance, the primary component of the Omao's diet (Wakelee and Fancy 1999), in the ginger invaded plots (Figure 5). A possible explanation is inter-specific competition between Omao and white-eyes, leaving a greater abundance of under-used resource in ginger-invaded plots. Ginger would serve as an indirect cause for lower Omao density with interspecific competition as a direct mechanism. While white-eyes are known to overlap in feeding strategies with native birds, they are not thought to do so with Omao (Mountainspring & Scott 1985). But conclusive, empirical evidence of such displacement competition is still lacking (Van Riper 2000). It may be that landscape characteristics such as topography and microclimate are influencing Omao density. Or even recent disturbance, for example: Ginger was eradicated from plot No Ginger 1 in 2000, whereas eradication in plot No Ginger 2 was conducted 15 years earlier in 1985. Ginger eradication is damaging to non-target understory vegetation, often leaving behind a barren habitat. Plot No Ginger 1 may not have had sufficient time to recover from the effects of invasion as well as eradication, explaining the much greater variability in Omao density in that plot (Figure 3).

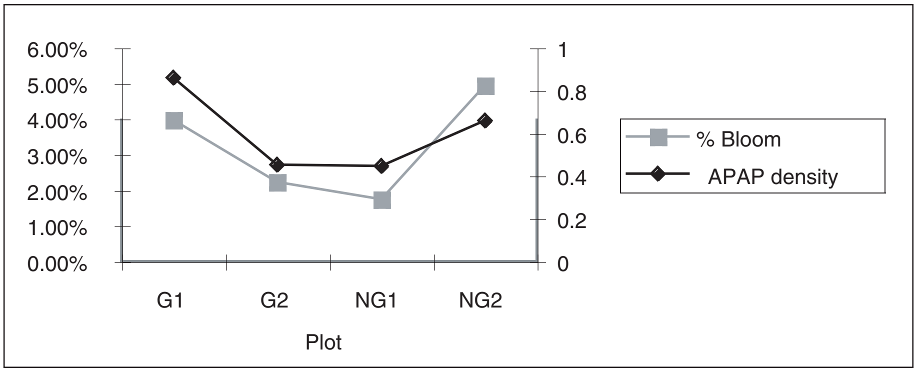


Figure 7 *Percent Ohia bloom vs. Apapane density.*

Apapane density does not seem to be directly affected by ginger invasion as would be expected for a wide-ranging canopy honeycreeper that feeds mainly on Ohia nectar. The significantly higher density of Apapane in Ginger 1 may result from local variation in Ohia bloom abundance, as Apapane density is known to be highly correlated with Ohia flowering (Fancy & Ralph 1997). Such a trend was supported by data collected on the percent of Ohia canopy in bloom (Figure 7).

Results support the hypothesis that species less dependent on native fruiting plants in the shrub layer and understory will remain unaffected or possibly be augmented (Apapane and Japanese White-eye), but do not support the hypothesis that ginger invasion decreases density of understory-feeding birds (Omao). The positive correlation between ginger invasion and increased density of alien Japanese White-eyes may impair the long-term capacity of native forest to sustain native Hawaiian birds through competition or continued habitat alteration. It may also be worth considering the possibility that white-eyes fill an ecological niche of extinct or rare bird species, although the line between filling an empty niche and pushing out other species is far from clear, such as the Hawaiian creeper (Mountainspring & Scott 1985), neither are side effects of niche replacement by an alien species.

Management implications of this study stem from idea that the reinforcing interplay and mutual perpetuation often found among invasive species (Staples & Crowie 2001), may also, in certain circumstances, provide a means to influence non-target invading organisms. This underscores the importance for managers to consider the entire invasion front, not just species by species impacts. Which bird species are influenced by ginger invasion, and how, seem to depend on habit, diet, and possibly the complex interplay among other bird species and available resources.

Long-term ecological research is needed on many aspects of this pilot study. Further investigation of the mechanisms underlying the White-eye/ginger relationship and clarification of the Omao/ginger relationship would be helpful for management decisions regarding the short-term impact of ginger eradication. Such studies should be expanded spatially and temporally to produce greater resolution of the mechanisms at work. In addition, the scope of this study did not allow for collection of survival and reproduction data, and thus follows the assumption that bird density and habitat quality are positively correlated. Van Horne (1983) has shown that in specific instances this assumption does not hold without supporting demographic data. Future studies on the topic should include the collection of demographic data.

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References

BBIRD. Montana Cooperative Wildlife Research Unit, University of Montana, Biological Resources Division, USGS, http://pica.wru.umt.edu/BBIRD/

Buckland, S.T., Anderson, D.R., Burnham, K.P., Laake, J.L., Borchers, D.L. and L. Thomas. 2001. *Introduction to Distance Sampling: estimating abundance of biological populations.* New York, Oxford University Press.

Camp, R. 2002. Personal communications.

Cody, M.L. 1981. Habitat selection in birds: the roles of vegetation structure, competitors, and productivity. *Bioscience* 31:107-113.

Daily, G.C., Ehrlich, P.R. and G.A. Sanchez-Azofeifa. 2001. Countryside biogeography: Use of human-dominated habitats by the avifauna of southern Costa Rica. *Ecological Applications* 11(1):1-13.

Elmqvist, T. 2000. Invasive species on islands: consequences and management options. EC Portuguese Presidency meeting on Biodiversity Research. http://cimar.org/biodiversity/papers/elmqvist.htm.

Elton, C.S. 1958. *The Ecology of Invasions by Animal and Plants.* Chicago, University of Chicago Press.

Fancy, S.G. 1997. A new approach for analyzing bird densities from variable circular-plot counts. *Pacific Science* 51(1):107-114.

Fancy, S.G. and C.J. Ralph. 1997. *Apapane Himotione sanguinea. The Birds of North America,* No. 296. The American Ornithologists' Union.

Glover, N. 1999. Hawaii's Forest Birds: An Inventory of Research Conducted 1992-1998. http://www2.hawaii.edu/scb/lib_researchFB1toc.htm.

Jacobi, J. and C. Atkinson. 1995. *The Status and Trends of Our Nation's Biological Resources.* http://biology.usgs.gov/s+t/index.htm.

Lenz, L. and J. Taylor. 2001. The influence of an invasive tree species (*Myrica faya*) on the abundance of an alien insect (*Sophonia rufofascia*) in Hawai'i Volcanoes National Park. *Biological Conservation*, 102(2001):301-307.

Lloyd, J., Mannan, R.W., Destefano, S. and C. Kirkpatrick. 1998. The effect of mesquite invasion on a southeastern Arizona grassland bird community. *Wilson Bulletin*. 110(3): 403-6.

Loope, L., Howarth, F.G., Kraus, F. and T.K. Pratt. 2001. Newly emergent threats and future threats of alien species to Pacific birds and ecosystems. *Studies in Avian Biology* 22:291-304.

MacArthur, R.H. and J.W. MacArthur. 1961. On bird species diversity. *Ecology* 42:594-598.

Mountainspring, S. and J.M. Scott. 1985. Interspecific competition among Hawaiian forest birds. *Ecological Monographs* 55: 219-239.

Nelson, J.T. and S.G. Fancy. 1999. A test of the variable cirsular-plot method where exact density of a bird population was known. *Pacific Conservation Biology* 5:139-143.

Ralph, C.J., Geupel, G.R., Pyle, P. Martin, T. and D.F. DeSante. 1993. *Handbook of field methods for monitoring landbirds.* USDA FS General Technical Report PSW-GTR-144. Pacific Southwest Research Station. Albany, California.

Reynolds, R.T., Scott, J.M. and R.A. Nussbaum. 1980. A variable circular-plot method for estimating bird numbers. *Condor* 82:309-313.

Robinson, S.K. and R.T. Holmes. 1982. Foraging behavior of forest birds: the relationship among search tactics, diet, and habitat structure. *Ecology* 63:1918-1931.

Staples, G. and R. Crowie. 2001. *Hawai'i's invasive species.* Bishop Museum Press. Honolulu, Hawaii.

Smith, C.W. 1985. Impact of alien plants on Hawai'i's Native biota. In *Hawai'i's Terrestrial Ecosystems: Preservation and Management*. C.P. Stone and J.M. Scott (eds.) Cooperative National Park Resources Studies Unit, University of Hawaii Press.

Thomas, L., Laake, J.L., Strindberg, S., Marques, F.C.C., Buckland, S.T., Borchers, D.L., Anderson, D.R., Burnham, K.P., Hedley, S.L. and J.H. Pollard. 2002. *Distance 4.0.* Release 1. Research Unit for Wildlife Population Assessment, University of St. Andrews, UK. http://www.ruwpa.st-and.ac.uk/distance/

Van Horne, B. 1983. Density as a misleading indicator of habitat quality. *Journal of Wildlife Management* 47(4):893-901.

Van Riper, S.G. 2000. Japanese White-eye *Zosterops japonicus. The Birds of North America*, No. 487. The American Ornithologists' Union.

Vitousek, P.M., Antonio, J.M.S., Loope, L.L., Rejmanek, M. and R. Westbrooks. 1997. Introduced Species: A Significant Component of Human-Caused Global Change. *New Zealand Journal of Ecology* 21(1):1-16.

Vitousek, P.M. and L.R. Walker. 1989. Biological invasion by Myrica faya in Hawaii: plant demography, nitrogen fixation, ecosystem effects. *Ecological Monographs* 59:247-65.

Wakelee, K.M. and S.G. Fancy. 1999. Oma'o *Myadestes obscurus. The Birds of North America*, No. 460. The American Ornithologists' Union.

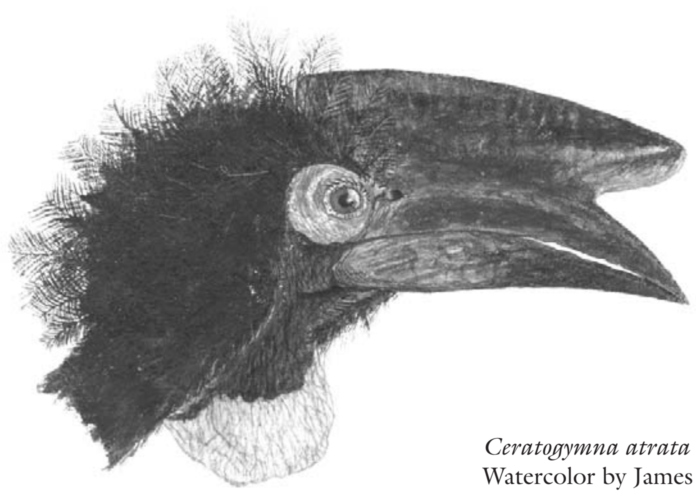
Warschauer, R. 2002. Personal communications.

Wilcove, D.S., Rothstien, D., Dubow, J., Phillips, A. and E. Losos. 1998. Quantifying threats to imperiled species in the United States. *Bioscience* 8: 607-615.

Wolf, E. and J. Morris. 1996. *Geologic Map of the Island of Hawaii.* Geologic Investigations Series Map I-2524-A. U.S. Geological Service.

Woodward, B. 2002. Personal communications

Zimmer, C. 2002. Personal communication.



Ceratogymna atrata
Watercolor by James Chapin
Congo Expedition 1909-1915
American Museum of Natural History Library

Forest use and human-wildlife conflicts in Bhadra Wildlife Sanctuary, Karnataka, India

Krithi D. Karanth, MESc 2003

Introduction

Protected areas (PAs) in India cover about 5% of the land area (earmarked under the wildlife protection act specifically for conservation) and are home to approximately 4.5million people. The small protected area size (avg. <300 km^2) and enclosure by densely populated areas (>300 people/km^2) make them vulnerable to human and livestock population growth, making them distinctive from PAs in Africa and the Americas (Rodgers et al. 2003, Terborgh 2002). In India, people have been a major component of the landscape for several centuries but widespread poverty, land-hunger, predominance of agriculture and animal husbandry, and dependence on plant biomass for food, fodder and shelter have led them to exert tremendous pressures on already fragile protected areas (Karanth 2002).

Human livelihood activities of livestock grazing, agriculture, hunting, fishing, and collection of timber, fuel wood and non-timber forest products (NTFPs) have altered land cover and affected biological diversity in many Indian PAs (Rahmani 2003, Karanth & Madhusudan 2002, Somanathan & Borges 2000). Grazing of domestic livestock has directly decreased food available for wild herbivores, and shifted nutrient dynamics and plant composition in cattle grazed ecosystems (Middleton 2003). Heavy grazing has resulted in local extinctions or emigration of animals dependent on plant cover for food, shelter or nesting (Madhusudan & Mishra 2003). It has also increased soil erosion and compaction, transmission of diseases and parasites to wild herbivores (Rahmani 2003). However, at moderate densities livestock have been found to benefit smaller grazing herbivores (Saberwal 1996).

Fuel wood and NTFP collection of assorted plant parts along with extraction of gum and honey has directly affected food availability for species dependent on these resources. Indirect effects of extraction include plant survival, regeneration and recruitment patterns (Murali et al. 1996, Somanathan & Borges 2000). Several studies suggest that NTFP collection is only beneficial to small populations of collectors with extensive knowledge of the forest. The expansion of markets for these products will lead to over-harvesting and exploitation that is unsustainable (Borges 2003, Murali et al. 1996). People have hunted to meet their subsistence needs for food and to sell animal by-products in markets, but there have been few attempts to quantify patterns and impacts of hunting and fishing in India (Robinson & Bennet 2000, Madhusudan & Karanth 2000). Robinson (1993) suggests that such human activities are often unsustainable and have concomitant effects on community dynamics and ecosystem functioning, thereby having pervasive effects on overall biological diversity.

Across India, people living in and around PAs have been subject to restricted access to forest resources during the times of colonial British and independent India, with the common thread being state control of forested areas (Rangarajan 2001). The survival of many Indian species today is partly due to the remarkable resilience and tolerance shown by people, despite devastating losses suffered with respect to crops, property, livestock and human lives. Livestock predation and crop raiding have become widespread and frequently occurring problems in many Indian reserves. Increasing conflicts between humans and wildlife have lead to angry reprisals that include poisoning of kills, shooting crop-raiding species, confrontations with forest guards and setting forest fires (Rahmani 2003, Karanth 2002). Attitudes of people have changed from tolerance and sacrifice to retaliation and usurpation (Madhusudan & Mishra 2003).

It is widely accepted that parks in India are in peril, and subject to increasing human-wildlife conflicts similar to those in African and American parks (Saberwal & Rangarajan 2003, Karanth 2002, Rodgers et al. 2003, Terborgh 2002). The current worldwide debate involving academics and conservation practitioners centers on the rights of human settlements and village communities found in and around PAs (Saberwal & Rangarajan 2003, Terborgh 2002, Karanth 2002, Agarwal & Gibson 2001). Human pressures continue to threaten wildlife survival, habitat protection and biological diversity, yet it is neither ethically right nor often administratively or politically feasible to evict people living in PAs.

The current challenge is understanding how human-dominated ecological systems function and the ecological implications of these human-activities. We need to determine if and how management objectives can be directed to allow for co-existence, especially when no viable alternatives exist. Habitat conservation and wildlife protection in PAs must incorporate multiple-use objectives and minimize risks to human lives, crops, property and livestock. This study focuses on forest use patterns and human-wildlife conflicts specifically in villages found within Bhadra Wildlife Sanctuary. I examined how multiple land-use and activities such as firewood collection, livestock grazing, NTFP collection, fishing and hunting vary among villagesand the losses households have incurred from wildlife raiding crops and preying on livestock.

Research site and natural history

Bhadra Wildlife Sanctuary (Figure 1) is a protected area covering an area of 492 km^2 in India's Western Ghats, a region delineated as one

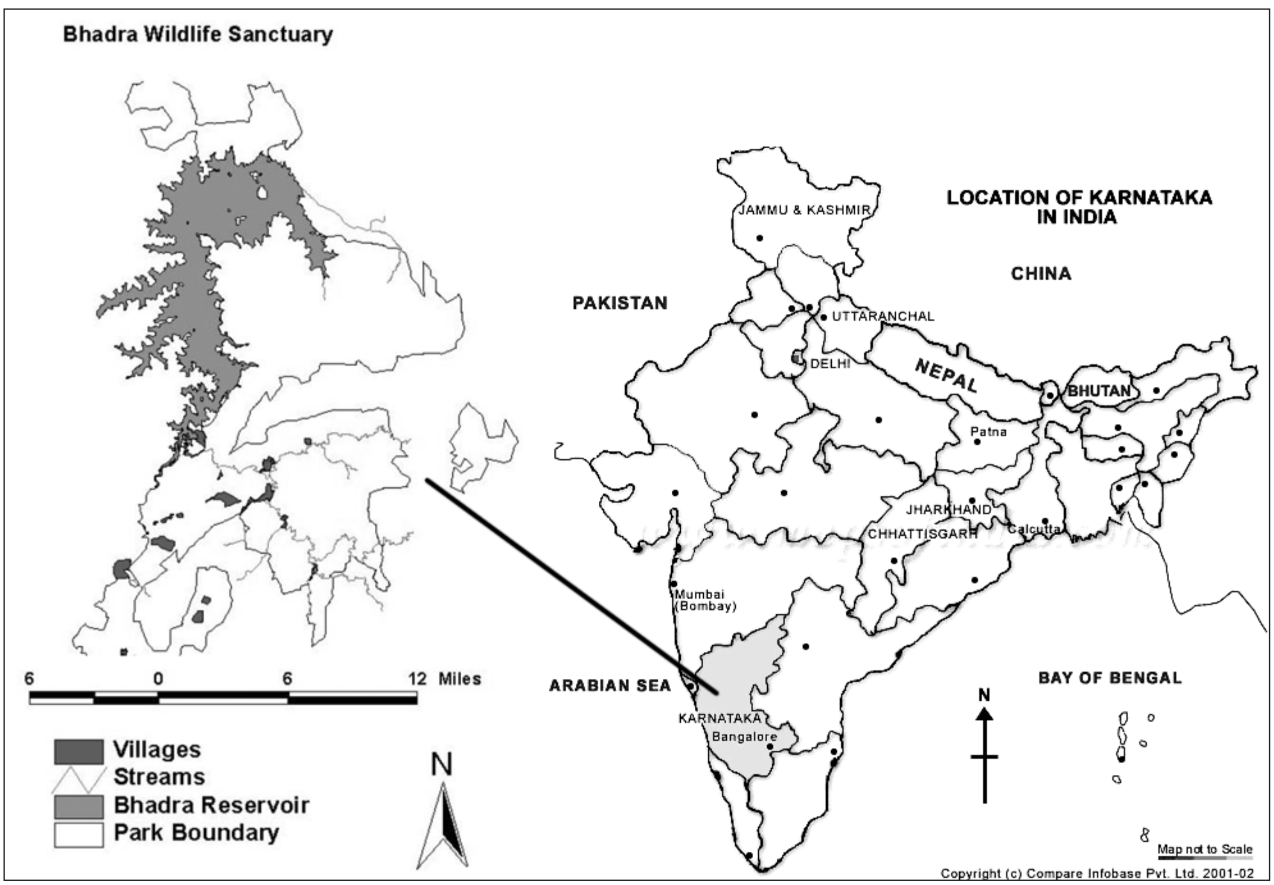


Figure 1 *Location of Bhadra Wildlife Sanctuary in India.*

of the world's 18 biodiversity hotspots (Myers et al. 2000, Ward 2002). The upper elevations and hillsides are covered by wet evergreen forests, and lower slopes and valleys with bamboo dominant moist deciduous forests. The forest canopy is comprised of valuable timber species such as *Tectona grandis, Terminalia tomentosa, Terminalia paniculata* and *Lagerstromia lancelota* (Karanth 1982). The lower slopes and valleys are dominated by several bamboo species especially *Bambusa arundineacea* and *Dendrocalamus strictus* (Karanth 1982). The earliest British record documenting human presence dates from 1917 when a portion of the sanctuary was classified as a state forest by the British and a survey conducted describes 'the village as being sparsely populated' with 88 people and 186 cattle occupying an area of 4.19 km^2 (Anonymous 1917).

At present, ca. 4000 people inhabit the 16 villages found within the park. Villagers have encroached forests and grasslands converting them to coffee plantations and rice paddy fields. Poaching of wild animals, livestock grazing and collection of firewood, small timber and forest products occurs despite protection efforts by the forest department (Karanth 1982). Severe human wildlife conflicts are occurring with crop raiding by elephants and ungulates as well as livestock predation by tigers and leopards (Madhusudan & Mishra 2003). Construction of a dam and a major irrigation reservoir in the 1970's isolated these villages, and park protection provisions have limited infrastructure and social service development within the park. Given this context, families from these villages have sought voluntarily to relocate to areas if their socio-economic needs are met (KFD Report 1999). A voluntary resettlement project is currently underway, implemented by the Government of India with the active involvement of local conservation non-governmental organizations (KFD Report 1999).

Methodology

Village society composition and demographics

I conducted a household level social survey in the local languages Kannada and Tulu in all the sixteen villages in Bhadra. Here I describe the results from six villages: Karvani, Kesave, Muthodi, Hebbe, Hipla and Madla (Figure 1). Based on population size and spatial extent, these villages were grouped into small, medium and large villages for analyses. The small villages of Karvani, Kesave and Muthodi had ≤ 30 households while the mid-sized villages of Hebbe and Hipla had a total of ≥ 60 households within the village. Madla had ≥120 households and represents the largest village in the sample. The survey compiled basic demographic data and questioned households on livelihood activities such as collection of firewood and NTFPs, livestock grazing, fishing and hunting, along with crop raiding and livestock predation that they experienced.

A total of 196 out of 319 households were interviewed from July to August 2002 in the six villages. The proportion of households interviewed range from 42% in Karvani to 69% in Muthodi (Figure 2). These villages were remarkably homogenous across several major socio-economic and demographic characteristics with a few significant differences among them. The average time that a household had existed in a village was similar and ranged from 38.7 to 45.6 years ($N = 196$, $p > 0.05$). Household size differed among villages ($N = 196$, $p < 0.03$). Males headed 64% of the households in Kesave to 89% in Karvani, while females were household

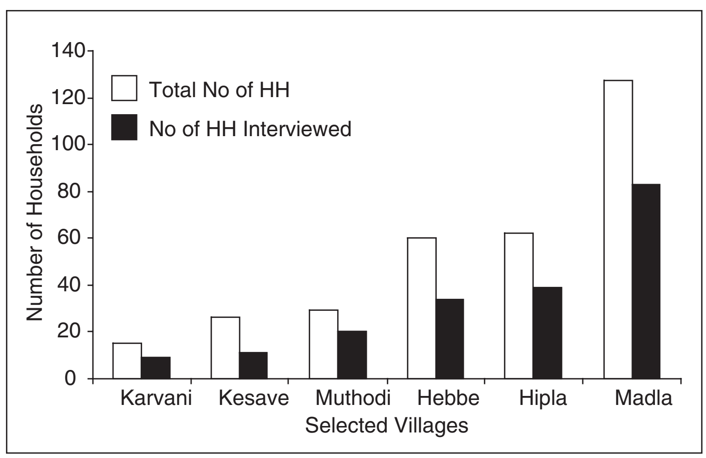


Figure 2 *Proportion of households (HH) interviewed in villages of Bhadra.*

heads in the remainder. Proportion of household heads who remained in their natal village was similar and ranged from 50% in Muthodi to 77% in Hebbe (N = 196, p > 0.05).

Hinduism is the dominant religion practiced by 82% to 100% of households with the others practicing Islam. Villages were comprised of a heterogeneous mixture of twelve castes and their composition differed significantly among villages (chi-square test p < 0.0001). Numerically dominant castes were Kumbhar Shettys (KS), Vokkaliga Gowdas (VG), and Scheduled Castes (SC) (Figure 3). The minor castes were Achaaris, Poojaris, Scheduled Tribes, Gounders, Namdhari Gowdas, Naidus, Nayaks, Nairs, and Maratis along with migrant families belonging to different castes from the neighboring states of Kerala and Tamil Nadu. Because the minor castes comprised only a few households per village they were combined into a single category: "other" (Figure 3).

Agriculture ranked as the primary source of income for 35% to 100% of households in all villages (N = 163, p > 0.05), and wage labor as the secondary income source differed between villages (N = 125, p <0.001). Other income sources included NTFPs, livestock (mostly cattle) and home-gardens. The proportion of households with legal land rights differed significantly (N = 196, p < 0.005) but households additionally renting land were similar between villages (N = 196, p > 0.05). The proportion of households that had encroached onto land varied very significantly among the villages (N = 196, p <0.0000001). The average number of years a household had been farming varied significantly

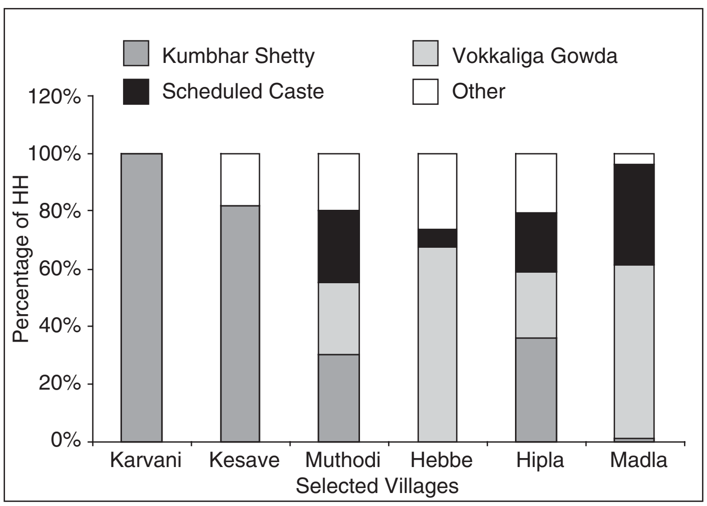


Figure 3 *Caste composition in villages of Bhadra*

ranging from 28 years in Madla to 43 years in Kesave (N = 169, p < 0.03). The average size of a plot of land (either owned or encroached) averaged from 2.3 acres in Muthodi to 4.6 acres in Hebbe (N = 160, p < 0.01). The average distance from home to the agricultural field also varied significantly from 0 km in Kesave to 0.62 km in Madla (N = 165, p < 0.025). Paddy (rice) was the single most common crop grown (97-100%) in all the households. Other crops grown were coffee, areca (betel nut) and rubber, which were fertilized by combining cow dung with chemical fertilizers.

Results

Firewood consumption

All the households interviewed described the forest as their only source of firewood and a few villagers explained that they only collected dead and fallen wood as opposed to cutting trees or lopping branches. The average distance walked to gather firewood ranged from 0.54 km in Hebbe to 0.93 km in Madla (N = 196, p< 0.001). The firewood gathered per household every week was similar (N = 196, p > 0.05) and averaged between 4.89 to 5.81 bundles. Since all households collect firewood from the forest, each village's firewood demand can be estimated (Figure 4). A firewood consumption rate consists of 73 bundles/week (2190 kg) in the smallest village Karvani and 738 bundles/week (22140 kg) in the largest village Madla.

Livestock grazing

Across all villages, cattle were the primary livestock with much smaller numbers of sheep, goats, pigs and buffalos. Livestock were largely grazed in

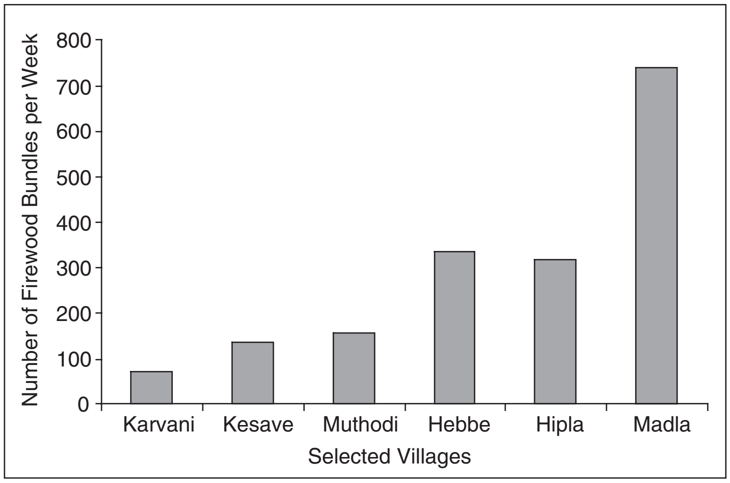


Figure 4 *Total firewood (in bundles/week) collected from the forest in villages of Bhadra*

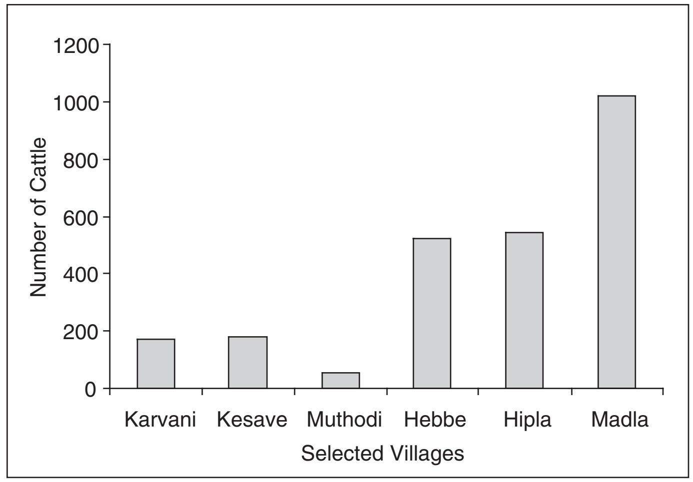


Figure 5 *Total number of cattle in villages of Bhadra (94-100% grazed in the forest).*

the forest (94-100%). Households in five of the villages averaged 7 to 12 cattle with the only exception being the small village of Muthodi with <2 cattle per household. The number of cattle found in households differed significantly (N = 196, $p < 0.025$). The total number of cattle for each village estimated ranged from 55 cattle in the small village of Muthodi to 1,021 cattle in the large village of Madla (Figure 5).

Non-timber forest product

NTFPs were divided into commercial and non-commercial products based on responses from the survey. The commercial NTFPs collected and sold in urban markets were seegakai (*Acacia concinna*), soap nut (*Sapindus emarginatus*) and wate huli (*Artocarpus lacoocha*). Although seegakai collection (every alternate year) varied by household (N = 196, p < 0.0000001), the percentage sold commercially, quantity collected and market price was similar (N = 97, 59 and 58 with p > 0.05, Figure 6 and Table 1b).

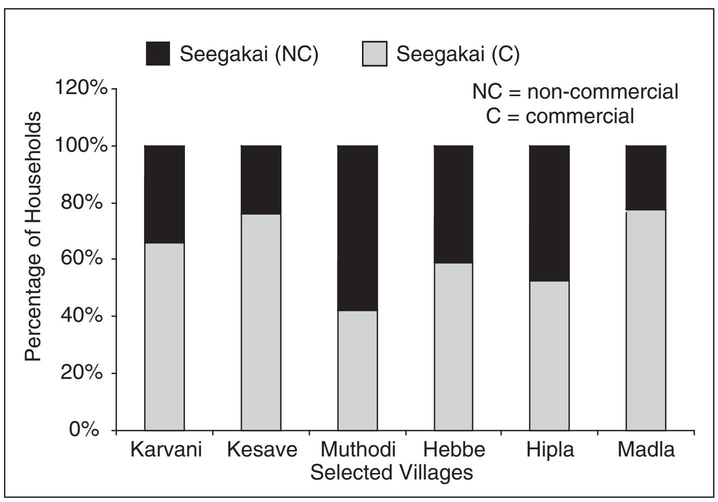


Figure 6 Seegakai (Acacia concinna) *was collected once every two to three years by households and sold commercially in urban markets. Its price ranged from Rs 985 to Rs 1675 ($20.31 to $34.54) per 100 kgs and average quality collected ranged from 100 kgs/hh in Karvani to 1000 kgs/hh in Hebbe.*

Soap nut was harvested yearly and its commercial use, quantity collected and market price was similar across the villages (N = 45, 21 and 17 with p > 0.05, Figure 7 and Table 1b).

Wate Huli was gathered seasonally in villages (N = 196, p > 0.05, Figure 8) by 10% to 33% of households.

The non-commercial NTFPs collected were bamboo, honey, savige (*Sterculia villosa*), nellikai (*Emblica officinalis*), wild fruits and edible mushrooms. Bamboo was gathered year round by all household members in all villages (N = 196, p > 0.05). Honey collection was restricted to men and differed among villages (N = 195, p < 0.5). Savige

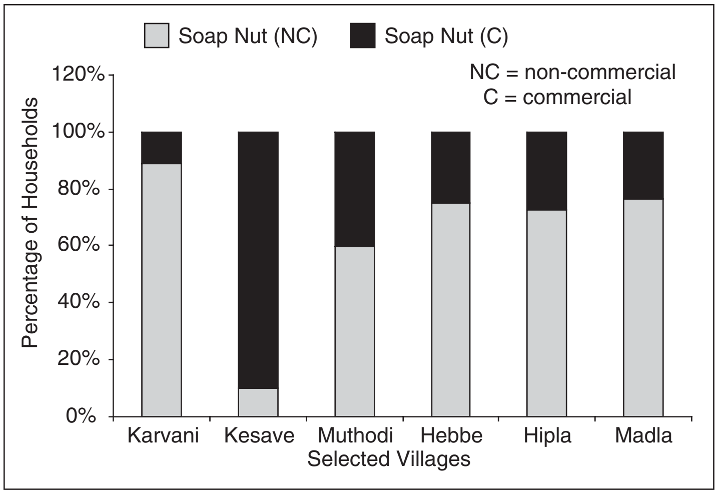


Figure 7 Soap Nut (***Sapindus emarginatus***) *was collected once a year by households and sold commercially in urban markets. Its market price ranged from Rs 300 to Rs 1317 ($6.19 to $27.16) per 100 kgs and average quantity collected ranged from 10 kgs to 550 kgs per hh in the village.*

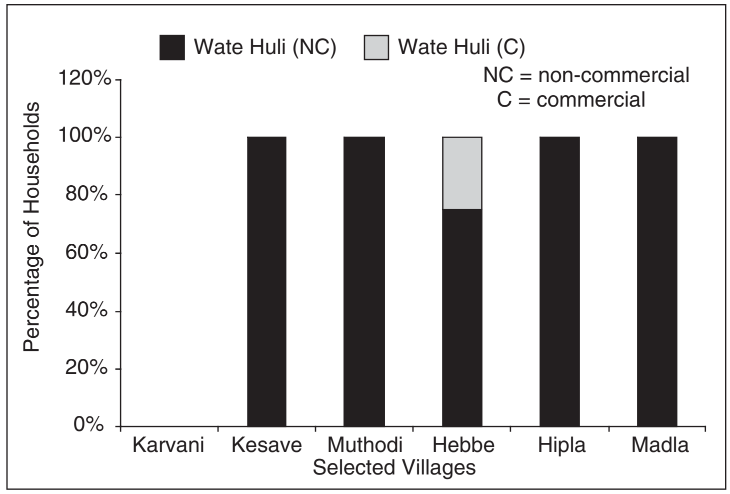


Figure 8 ***Wate Huli (Artocarpus lacoocha)*** *was collected seasonally and mostly used by households for non-commercial purposes except in the village of Hebbe. This species was not found near Karvani.*

was collected twice per year, coinciding with the harvesting of paddy but its collection varied between villages (N = 196, $p < 0.05$). Nellikai was gathered seasonally in all villages (N = 196, $p > 0.5$). Edible mushroom collection varied among households (N = 196, $p < 0.05$). Wild fruits were harvested year around, often by children and similar in villages (N = 196, $p > 0.05$, Figures 9a and 9b).

Detailed information about these NTFPs including their specific uses are in Tables 1a and 1b.

Hunting and fishing

During my interviews, people were hesitant to discuss gun ownership and were highly sensitive to issues surrounding hunting practices as hunting in Bhadra is illegal as per Indian law. Therefore, the

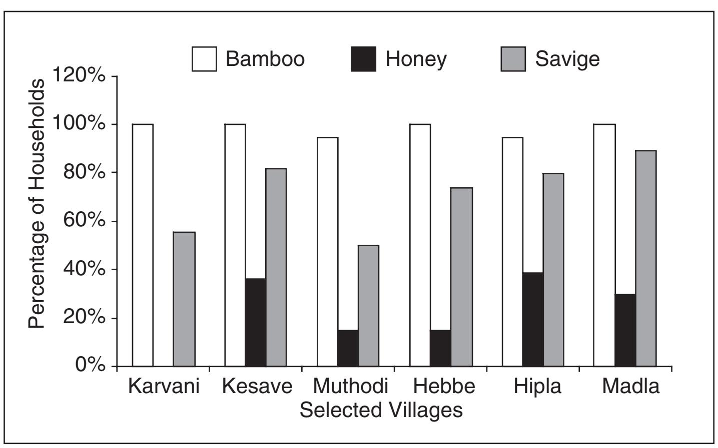


Figure 9a *Non-commercial NTFPs collected by villages. Bamboo and honey are collected all year round.* ***Savige (Sterculia villosa)*** *is collected to make ropes twice per year coinciding with the harvesting of paddy in all households.*

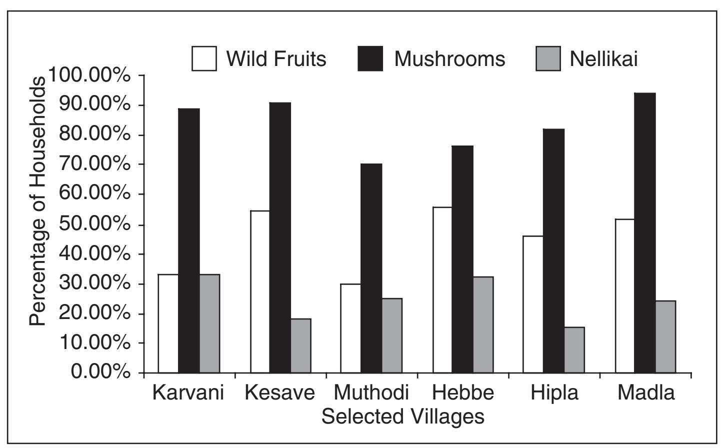


Figure 9b *Non-commercial NTFPs collected by villages. Wild fruits and edible mushrooms are collected seasonally.* ***Nellikai (Emblica officinalis)*** *was collected during the months of November-February and primarily used for household consumption.*

results for gun ownership and hunting practices must be viewed conservatively. The proportion of households that were licensed gun owners were 0% in Madla and 28% in Kesave. The proportion of households reporting hunting activities varied significantly between villages and were from 0% in Madla and Muthodi to 18% in Kesave ($N = 196$, $p < 0.001$). Hunted species include sambar (*Cervus unicolor*), muntjac (*Muntiacus muntjak*), wild boar (*Sus scrofa*), hare (*Lepus nigricollos*), giant squirrel (*Ratufa indica*), monitor lizard (*Varanus flavescens*) and jungle fowl (*Gallus lafayetii*).

Fishing was an important source of protein in most of these households. The proportion of households fishing was similar in villages and was 65% in Muthodi to 89% in Hebbe ($N = 196$, $p > 0.05$). Fish were caught in streams, rivers and in the Bhadra reservoir using bamboo traps, hands, nets and occasionally even dynamite (Figure 10). Some villagers mentioned that increased use of chemical fertilizer in their fields had led to a great proportion of fish being abnormal or cancerous thereby restricting fishing over the past five years.

Crop raiding and livestock predation

Crop raiding by elephants and wild boar resulting in extensive crop damage was extremely high (73-100% of households) in all villages ($N = 196$, $p > 0.05$, Figure11). Villagers complained that much time was spent watching for animals and animals were chased using fire, gunshots, firecrackers and noise. A family in Karvani also reported that a family member was killed during an altercation with an elephant. Livestock predation by tigers and leopards was found to have affected 18% to 100% of households and varied between villages ($N = 196$, $p < 0.0001$, Figure 12). The average number of cattle reported lost varied between 1-3 per household/year ($N = 196$, $p < 0.00001$). The livestock predation rate ranged between 11.5% in Karvani to 24.8% in Hipla. In one interview, a villager in Hebbe also reported to have lost a few cattle to crocodiles in the reservoir.

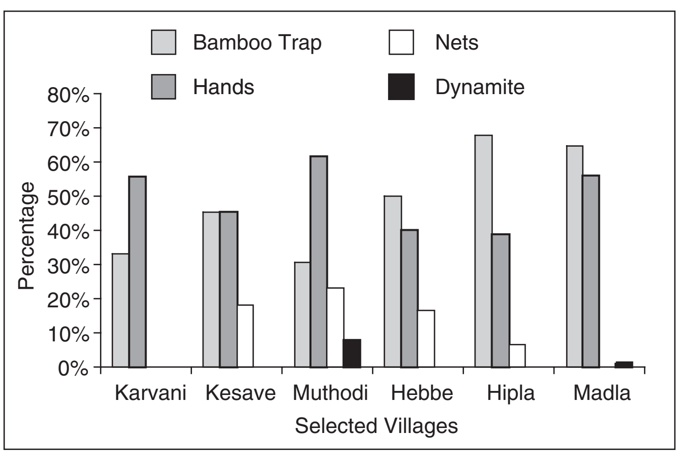


Figure 10 *Fishing methods by households in villages of Bhadra.*

Discussion

Villages have existed in Bhadra for at least 85 years, but the number of villages and household numbers have grown substantially. Households are dependent on the forest to meet livelihood needs of food, fuel wood, fodder and shelter and generate income by selling forest products in markets. They have also suffered damage to crops and property, loss of livestock and occasionally even lives. The results suggest that there is a multitude of factors that govern a household's dependence on natural subsidies from the forest and these households, in turn, are subject to severe human-wildlife conflicts.

Regardless of their socio-economic status and their ability to afford alternatives, all households collected firewood. The number of firewood bundles collected was similar but the distance walked to collect firewood differed in the villages. The firewood consumption rate varied between 73 bundles/week (2190 kg) in the smallest village and 738 bundles/week (22140 kg) in the largest village. The standing biomass around each village is predicted to be affected by the distances walked to collect firewood and the number of firewood bundles collected, thereby determining how much a villages footprint extends into the forest. This study also suggests people's dependence on firewood is not affected by their socio-economic status rather by the presence of natural subsidies with unrestricted access.

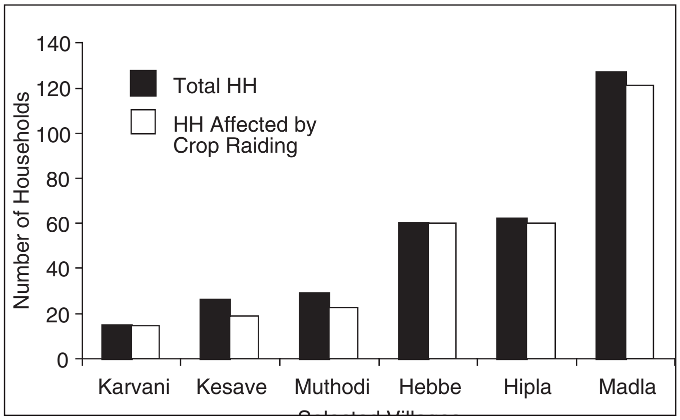


Figure 11 *Proportion of households affected by elephant and wild boar crop-raiding incidents.*

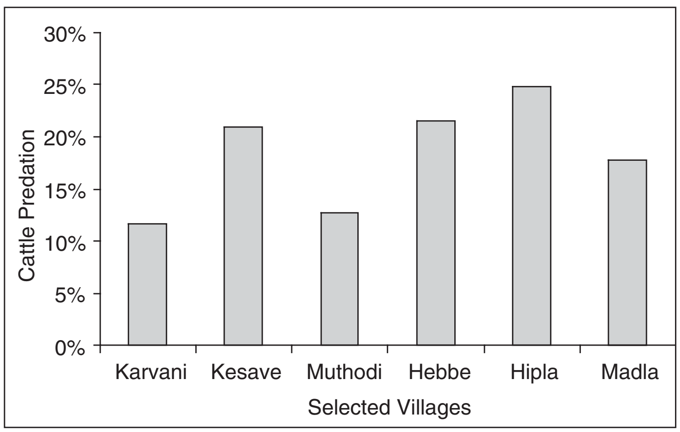


Figure 12 *Percentage of livestock lost to predation by tigers and leopards in every village.*

Livestock were grazed primarily in the forest and the average number of cattle was similar in five villages with the exception of Muthodi. In Muthodi, with the exception of two large land-owning households, most other households owned few or no land or cattle. Households in other villages were able to encroach onto land and own more cattle. The number of cattle present in a village is predicted to affect the quality of palatable forage around it and ecological impacts of grazing to vary around villages.

Three commercial NTFPs were collected and sold to traders or directly in urban markets. Collection of seegakai was restricted to alternate years because of biennial fruit production and the percentage sold commercially, quantity collected and market price were similar in all villages. Quantities collected ranged between 500 kg in Karvani to 46,632 kg in Madla with resulting incomes of Rs. 5500 ($113) and Rs. 459,325 ($9,393). Soap Nut was collected annually and sold for similar market prices in all villages. Quantities collected ranged between 20 kg in Kesave to 11,200 kg in Madla with resulting incomes of Rs. 60 ($1.25) and Rs. 100,800 ($2,061). Wate Huli was mostly consumed by households and sold in markets occasionally. Seegakai and soap nut are collected in large quantities and generate substantial income for people, making these species vulnerable to over-exploitation, especially when other sources of income are threatened (i.e., crop failure or damage due to crop raiding).

Several species of bamboo, nellikai and wild fruits were collected universally, while collection of honey, savige and edible mushrooms differed among villages. The collection of non-commercial NTFPs appears to be driven by their distribution and ease of extraction. Bamboo, nellikai and wild fruits are more easily available to villagers and collected by all household members, while honey and savige extraction is a more laborious task requiring more effort and skill, and restricted to men. NTFP collection in Bhadra is determined by a suite of socioeconomic and ecological factors that include distribution, unrestricted access, ease of extraction and, very importantly, market price. Thus, NTFP collection is market-driven rather than solely for household subsistence.

Fishing was an important source of protein and was admitted as a widespread activity in all villages. Hunting, on the other ha,d conservatively identified sambar, muntjac, wild boar, hare, giant squirrel, monitor lizard and jungle fowl as favored species. People do not depend solely on hunting for nutrition and have access to other livestock and dairy products.

Crop raiding by elephants and wild boar resulting in extensive crop damage was extremely high in all villages. Resulting economic losses were severe and time spent watching for animals was considerable. Predation by tigers and leopards varied between villages and the average number of cattle lost was reported to between 1-3 per household/year. The predation rate was between 11.5% in Karvani to 24.8% in Hipla. These results are consistent with findings from a previous study of Bhadra that found villagers lost 15% of paddy to raiding elephants and tigers, and leopards annually attacked and devoured about 12% of their livestock (Madhusudan 2000). Escalations of human wildlife conflicts can be attributed to increases in livestock density or extent (and juxtaposition) of crop fields in large mammal habitat, increases in large mammal density (due to successful conservation programs) and declines in availability of wild prey and palatable forage (Madhusudan & Mishra 2003).

Fuel wood, fodder, fish and NTFPs are major natural subsidies for households in villages in Bhadra. Their current availability, unrestricted access, ease of extraction and market price make them very appealing options to villages, therefore extremely vulnerable to over-exploitation, and I expect in the long run unsustainable. Several significant differences were documented among villages driven by the number of households. This study suggests that villages in Bhadra benefit socio-economically from access to forest resources and suffer from serious human-wildlife conflicts unlike other villages in the area (located farther away from the PA). The standing biomass, quantity and quality of palatable forage available to wild species are predicted to be affected by these activities. In the long-term, these activities will affect plant survival, regeneration and recruitment patterns along with distribution of animals dependent on these plant species.

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References

Agrawal, A. and C. Gibson. 2001. The Role of Community in Natural Resource Conservation. In *Communities and the environment: ethnicity, gender and the state in community-based conservation*, Arun Agrawal and Clark Gibson (eds.). New Jersey, Rutgers University Press.

Annonymous. 1917. Proceedings of the Government of his Highness The Maharaja of Mysore, November 30th.

Borges, R. 2003. The Anatomy of Ignorance *or* Ecology in a Fragmented Landscape: Do We Know What Really Counts? In *Battles Over Nature: Science and Politics of Conservation*, Vasant Saberwal and Mahesh Rangarajan (eds.). New Delhi, Permanent Black.

Karanth, K.U. 1982. Bhadra wildlife sanctuary and its endangered ecosystem. *Journal of Bombay Natural History* 79: 79-86.

Karanth, K. U. 2002. Nagarahole: Limits and Opportunities in Wildlife Conservation. In *Making Parks Work: Strategies for Preserving Tropical Nature*, John Terborgh, Carel van Schaik, Lisa Davenport and Madhu Rao (eds.) Washington, D.C, Island Press.

Karanth, K. U. and M.D. Madhusudan. 2002. Mitigating Human-Wildlife Conflicts in Southern Asia. In *Making Parks Work: Strategies for*

Preserving Tropical Nature, John Terborgh, Carel van Schaik, Lisa Davenport and Madhu Rao (eds.).Washington, D.C, Island Press.

Karnataka Forest Department (KFD) Report. 1999. Bhadra Rehabilitation Project Report.

Madhusudan, M. D. 2000. Sacred cows and protected forests: a preliminary survey of livestock presence in wild-life reserves. CERC technical report # 4. Center for Ecological Research and Conservation, Mysore, India.

Madhusudan, M.D. and C. Mishra. 2003. Why Big, Fierce Animals are Threatened: Conserv-ing Large Mammals in Densely Populated Landscapes. In *Battles Over Nature: Science and Politics of Conservation*, Vasant Saberwal and Mahesh Rangarajan (eds.). New Delhi, Permanent Black.

Madhusudan, M.D. and K.U. Karanth. 2000. Hunting for an Answer: Is Local Hunting Compatible with Large Mammal Conservation In India? In *Hunting for Sustainability in Tropical Forests.* J.G. Robinson and E.L. Bennet (eds.). New York, Columbia University Press.

Middleton, B. 2003. Ecology and Objective Based Management: Case Study of the Keoladeo National Park, Bharatpur, Rajasthan. In *Battles Over Nature: Science and Politics of Conservation*, Vasant Saberwal and Mahesh Rangarajan (eds.). New Delhi: Permanent Black.

Murali, K.S., Shankar, U., Uma Shaanker, T., Ganeshaiah, K.N. and K.S Bawa.1996. Extraction of non-tiber forest products in the forests of Biligiri Rangan Hills, India. 2. Impact of NTFP extraction on regeneration, population structure, and species composition. *Economic Botany* 50: 252-69.

Myers, N., Mittermeier, R.A., Mittermeier, C.G., da Fonseca, G. A. B. and J. Kent. 2000. Biodiversity hotspots for conservation priorities. *Nature* 403: 853-858.

Rangarajan, M. 2001. *India's Wildlife History: An Introduction*. Delhi: Permanent Black.

Rahmani, A. 2003. Conservation Outside Protected Areas. In *Battles Over Nature: Science and Politics of Conservation*, Vasant Saberwal and Mahesh Rangarajan (eds.). New Delhi,Permanent Black.

Robinson, J.G. 1993. The Limits to Caring: Sustainable Living and the Loss of Biodiversity. *Conservation Biology* 7: 20-28.

Robinson, J.G. and E.L. Bennet. 2000. *Hunting for Sustainability in Tropical Forests.* New York, Columbia University Press.

Rodgers, A., Hartley, D. and S. Bashir. 2003. Community Approaches to Conservation: Some Comparisons from Africa and India. In *Battles Over Nature: Science and Politics of Conservation*, Vasant Saberwal and Mahesh Rangarajan (eds.). New Delhi, Permanent Black.

Saberwal, V. and M. Rangarajan. 2003. Introduction. In *Battles Over Nature: Science and Politics of Conservation*, Vasant Saberwal and Mahesh Rangarajan (eds.). New Delhi: Permanent Black.

Saberwal, V. K.1996. Pastoral politics: Gaddi grazing, degradation, and biodiversity conservation in Himachal Pradesh, India. *Conservation Biology* 10: 741-749.

Somanathan, H. and R. M. Borges. 2000. Influence of exploitation on population structure, plant spacing and reproductive success in dioecious tree species within a fragmented cloud forest in India. *Biological Conservation* 94: 243-256.

Terborgh, J. 2002. Overcoming Impediments to Conservation. In *Making Parks Work: Strategies for Preserving Tropical Nature*, John Terborgh, Carel van Schaik, Lisa Davenport and Madhu Rao (eds.) Washington, D.C, Island Press.

Ward, G.C. Jan 2002. India's Western Ghats. *National Geographic*.

Appendix

Name	% Households Citing Use	Use
Several species of edible mushrooms	70%-94%	Used in cooking.
Several species of wild fruits for example: Jack Fruit (Artocarpus heterophlyllus), Mango (Mangifera indica), Tamarind (Tamarindus indica), Jamun (Syzygium cumini) and Citrus species (Rutaceae).	30%-56%	Directly consumed, used to make pickles and preservatives and in cooking
Honey	0%-39%	Directly consumed and used as medicine

Table 1a *Non-timber forest products used in selected villages in Bhadra.*

Scientific Name	Common/Local Name	Plant Part Used	% Households Citing Use	Use	Commercial Use –Percentage, Quantity and Price
Bambusa arundinaecea, Dendrocalamus strictus, Oxytenthera monostigma and	Hebbidiru,Kirubi diru, Vate, and Ame Vate	Shoots	95%-100%	Fencing, walls, roofing, water pipes and firewood. Cook tender shoots.	Not Applicable
Sterculia villosa	Savige	Bark	50%-90%	Making ropes and coarse cloth.	Not Applicable
Emblica officinalis	Nellikai	Fruit	15%-33%	Fruit is a thirst quencher, pickles and preservatives. Leaves and bark used in tanning.	Not Applicable
Acacia concinna	Seegakai	Fruit, Bark Leaves	15%-82%	Pods and leaves are used as fodder. Bark and pods used for tanning. Spines used as fishing hooks.	21%-57% Q: 100kg-1000kg P: $20.31 to $34.54 per 100kg
Sapindus emarginatus	Soap Nut/Antwala	Fruit	9%-44%	Soap, shampoo and detergent.	11%-90% Q: 10kg-550kg P: $6.19 to
Artocarpus lacoocha	Wate Huli	Fruit	10%-33%	Fruit is used in cooking. Seeds yield medicinal edible fat. Acid in the fruit used in cosmetics, textiles, soaps.	0%-25% Q: 60kg P: $51.56

Table 1b *Non-timber forest products used in selected villages in Bhadra.*

The impact of sea turtle hatcheries on local communities in Sri Lanka

Naamal De Silva, MEM 2003

Introduction: the impact of ecotourism

Can ecotourism protect threatened species and ecosystems while providing local communities with income and empowerment?[1] Proponents of ecotourism as a conservation strategy believe that nature can only be protected as part of a human landscape. Without the support of local communities, conservation projects rarely succeed. To gain their support, communities must receive some of the benefits of biodiversity conservation. Too often, economic and social gains from conservation accrue to national governments and foreign companies rather than to local people. At the same time, communities living in and around conservation projects often bear many of the costs of the venture (Wells 1994).

Ideally, ecotourism allows communities to obtain sustainable sources of income while at the same time allowing tourists to gain an appreciation of unique cultures and ecosystems. Such appreciation could lead in turn to additional income for local people.

The opposing view is preservationist: threatened species and ecosystems can only be protected in isolation from humans. Tourists, even environmentally sensitive tourists, bring development and degradation. Vulnerable local cultures, traditions, and value systems can be destroyed or diminished by the imposition of foreign values and ideas. According to this view, the best way to protect threatened ecosystems is to isolate them from contact with humans.

Both sides have valid points. Tourism undoubtedly leaves a footprint, and often leaves a heavy one. At the same time, economic gains from tourist ventures can generate local support for conservation projects, without which success can only be, at best, limited. Thus, most communities are likely to both gain and lose from ecotourism projects.

Problem statement

Five out of the seven species of sea turtles nest in Sri Lanka; these turtles face numerous threats due to poaching and coastal development.[2] Hatcheries catering to foreign and local tourists have been the major means of sea turtle conservation in Sri Lanka since the late 1970s. These ecotourist ventures portray themselves as saving millions of sea turtle eggs from certain consumption by humans and other predators. They also claim to aid surrounding communities by providing employment and income: the hatcheries buy sea turtle eggs from community members at the market rate and then re-bury them in protected egg beds on the hatchery premises.

These are their claims. But it is unrealistic to assume that such major benefits accrue to communities without any losses. The goal of my study is to examine the overall impact of the hatcheries on the communities that surround them. Do the hatcheries positively affect the behavior and attitudes of community members in areas where turtle habitat continues to be destroyed, and where the consumption of turtle eggs, meat and shells continues in spite of a total ban on the trade of all turtle products? Do they provide a significant source of income for local people? Are they merely a means of appropriating and exploiting turtles as a moneymaking venture for hatchery owners and an amusement for tourists?

Methods

Site selection

This research took place in Sri Lanka between May and July 2002. The bulk of the fieldwork took place in and near hatcheries along the southwest coast, from Negombo to a few kilometers south of Hikkaduwa. The other field site was Rekewa, on the southern coast, near Tangalle (Figure 1). Archival research took place throughout the study area, but especially in the capital, Colombo, where the largest libraries and bookstores are concentrated.

Experimental design

For purposes of triangulation, I undertook three types of research: semi-structured interviews, participant observation and archival research. The bulk of the research consisted of 103 interviews. I conducted the majority of the interviews in Sinhalese.[3]

In each town or village with a hatchery, I talked to hatchery owners and employees, visitors to the hatcheries, government employees (mainly police) and community members living near the hatcheries (Figure 2). While in Colombo, I also interviewed government officials from the Department of Wildlife and the National Aquatic Research Agency (NARA).

Figure 1 *Map of Sri Lanka. Kosgoda is near Ambalangoda, in the southwest. Rekewa is near Tangalla, in the South. Map from* ***www.lonelyplanet.com****.*

Negombo was a special case, where there were no hatcheries, but where people eat turtle meat as well as eggs. There, I interviewed policemen and members of Tamil and Sinhalese fishing communities.

In Rekewa, the hatchery was government-run, but had belonged to an NGO until the previous year. Many of the former employees had become tourist guides. I interviewed the current and former employees of the projects, as well as the tourists who were led by former hatchery employees.

At several of the hatcheries, I carried out participant observation to corroborate the answers of respondents, and to gain a sense of how sea turtle conservation techniques affect turtle hatchlings (Emerson et al. 1995). I observed the visitors, guides, and other employees, and noted interactions among them. In addition, I took photographs and made brief observations of the turtles and turtle hatchlings. In Rekewa, I observed egg collection by hatchery employees, nesting by a green turtle near the government hatchery, and the release of hatchlings at the private hatchery. Finally, I visited fish markets in Hikkaduwa, Ambalangoda (Kosgoda) and Negombo.

As a final form of triangulation, I carried out archival research to gather relevant articles and books that are published locally, to which I would not have access in the United States. In each town or village with a hatchery, I visited the local library and/or bookstore.

Results

Consumptive utilization of sea turtles: egg exploitation

As in many other parts of the tropics, coastal people throughout Sri Lanka have harvested sea

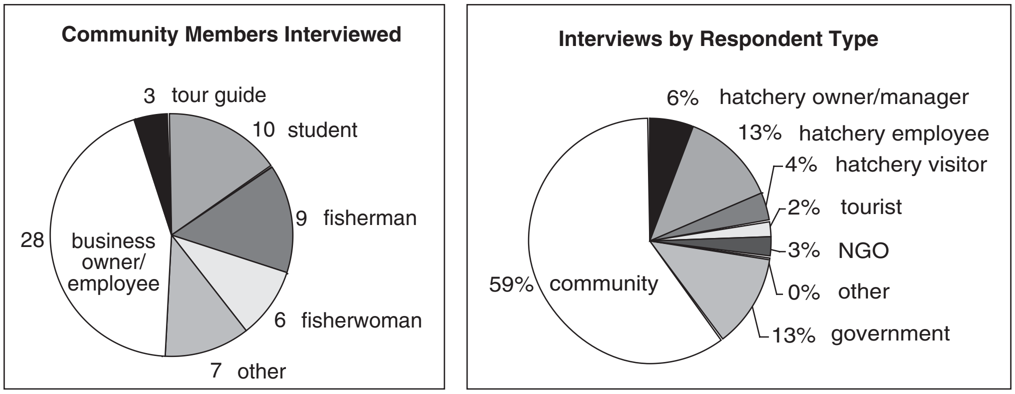

***Figure 2 a)** Respondents by type **b)** Elaboration of "community" section of respondents interviewed.*

turtle eggs for hundreds, if not thousands, of years (Kar & Bhaskar 1982). Over the past three decades, local people have reportedly disturbed almost 100% of turtle nests throughout the country in their search for eggs, in spite of long-standing legislation protecting sea turtles and turtle products (http://www.search.lk/turtle/pgs/marine.html, Fisher 1995).

Since the establishment of sea turtle hatcheries along the southwest coast, there has been a partial shift from eating eggs or selling them as food, to selling them to hatcheries. This is essentially a shift from consumption to conservation. Over 50% of respondents admitted to having eaten turtle eggs in the past, but only a little over 30% said they currently ate turtle eggs (Figure 3).

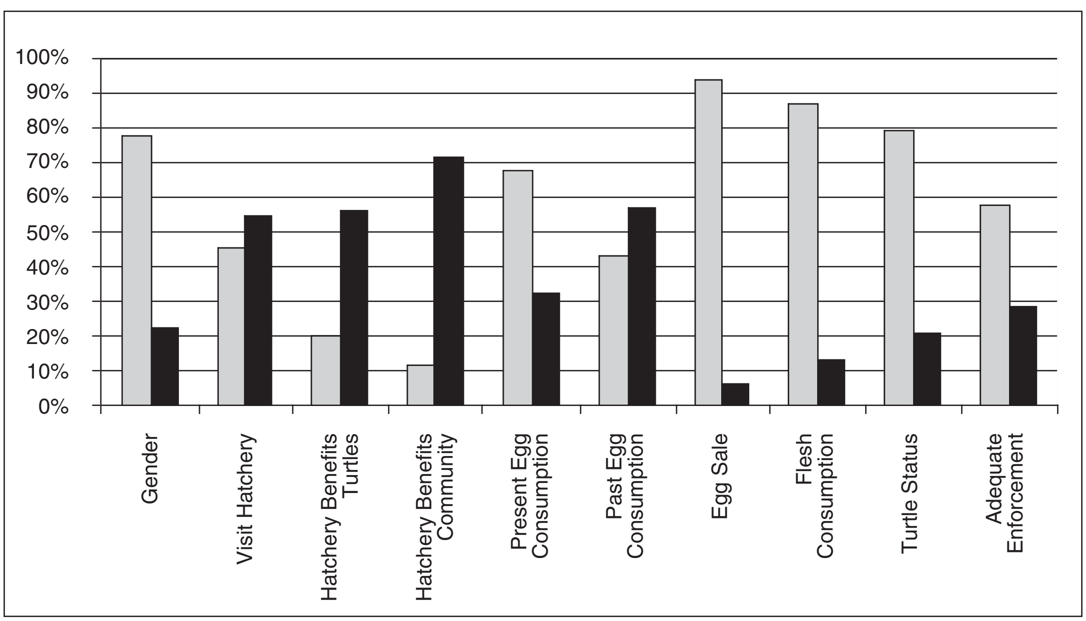

***Figure 3** Table summarizing responses from interviewees. In the fist category, gender, the gray bar represents male and the black line represents female. For column nine, turtle status, the gray bar means turtle populations are declining, while the black bar means populations are stable (and large). For all other columns, gray means "no" and black means "yes."*

This was true for all hatchery personnel and police, as well as for some community members.

Just over 10% of respondents admitted to eating turtle flesh, either in the past, or in the present (Figure 3). All of these respondents were from Negombo, where turtle flesh was commonly eaten until a few years ago. None of the respondents in other areas admitted to eating turtle flesh; most stated that they would not eat turtle meat for religious reasons, and that people in Negombo eat turtle meat because they are Christians (the vast majority of respondents in the southwest were Buddhist).

According to Mutukumara (1998) people in southern Sri Lanka unearth eggs for both subsistence and for lucrative local markets. However, I was unable to find any evidence that eggs were still sold in the physical structures of local markets, thereby suggesting a shift from the official to the unofficial sector of the economy. Community members, policemen, and market vendors all stated that eggs have not been sold in markets for at least five years. According to several respondents, turtle eggs are no longer sold in markets due to a recent increase in the enforcement of laws preventing the consumption and possession of turtle products. The increase in enforcement seems to have coincided with a drastic increase in fines for possessing sea turtle products, from a few hundred rupees to Rs.10,000-30,000 ($100-300).

Non-consumptive utilization of sea T\turtles: the hatcheries

The hatcheries along the Southwest coast vary widely in size and age; the oldest was established in 1965. However, most of them utilize the same techniques. They purchase sea turtle eggs from community members for between Rs. 3 and 8 (about $0.30–0.80) depending on the species and hatchery. Villagers collect the eggs from nearby beaches during the night, either as the female is laying them, or soon after. Hatchery personnel, who are generally from surrounding communities, then re-bury the eggs in enclosed beds of sand. After burial, the clutch is generally marked with a small sign listing the number of eggs, the date of burial and the species.

After approximately 40-60 days depending on the species and the weather, the eggs hatch. Employees transfer the hatchlings to plastic basins and then to concrete tanks filled with salt water. In most hatcheries, the hatchlings are fed with chopped fish, though some data suggests that they do not feed for the first two to three days (Carr 1982). They are generally kept in the tanks for three days, though some hatchery owners admitted that they keep them from three days to a month depending on the number of hatchlings they have at a given time.

Only in the southern area around Rekewa did I find hatcheries that do not hold hatchlings in tanks. All three hatcheries in the area release the turtles as soon as they hatch. In the government-run hatchery, the egg beds are not enclosed, so the hatchlings are able to crawl directly to the water the night after hatching, as they would in nature (Deraniyagala 1939). At a hotel-run hatchery, the egg beds are enclosed, so an employee scoops the hatchlings into a basin and releases them just outside the enclosure, from where they crawl to the sea. The Tangalle hatchery plans to use a similar protocol once they open their operation.

All hatchery personnel to whom I talked said that they release hatchlings during the night to decrease the risk of predation by diurnal animals such as dogs, seagulls and crows. However, some of these respondents claimed that employees of hatcheries other than their own release hatchlings during the day for a fee, for the benefit of curious tourists.

Knowledge

Hatchery owners and employees implied that they possessed the only “real” knowledge regarding turtles - knowledge derived mainly from the literature on sea turtles, and to a lesser extent on observation and word of mouth. They often labeled the beliefs of community members as myths or as arising from ignorance.

Community members derived their knowledge about sea turtles from various sources, including word of mouth (stories told by older family members and others), direct observation and the media. Some individuals were highly knowledgeable about the details of turtle nesting behavior, as well as about means of locating turtle eggs. Some fishermen and dive instructors knew a lot about off-shore behavior through direct observation. However, just as hatchery personnel often stated that local knowledge was not real, community members often began by stating that they knew nothing about sea turtles. The women I interviewed were particularly reluctant to share what they knew about sea turtles. They would direct me to the nearest hatchery, or to the largest hatchery in the country, the Hasselblad Hatchery in Kosgoda. Respondents in Hikkaduwa pointed me to the local Wildlife Department Office. Many respondents also suggested that I watch Discovery Channel documentaries and locally filmed programs on sea turtles.

Discussion

The presence of hatcheries in southern Sri Lankan coastal communities has affected resource flows and the legitimacy of local knowledge. The hatcheries have appropriated both sea turtle eggs and knowledge about sea turtles from surrounding communities. This appropriation has had both positive and negative consequences.

Impact of hatcheries on surrounding communities

Without a doubt, the presence of hatcheries has provided some significant socioeconomic benefits to surrounding communities. Perhaps the most obvious of these is income generation. The larger hatcheries employ a dozen or so local men as tour guides and caretakers. Since the decline of fisheries in southern Sri Lanka has increased unemployment in coastal communities, such employment opportunities are valuable. Also, the presence of hatcheries attracts groups of foreign and local visitors, who often spend money in nearby shops and restaurants. Finally, by purchasing sea turtle eggs from any community members who will sell them, the hatcheries provide an important source of supplemental income to many residents. Due to the flow of money from the hatcheries to surrounding communities, most coastal residents perceive the hatcheries positively.

While most community members and hatchery personnel mentioned economic benefits rather than education, most hatcheries do attempt to educate local school children. Entire classes of students visit the larger hatcheries (Figure 4). Most hatcheries either waive the entry fee for student groups or charge a nominal amount. In addition, students visit the hatcheries to learn about sea turtles for independent projects. Since library facilities are limited in the smaller towns and villages, the hatcheries provide an important service to students interested in marine biology and environmental studies.

Figure 4 *The education of local schoolchildren is one of the main benefits of hatcheries. In addition to higher cost tours for foreign tourists, most larger hatcheries welcome groups of students, and many give in depth assistance to students conducting research projects.*

Nevertheless, the educational benefits of the hatcheries are limited. Many adults in surrounding communities perceive the hatcheries irrelevant, as a resource and a source of entertainment only for children and for foreign visitors. Thus, the hatcheries fail to actively target the groups that are currently most active in consuming sea turtle eggs.

In addition, the appropriation of knowledge by hatcheries could lead to the loss of local knowledge regarding sea turtles. Community members dismiss the information that they have collected through observation and word of mouth in favor of the "official" information given out by hatchery personnel. Also, though people in these areas have eaten sea turtle eggs for centuries, I was unable to find any information on possible traditional management mechanisms. If such mechanisms existed in the past, they may have already been lost.

Impact on sea turtle populations

The hatcheries have brought about a shift from probable consumption of all sea turtle eggs in Southern coastal areas to the conservation of some portion of the eggs. Thus, the presence of the hatcheries increases the probability that sea turtles nesting in these areas produce viable offspring (without the hatcheries, the probability is close to zero).

Though the hatcheries are successful in protecting sea turtle eggs, the conservation techniques they employ allow turtles to reproduce and ultimately survive only through human intervention in the nesting process. Thus the fate of the Sri Lankan populations of five species of endangered sea turtles rests largely in the hands of a few individuals, most of whom are at least as concerned with profit as with conservation.

Shifting sea turtle reproduction from the beach to the hatchery is dangerous. This shift does not encourage a decrease in sea turtle egg utilization, and therefore one cannot hope to see a decrease over time in the number of disturbed sea turtle nests. If the hatcheries are banned, or if they close down for financial or other reasons, the survival of the Sri Lankan sea turtle populations becomes threatened. The hatcheries depend mainly on economic incentives to promote sea turtle conservation. Unlike with education, as well as moral, aesthetic and other non-economic forms of valuation, the desire to conserve will only last as long as the money. Also, if the hatcheries fail to pay as much as private consumers, hotels or merchants, locals will again favor consumption over conservation. This possibility is an innate part of conservation projects based on economic incentives (Hackel 1999).

Furthermore, protecting eggs from consumption does not guarantee healthy hatchlings. Holding hatchlings in tanks is a highly controversial procedure, though universally practiced in the hatcheries of the southwest coast (Figure 5). Knight (1999) was told that the holding period helps prevent infections and parasites. Several hatchery personnel told me that the holding period was meant to allow the hatchlings to become stronger, or that it was to allow time for the "wound" on the stomach to heal.[4]

Finally, continued coastal development threatens to eliminate nesting beaches in the coming decades (Figure 6). Beach erosion and pollution would decrease available nesting sites. The increasing human population could prevent nesting, since nesting females tend to be frightened away from laying by noise and light.

In spite of these drawbacks, hatcheries are currently the only attempt at conserving sea turtles along most parts of the Southern coastlines. Without the hatcheries, hardly any eggs would hatch since most, if not all, nests are discovered by coastal residents.

Overall, the benefits to sea turtle populations of hatcheries are questionable. They have potential, but the profit-conscious entrepreneurs who run most of the hatcheries do not adequately

Figure 5 *Handling and overcrowding of sea turtle hatchlings in tanks can lead to infection, wounds and overall weakening (Knight 1999, Goonathilake 1999, Wagner 1995).*

Figure 6 *Increasing coastal development threatens nesting beaches. In a few decades, turtles returning to beaches near the hatcheries where they were released may not be able to find suitable sites. This raises the question: is there any point to releasing hatchlings from unprotected beaches?*

utilize this potential for the benefit of the turtles. This pattern is not atypical, as many projects and programs that attempt to reconcile development and conservation end up favoring development (Wells 1994, Kellert et al. 2000). Most successes are socioeconomic, most failures are in conservation of biodiversity and in attaining sustainability. In some cases, socioeconomic objectives can subvert conservation goals (Kellert et al. 2000).

Recommendations and alternatives

The popularity and success of hatcheries has to do with the combination of tourist appeal, location and economics. Many of the hatcheries are primarily business ventures, not conservation efforts. Also, they are located in popular tourist areas of the country, and therefore are more accessible to visitors, both local and foreign. The beaches in these areas are not protected, and are fringed by coastal development, including hotels, stores, houses and restaurants. Due to the density of development, alternative conservation techniques such as nest protection would be both difficult and expensive. Also, the hatcheries hold a great deal of appeal for tourists. Most tourists of all ages enjoy seeing the hatchlings in tanks, getting to hold and to photograph them. More beneficial techniques, such as *in situ* conservation, leave little to see, since hatchlings are not held in tanks, and since newly hatched turtles crawl to the sea at night.

In situ conservation, conservation without direct human intervention in the nesting and hatching process, is far more likely to benefit turtle populations. The ideal for sea turtle conservation is probably similar to what was attempted by a foreign NGO in Rekewa: a community-based project that employs guards and researchers to monitor and protect sea turtle nests along stretches of undeveloped beaches. Unfortunately, not many traditional turtle nesting areas, or rookeries, are located along stretches of coast untouched by development. The few rookeries in undeveloped areas should be made into protected areas, preferably into marine protected areas that conserve both the beach and the adjacent coastal ocean. Nest protection programs could be located within or at the boundaries of these areas.

Nest protection projects could be funded by charging more money per visitor than the conventional hatcheries. As it is, in Rekewa, former employees of the nest protection project charge tourists Rs.300 (about $3) to see nesting turtles. This is 3-6 times what the hatcheries charge, but is still far less than what most foreign tourists would be willing to pay for the experience of seeing a wild sea turtle nesting. By keeping admission costs high, nest protection projects could keep the number of visitors low enough to prevent disturbing the turtles and polluting the beaches. At the same time, there should be enough funds to initiate education programs for local school children.

Hatcheries may remain the best option for developed areas. However, current hatchery practices would have to be modified. According to Kosgoda hatchery owner, Chandrasiri Amaresena, no more than 10% of hatchlings should be kept in tanks (pers. comm). All other hatchlings should be released on the night after they hatch, and should be allowed to crawl from the edge of the beach to the sea. Also, egg collection needs to be restricted to a small area around the hatcheries, both to reduce transportation time, and to imprint the hatchlings to the correct nesting beach.[5] Finally, hatcheries need to focus more on training and educating egg collectors in particular, and community members in general, regarding the threats to sea turtles resulting from egg consumption. At the same time, they need to emphasize the value of local knowledge.

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References

Carr, A. 1982. Notes on the behavioral ecology of sea turtles. In *Biology and Conservation of Sea Turtles* (Revised), K. Bjorndal (ed.). 1995. Washington, D.C., Smithsonian Institution Press.

De Silva, N. 2002. Rekewa: Successes and failures of community based sea turtle conservation in Sri Lanka.Yale University School of Forestry and Environmental Studies. Unpublished Report.

Deraniyagala, P. E. P. 1939. *The Tetrapod Reptiles of Ceylon. Volume I: Testudinates and Crocodilians.* London, Dulau & Co., Ltd.

Emerson, R. M., Fretz, R.I. and L.L. Shaw. 1995. *Writing Ethnographic Field Notes.* Chicago: The University of Chicago Press.

Fisher, S. 1995. Illegal turtle trade in Sri Lanka and the Maldives - and an encouraging note of progress. *Marine Turtle Newsletter* 71:10-11.

Goonathilake, T. 1999, August 11. Policy to breathe new life into sea turtles. *Daily News.*

Hackel, J. D. 1999. Community conservation and the future of Africa's wildlife. *Conservation Biology* 13 (4):726-734.

Kar, C.S. and Satish Bhaskar.. 1982. Status of sea turtles in the Eastern Indian Ocean. In *Biology and Conservation of Sea Turtles* (Revised), K. Bjorndal (ed.). 1995. Washington, D.C., Smithsonian Institution Press.

Kellert, S. R., Mehta, J.N., Ebbin, S.A. and L.L. Lichtenfield. 2000. Community natural resource management: promise, rhetoric, and reality. *Society and Natural Resources* 13(8): 705-716.

Knight, A. 1999. Sri Lanka Turtle Project. At http://www.iar.org.uk/Pages/turtrep.html/. Retrieved November 24, 2001.

Mercer, D.1996. Ecotourism. *Geodate* 9 (1): 1-4

Mutukumara, N. 1998, April 17. The fascinating world of turtles in Sri Lanka. *Daily News.*

Turtle Conservation Project website. At http://www.search.lk/turtle/pgs/marine.html.. Retrieved November 20, 2001

Wagner, T. 1995, June 18. Endangered sea turtles facing array of enemies. *Los Angeles Times: Sunday Bulldog Edition.*

Wells, M. 1994. Biodiversity conservation and local development aspirations: New priorities for the 1990s. In *Biodiversity Conservation,* Perrings, C.A., Maler, K.G., Folke, C., Holling, C.S. and B. O. Jansson (eds.). The Netherlands, Kluwer Academic Publishers.

Notes

1 Ecotourism is a concept that has been defined as many things. Not all ecotourism is community based, but much community based conservation involves ecotourism. The Sri Lankan hatcheries can be considered ecotourist initiatives under a broad definition, such as that of the Ecotourism Association of Australia (EAA). According to the EAA, "ecotourism is ecologically sustainable tourism that fosters environmental and cultural understanding, appreciation, and conservation" (Mercer 1996).

2 The seven species of sea turtles are: the small Olive Ridley (*Lepidochelys olivacea*), the huge Leatherback (*Dermochelys coriacea*), the commercially valuable Green Turtle (*Chelonia mydas*), the Flatback (*Chelonia depressa*), the Loggerhead (*Caretta caretta*), the Kemp's Ridley (*Lepidochelys kempi*), and the Hawksbill (*Eretmochelys imbricata*). The Kemp's Ridley and Flatback are not found in Sri Lanka.

3 Most residents of the southern coastal towns and villages with hatcheries were Sinhalese, and most Tamils in this region speak Sinhalese in addition to Tamil. The few interviews I conducted in English were with high-level government employees and NGO representatives in Colombo.

4 This "wound" is actually the remnant of the embryonic yolk sac, which is thought to contain energy for the swim to deeper water (Carr 1982).

5 Transportation of eggs over long distances increases the chance of damage to the embryos through jostling, crushing, and temperature change. Temperature change can change the sex ration, and if extreme, can kill the embryo.

Part Dissipation: the Free Trade Area of the Americas and civil society

Nikhil Anand, MESc 2004 and Jonathan Cook, MEM 2004

Introduction

In recent years, states and multilateral development agencies have increasingly emphasized the importance of local institutions for resource management. The language of local participation, as emblematic of values of democracy and representative decision-making, is grafted onto a whole host of development projects ranging from watershed revitalization to forest and ecosystem management. Many studies have focused on the extent of actual participation in these local-level efforts. On the other hand, citizen participation in the process of constructing international trade agreements has rarely been explored. Yet these global negotiations are often deeply influential on local resource management regimes. This paper will examine the processes of participation by civil society in the ongoing talks surrounding a potential Free Trade Area of the Americas (FTAA).

Over the last decade, the United States has pressed hard for the expansion of free trade throughout the Western Hemisphere. In 1990, US president George Bush announced plans for a free trade zone that would stretch from Anchorage, Alaska, to Tierra del Fuego at the southern tip of South America. Four years later, in Miami, heads of state from 34 nations of the Americas (with the exception of Cuba) announced an initiative seeking to integrate their economies through a major trade agreement. This came to be known as the FTAA. At its basis is the conviction that economic integration has a crucial role to play in strengthening democracy, creating prosperity, and realizing human potential (FTAA 2002a). As of 2002, nine FTAA negotiating groups were in place, organized around themes of (a) agriculture, (b) investment, (c) services, (d) intellectual property rights, (e) subsidies and countervailing duties, (f) competition policy, (g) market access, (h) government procurement, and (i) dispute settlement. Committees on (a) e-commerce, (b) small economies, (c) civil society, and (d) institutional issues were also formed to provide recommendations to the negotiators. FTAA negotiations are scheduled to end by January 2005.

This paper looks more closely at the FTAA Committee of Government Representatives on the Participation of Civil Society (hereafter referred to as the Participation Committee or the Committee). We argue that, in setting up this Committee, the FTAA negotiators have done little more than create a superficial process by which to take on a more democratic appearance. We also examine the varying responses of civil society organizations towards this official offer of engagement, as well as their own ideas about participating in the FTAA process. We do this through a closer look at events surrounding the FTAA ministerial negotiations in Quito, Ecuador, in October 2002.

Constitutions of participation

The Participation Committee emerged in 1998, four years after regional heads of state agreed to support the FTAA. The Committee was an attempt by nations of the Americas to "affirm their commitment to the principle of transparency and to acknowledge and welcome the interests and concerns expressed by different sectors of society in relation to the FTAA" (FTAA 2002b). When they met subsequently in Buenos Aires and Quito, trade ministers recognized the need to "build public understanding and support for hemispheric trade liberalization" (FTAA 1999).

From the start, the goal of public participation was not to determine the form of a hemispheric trade agreement, but to secure consent for one that was already being drafted.

Framing the engagement of civil society within the context of the FTAA was a clever way to ensure an understanding that there will be, and should be, an FTAA. By "acknowledg[ing] and welcom[ing]... concerns," the participatory frame is arranged in a way that empowers those doing the welcoming and acknowledging, that places them in a position of power above those who are invited to participate. This leaves civil society organizations with a difficult dilemma. To what extent does participating in the process legitimize it? How effective is a strategy of protesting outside ministerial meetings compared with the possibility of negotiating inside though with few opportunities for any substantive negotiation? Confronted with these questions, groups are responding in different ways.

The views of civil society vis-à-vis the FTAA participatory process can be loosely arrayed along a spectrum that ranges from total opposition to reformist engagement .[1] Some critics want increased access to the negotiators, and greater inclusiveness and transparency for the process. This may stem from a belief in the inevitability or necessity of an FTAA, and/or a pragmatic desire to mitigate its negative aspects while there is still a chance to do so. Anderson and Cavanagh (2002) distinguish between those who see reform measures as a way to ensure the eventual approval of an FTAA, and those who see them as an opportunity to improve the content of an FTAA that is already ensured of approval. Some reformists explicitly justify their participation in the process as a way to "enhance [the] credibility" of a future agreement (Gitli and Murillo 2002: 282). Other critics want to abolish the FTAA even before it begins. They believe an agreement would be inherently flawed, without a popular mandate, and produced by a bad system and they want nothing to do with it.

CEDA — just participation?

The Participation Committee calls upon countries hosting negotiating rounds "*to extend the necessary courtesies to civil society organizations wishing to host parallel conferences or be heard*" (FTAA 2002b, emphasis added) This approach to participation is reinforced in frequent calls for constructive contributions. Clearly, 'constructive contributions' are seen as those that strengthen the FTAA negotiating process.

Some groups have responded to this call. These organizations, including major transnational NGOs, research institutes, and nonprofit foundations, strive to take advantage of recently opened spaces for participation (however limited) in the FTAA process. They are among the most faithful participants in the Participation Committee, offering a range of proposals for greater transparency and accountability and generally seeking to influence the process from inside.

At the ministerial summit in Quito last year, two NGOs from Ecuador, CEDA (the Ecuadorian Center for Environmental Law — closely linked with IUCN, the International Union for the Conservation of Nature) and FFLA (Latin American Foundation for the Future), organized a series of seminars and discussions prior to the FTAA ministerial negotiations under the heading "Towards civil society participation in the Americas". Other sponsors and participants were a mix of environmental groups and think tanks, many of them based in the USA or Canada and with a reputation for mainstream policy positions, like the World Wildlife Fund, the World Resources Institute, and the Carnegie Endowment for International Peace. Representatives from these groups worked to compile a comprehensive set of recommendations, which were to be presented to the trade ministers later that week.

A welcome letter distributed at the CEDA/FFLA conference looked forward to productive discussions of trade and environmental issues "in the context of the future Free Trade Agreement of the Americas" (CEDA 2002b). The conference invitation declared that the FTAA "requires public support for the continuance of the negotiations and to achieve broader legitimacy and regional balance" (CEDA 2002a). There are important assumptions explicit in these phrasings that an agreement is inevitable; that cooperation by civil society can provide it with a legitimacy that it currently lacks. Despite representing only a fraction of Latin Americans, and despite a distinct lack of interest in some of the most commonly heard concerns about the FTAA, the CEDA/FFLA project provides an aura of reasonable and well-meaning criticism. Because it shies away from questioning the basic legitimacy of the FTAA process, it is that much more easily appropriated into the process of FTAA self-constitution.

Submit!

Ever since its formation, the Participation Committee has been struggling for this legitimacy. It has issued three invitations (through the Internet) for civil society input first in 1999, and subsequently in 2001 and 2002. During this period, the Committee received submissions from about 130 individuals and organizations. For a trade agreement of this magnitude, this is not much in the way of public participation.

In 1999, organizations from only 16 countries sent in submissions; half of these were from the US or Canada.[2] A third were from the business sector, which is also considered part of "civil society" and which saw a clear opportunity to advance its own agenda. The narrowness of representation was worrying even to the Committee, which saw the range of opinions as not representative of civil society throughout the hemisphere (FTAA1999:3). The implications of this lack of participation were both obvious and important: either the citizens of the countries in question did not know about the FTAA process, or they did not see any significant benefit in providing input to the process. By 2002, according to the Participation Committee's own statistics, the bulk of submissions were not recommendations to any single negotiating group (such as agriculture or market access), but more general concerns about the FTAA process itself and the role of civil society within it. Many of those who chose to participate were thus doing so by questioning the framework of participation itself.

After all, there is considerable evidence that civil society participation is having little impact on the actual course of the FTAA negotiations. Even at CEDA's workshop on investment policy, attendees expressed frustration about their suggestions dropping into a bottomless "participation mailbox". While the Participation Committee receives concerns from civil society, it is not obliged to respond to them, leaving many concerns about the FTAA unacknowledged and unanswered. In addition, detailed objections and recommendations are being consistently marginalized and co-opted by the Committee.

Following each round of submissions, the Participation Committee prepares a report for the Trade Negotiations Committee. These written summaries of participant input over the last three years have been remarkably similar to each other and not representative of the opinions they pretend to summarize. Despite the fact that most input to the Participation Committee is critical of the FTAA, every summary begins with an example of support.

Intellectual propriety

Nowhere is this misrepresentation more clear than in the Committee's summary of participant input on the issue of intellectual property rights (IPRs). The draft FTAA echoes the TRIPs (trade-related intellectual property) provisions of the World Trade Organization, and requires states to enforce them. This is clearly a controversial issue: Of the 57 civil society responses received by the Participation Committee, 22 were directed towards the Negotiating Committee on Intellectual Property. Of these 22 comments, only six supported the approach of the Negotiating Committee (and its very existence). These came from the Argentinean Business Forum, the American Apparel and Footwear Association, the Brazil American Business Forum, the Council of the Americas, the International Trademark Association

(INTA), and an NGO called Caribbean Latin American Action.

Representing less than a third of the responses submitted, these pro-IPR opinions were nevertheless given considerable prominence by the Committee in its summary of civil society responses. The summary starts with a strong assertion of the need for intellectual property rights; significant objections to this viewpoint only appear later. None of the documents being summarized provide as clear a rationale for intellectual property rights as that given at the beginning of the summary itself. At best, the Committee is editorializing and rationalizing its own perspective in favor of IPRs.

Opposition to IPRs was manifested in comments from individual citizens, as well as the Canadian Postal Workers Union, the Carnegie Endowment for Peace, the National Foundation for Development in El Salvador, Health GAP, the UAW International Union, Doctors Without Borders, the American Friends Services Committee, and the Research Council for Central American Development, among others. Many of these saw the inclusion of IPRs in the FTAA as a process driven by the United States to advance its own interests. Doctors Without Borders (2002) argues that the US position on IPRs will have significant impacts on human health. Stronger IPR regimes would threaten pharmaceutical companies in developing countries with legal action, and as a result, much of the developing world, not just Central and South America, could lose access to life-saving prescription drugs.

However, these voices are completely absent in the Participation Committee's summary. When the Committee summarizes these dissenting opinions, they stand alone without the explanations provided in the original documents. The summary never explains why people are against IPRs, and completely ignores the potential impacts of IPRs on human health. Multiple arguments are merely condensed into a two-line item that mentions how some critics want limits on the protection of intellectual property in order to safeguard human health and safety (FTAA 2001). By contrast, a single submission that advocated moving towards the elimination of countervailing duties and antidumping measures is elucidated in a five-line note that even details a process by which this might take place.

By responding only to certain issues and perspectives, FTAA officials are thus actively engaged in shaping a particular discourse on IPRs. The Participation Committee reveals itself not as a conduit for the two-way flow of information, but as an active player in the process of shaping this information to manufacture consent. By inviting participation and then subsequently simplifying or erasing the responses received, the Committee asserts the power of a certain discourse over the diverse interests of other populations.

First — the rules of the game

For this reason, while civil society groups like CEDA willingly engage in the FTAA process, others are pursuing a strategy of mobilization and opposition from the outside (see Figure 1). They have essentially posed a critical question to the FTAA participatory process: "Can [this] really

Figure 1 *Demonstrators gather in Quito to march against the FTAA.*

help bring about new forms of knowledge, power, action and know-how, needed to create a different type of society?" (Rahnema 1992:124). For organizations fundamentally opposed to the FTAA, like the Mexican Action Network on Free Trade (RMALC) and the Latin American Congress of Rural Organizations (CLOC), tinkering with the official participatory process is a dead-end. These critics feel that the emphasis on process rather than substance is a Trojan horse, designed to secure tacit compliance with the negotiators' agenda in exchange for token gestures of inclusion. 'Participation' is seen as rubber-stamping rather than active involvement. civil society receives information on what is happening, but has little opportunity to affect it. At best, the constant rhetorical emphasis on 'transparency' suggests that the ministers simply intend that the heavily guarded fortress within which FTAA negotiations take place be equipped with glass windows.

For these critics, form and content are inextricably linked. According to the Hemispheric Social Alliance, a coalition of social movements from across the Americas, "the proposed [FTAA] text fails to incorporate the many proposals raised by citizens' organizations" (2002). Instead, the lack of a democratic and truly broad-based participatory process has produced a draft document that does not address critical issues facing the Americas. Activists have said that if there were truly a dynamic and constructive process of soliciting and including citizen input, the FTAA would not exist in its current form. Lori Wallach of the US group Public Citizen has compared the 'alternatives' produced through the existing framework of cooperative engagement to "rotten apples and rotten oranges" (Gerson, pers. comm.).

Consequently, many groups are keeping a significant distance from the official processes of consultation and inclusion. However, groups may send occasional comments to the Participation Committee and lobby their national governments in hopes of influencing negotiating positions. "We do see some value in participation because access to documents is helpful," adds one U.S. activist (Gerson, pers. comm.). And there is considerable public-relations potential to be derived from engaging in the participatory process as a strategy of monkey-wrenching that cleverly exploits and publicizes the gaps between rhetoric and reality: "A guy from Greenpeace not getting onto the Committee led to great press releases attacking the FTAA's secrecy" (Gerson, pers. comm.).

Strained encounters

This gulf between rhetoric and reality perpetuates the existence of significant barriers between FTAA negotiators and their supposed constituents — the people of the Americas. And so, even as governments solicit a certain kind of participation from inside the process, tens of thousands of people have taken to the streets of Quebec City (during the 2001 ministerial meetings) and Quito (in 2002) to protest from the outside. In Quito, towards the end of the official summit, these different forms of participation came face to face. After a chaotic day in which police and soldiers fired tear gas at thousands of demonstrating protesters, the Ecuadorian government requested that the trade ministers meet with a diverse range of representatives of civil society that had spent the day in the streets.

And so, along with the delegation from CEDA, whose recommendations had previously been solicited, leaders of organizations representing indigenous peoples, farm workers, and labor unions were grudgingly allowed to take their places in a conference room at the heavily guarded Swissotel. What followed was, depending on who described it later, either riveting political theater or a nasty bit of calculated rudeness. The CEDA representatives began reading their list of suggested reforms to the FTAA process, but were interrupted by the protesters (now participants), who shouted comments like "Aquí no hay democracia" ("There's no democracy here") and denounced the speakers as "sell-outs." The ministers then sat uncomfortably through powerful speeches by Leonidas Iza, the head of CONAIE (a coalition of indigenous groups in Ecuador), and

Maria Elena Siquiera, a leader of the Nicaraguan farm-workers movement, who read from their declaration: "We come here not to engage in a dialogue. The governments here have been closed to any real dialogue with their civil societies. We come here to demand that they suspend the negotiations of the FTAA... The ultimate authority in matters of national sovereignty is the people, and they should be making these decisions" (NO ALCA 2002).

The ministers had then expected a photo opportunity with their critics, as a way to generate visual evidence of "participation" by civil society. Instead, the flag-waving, singing delegation of activists crowded out of the room and, in a powerfully symbolic gesture, marched through the luxurious hotel lobby, past tightly packed lines of unsmiling security men, out the doors, and down the empty boulevard. In the distance, kept outside by a police cordon the space normally designated for dissenters unwilling to "participate" a crowd of cheering protesters awaited their return.

This unprecedented occupation of official ministerial space was a significant indication of how the FTAA opposition is challenging and reworking traditional notions of dissent and resistance to a hegemonic process. Successfully navigating a difficult set of dilemmas about cooptation, at least for the moment, the representatives of civil society had crossed into the fortress of power without participating on its terms. There, they had also confronted the reformist wing of civil society, criticized its representational politics, and denounced its recommendations as insufficient and incapable of effecting change within the rigid confines of the FTAA process.

In Conclusion

Meanwhile, in the absence of any meaningful engagements, the Participation Committee continues to lack credibility, and has essentially admitted as much. Participants in this consultative process have mostly been professional institutions who themselves doubt its efficacy and legitimacy. Following the summit in Quito, the Committee issued a 'permanent invitation' in an effort to gain additional input. But every step it takes to open up the process and gain credibility reveals more skeletons hiding in the closet. The misrepresentation of civil society opinions, for example, would not have been as visible had the Committee not chosen to make them available in an effort to seem 'transparent'. On the other hand, should it report civil society opinions, it makes visible the considerable dissent and disagreement felt about the FTAA.

In a way, the dramatic meeting in Quito satisfied both those participating within the FTAA participatory framework and those protesting outside. While expressing frustration with the Participation Committee, one group participating in the CEDA workshop privately admitted that the altercation between civil society groups had sent a powerful message to the negotiators to take the moderates more seriously.

While those at the CEDA meetings were aware that their input into the FTAA process was likely to be ignored or marginalized, the mood among those protesting in the streets was exuberant. Trade ministers were compelled to respond to their dissent by inviting them into the civil society meeting. Protesters managed to participate in that meeting even as they rejected the homogenizing logic of 'participation' within these structures of the FTAA as a false beginning, which can only lead to problematic ends.

Unconstrained by any sense that the FTAA is necessary or inevitable, groups like the Brazilian Landless Movement (MST) are taking 'public participation' to its logical end. They are organizing referenda in their communities to determine if regional economic integration is desired, and if so, what kinds. In doing so, they attempt to shift the locus of decision-making from elected leaders (who seek to convince their populations) to the populations whose preferences are supposedly being represented. When coupled with visible dissent on the streets, these groups opposing the FTAA are using the processes and language of direct democracy to deny the FTAA Participation

Committee, and those using it, the legitimacy of a popular mandate.

References

Anderson, S., and J. Cavanagh. 2002. State of the Debate on the Free Trade Agreement of the Americas. Institute for Policy Studies.

CEDA. 2002a. Invitation letter for "Towards Civil Society Participation in the Americas."

CEDA. 2002b. Welcome letter for "Towards Civil Society Participation in the Americas."

Doctors Without Borders. 2002. Open Invitation to Civil Society in FTAA Participating Countries. Doctors Without Borders (MSF).

FTAA. 1999. Report of the Committee of Government Representatives on the Participation of Civil Society to the Trade Negotiations Committee. FTAA- Committee of Government Representatives on the Participation of Civil Society.

FTAA. 2001. Report of the Committee of Government Representatives on the Participation of Civil Society to the Trade Negotiations Committee. FTAA- Committee of Government Representatives on the Participation of Civil Society.

FTAA. 2002a. "Ministerial Declaration of Quito," vol. 2002. Quito: FTAA- Committee of Government Representatives on the Participation of Civil Society.

FTAA. 2002b. Report of the Committee of Government Representatives on the Participation of Civil Society to the Trade Negotiations Committee (TNC FTAA Committee of Government Representatives on the Participation of Civil Society.

Gerson, Timi. Interview. November 20, 2002.

Gitli, Eduardo and Carlos Murillo. 2002. *Greening the Americas: NAFTA's Lessons for Hemispheric Trade*. Carolyn Deere and Daniel C. Esty (eds.). Cambridge, MA: MIT Press.

Hemispheric Social Alliance. 2002. Statement on the Declaration by Trade Ministers Meeting in Quito on the FTAA Negotiations.

No ALCA. 2002. Mensaje de la Movilización de los Pueblos de América a los Ministros de Economía y Comercio Reunidos en Quito, Ecuador. October 31, 2002. hyperlink: http://www.movimientos.org/noalca/show_text.php3?key=1153>, accessed April 1, 2003.

Rahnema, M. 1992. Participation. Pp. 155-176. In *The Development Dictionary- A Guide to Knowledge as Power*, W. Sachs (ed.). Hyderabad: Orient Longman Limited.

Notes

1 This echoes but was derived independently from the "Spectrum of Policy Reform Positions" established by Anderson and Cavanagh (2002), who array them as follows: "Stop FTAA," "Comprehensive Alternatives," "Reform," "Parallel Processes," and "'Clean FTAA."

2 During the Committee's second comment period, between April 10 and September 30, 2000, it received a total of 72 responses – of which 55 came from the United States, Canada, or Chile.

Finding a new direction during a participatory community mapping project

Amity Doolittle, Program Director Tropical Resources Institute

Introduction: tensions between academic and participatory research

Many students, scholars and practitioners of sustainable resource use believe that successful resource management projects must include the active participation and support of local communities. But how do we best achieve participatory research within the boundaries of academic work? Ideally in participatory action research (PAR) the community's and the researcher's objectives are compatible. However, the reality is that PAR is fraught with obstacles. Success in the academic world is based on the researcher's ability to collect unique data that can be used to test hypotheses, build compelling case studies and ultimately advance theoretical models. As a result it is not always easy to align the researcher's objectives with community priorities. Therefore, at a very basic level there is tension between participatory and academic research models. Yet, another overriding tension still drives many academics to attempt PAR: in addition to academic goals, many scientists are dedicated to empowering the people they work with and to finding real world applications to their research. The following case study demonstrates an example of how these tensions play out on the ground.

Community mapping: working with NGO members

In the summer of 2002, I was invited to join Dr. Lisa Curran's long-term research project exploring the influence of humans, land use change, fires and climate on forest dynamics and carbon sequestration in West Kalimantan, Indonesia. The main goal of this NASA-funded project was to document the rate and extent of land cover change in West Kalimantan and to explore the causal factors driving the change. As part of this research project Dr. Curran asked me to work with several local Indonesian NGOs and a local village on a community mapping project. Her objective for this component of the project was to equitably involve communities and local NGOs in gathering research data in order to promote positive changes in environmental management. The Indonesian NGOs involved in this project already had considerable experience and technical skills working with global positioning systems (GPS) and geographic information systems (GIS). My objective as a social scientists was to work with Dr. Jeff Fox (a geographer from the East-West Center) to train the NGO members in social science research methods that can be used to understand property rights systems, document oral histories of landscape change, and to look at contemporary patterns of land use and land conflicts. Our goal was to convey the notion that the landscape and the maps you make of it can be seen as "social histories of geography", not just symbolic representations of physical geographic features.

We began our training exercises in a classroom setting with Indonesian members of 15 different local NGOs from West Kalimantan. In the context of Indonesia and the current political instability associated with de-centralized governmental authority, community maps hold strong currency to individuals and communities trying to document their rights to land. These NGO members were all interested in supporting indigenous peoples in their struggles over land rights. Our first step was to facilitate discussions about the capacity of community maps to empower and the importance of understanding social meanings attached to natural resources. In the context of the larger research project, we emphasized skills needed to document changes in land use patterns within village territory. This data would be particularly valuable for determining the ability to predict land use regimes from remote-sensing images and scale up local observations to the province of West Kalimantan. Specifically, we were interested to see if differences between advanced secondary forest and managed fruit and rubber orchards could be determined from remote sensing images (Landsat ETM+ 30 m resolution). The answer to this question has powerful implications in terms of land rights. There are instances in Indonesia when government officials make decisions about boundary placement for plantations and forest concessions based on forest cover determined from satellite images. In these circumstances, their ability to recognize the signs of managed lands (such as fruit orchards and rubber tree gardens) and the existence of local use rights is crucial. If such a distinction could be made from satellite images, there is the potential to reduce land conflicts between indigenous people and concessionaires.

The classroom discussions quickly heated up as we worked through the broader implications of dealing with native customary law and community mapping in a political climate where traditional claims to land rights are often not legally recognized. The participants expressed concerns that a seminal court case in Sarawak, Malaysia, where community maps were not allowed as evidence of native people's ownership of customary forests, might have implications for Indonesia. We debated the pros and cons of re-invigorating or codifying native customary law, which by nature is designed to be flexible and responsive to political and economic changes. Given these discussions, it seemed as if all participants had similar objectives for this community mapping project.

Community mapping: working with the community

One of the NGO leaders had organized the entire field exercise and handled all the communications with the village. As a result, Dr. Fox and I had no prior knowledge of the region or community participating in the mapping workshop, which turned out to be a communication gap that hampered the progress of the project. One explanation for this communication break down is that the lead NGO, in an effort to gain legitimacy and increased power in the region, effectively co-opted the mapping exercise and attempted to control as much of the information flow as possible, for their own purposes.

As soon as we arrived in the village, two events occurred which indicated to me that the community had an agenda of which I was not previously aware. First, village elders greeted us with a ritual cleansing ceremony, which is traditionally used throughout Borneo to "cleanse" outsiders of evil spirits before they enter the village, and to gain permission from the deities for our visit. Several young men and women performed traditional dancing and we were offered rice wine from a water buffalo horn. It appeared as the villagers were placing considerable importance on our arrival, which suggested to me that this project was more important to the village than I had anticipated.

Second, I saw several young men wearing a tee shirt that said, "Give us back Bukit Bunga-Bunga (Flower Hill).[1] This indicated to me, as I later confirmed through interviews with villagers, that the village was well-organized on issues of land rights and they had a vested interest in the outcome of our mapping exercise. This community seemed mobilized for social action at a level we had not anticipated. While this was a welcome discovery, it did alter our first impressions of our role as facilitators. A better understanding of the roots of this collective action was key for us to be valuable facilitators of the mapping process

We started the following morning by working as a group (facilitators, NGOs members and villagers) to identify key topics that we might like to explore in interviews about land rights and resource use. These topics included agricultural cycles, gender differences in resource use, oral histories of landscape change, resource use conflicts, village resource-based economics, and so on.

Over the next few days as I interviewed villagers, I learned about the central issue that was motivating both the villagers and the NGOs in their participation in the mapping exercise. In 1992, a massive oil palm plantation had been planted on land that the villagers felt was their territory. The plantation owner had arranged compensation for the village; each household had the right to manage and harvest palm fruits on a small plot of the plantation. However, 30% of the profits from the fruits had to be returned to the company. To many villagers, this seemed less like compensation, and more like coerced sharecropping on their own land. Villagers were determined that the land, known locally as Bukit Bunga-Bunga, should be returned to the village. We were aware of the conflicting claims resulting from the plantation prior to this mapping exercise. But since the plantation and village had reached a settlement over a decade ago, we had not anticipated that this conflict would still be considered unresolved by villagers. Yet it was this very conflict that was motivating the villagers to produce a map showing the village territorial boundaries. They hoped that a map could be used as evidence of ownership to reestablish their rights to village territory. Their desire to map the perimeter of the village meant that our interests in mapping land use patterns, the social history of land use changes and other “social” aspects of the landscape were not compatible with those of the community members. In fact, our research objectives seemed irrelevant in the current context of village life. We felt that knowledge of the social processes surrounding resource use and ownership were important for the village and local researchers in their negotiations with outsiders who have encroached (with state sanction) on their territory. NGO and village researchers, however, were more concerned with a different type of knowledge production: the mapping of their territorial boundaries.

Following the spirit of PAR it was our role to provide the villagers and NGO members with the tools to reach their objectives. Yet in terms of obtaining the data that was valuable to the larger research project, it was our job to try and map land use regimes inside the village boundaries, and to train the NGO members to be able to replicate this work in other villages. While we wanted to conduct interviews and transect walks, most participants wanted to walk the village boundaries with GPS units. How could we reconcile or bridge these differences?

As facilitators, we chose to make ourselves available to any community members and NGO members who wanted to conduct interviews with villagers in order to gain a social understanding of the landscape. A small group stayed with us each day to interview people, conduct transect walks through gardens and managed forests, and visit places of ritual and historical importance to the village. A much larger group, however, met each morning to mark the village boundaries with GPS technology. In the evenings, both groups would meet and share data. The group that conducted interviews would share their key findings with the larger group and the ones that collected GPS points would translate that data to a GIS database to be overlain on the satellite image. In order to fulfill our objective of emphasizing the social nature of landscape change, we would focus our discussion on why a social history of the landscape was valuable in terms of long-term management of the village’s resources. By providing the community with this knowledge, we were hopeful that we could provide them with tools that would increase their power and authority in future community efforts to validate their historical ownership and claims to their land.

Conclusions

Several interesting conclusions can be drawn from this case study in PAR. First, there were many obstacles to the success of this project. One obstacle was the early communication failure between all the groups involved. Open communication is absolutely necessary for the success of any project. We did not know that the village had a clear objective prior to our arrival. If we had known about the strength of the villager's opposition to the settlement from the oil plantation, we would have realized the importance of resolving external boundary conflicts for this village. Instead, we focused our early exercises on understanding internal village dynamics over resources ownership and management. It is not uncommon for Indonesians not to correct outsiders when they are wrong or operating under incorrect assumptions. Therefore, it took us some time to understand why the villagers' interest in this topic was not high. Once we did reach this understanding, we were able to refocus our group activities to meet village priorities. Reaching these kinds of hurdles in research is the relatively common; this example emphasizes the need to be self-reflexive in the field.

Another obstacle was our limited time with the village and NGO members. If we had more time to stay in the village to continue this work it might have been much easier to fulfill both the village's and our objectives. It would not have compromised either objective to have two different groups gathering different types of data and meeting in the evenings to share their findings. But since we were there for less than two weeks, ultimately we had ensure that the villagers' goals were the primary objectives, even though it meant that ours were sacrificed. The final product of our research was a map of the village perimeter. We only collected very basic data on the land use regimes, resource management systems and the social history of the landscape. And we were not able to map the variations in land use within the village boundaries.

A second conclusion can be drawn from this case study: this is a clear example of the community (and the organizing local NGO) using "experts" (western social scientists) in a political manner to support their position in a century-long struggle over land rights. It is not unusual for governments and conservation groups to use western experts to support their goals, but it is a turning of the tables for an indigenous community to use western researchers in this way. It seems appropriate for the positions to be reversed, given that this was a PAR project, designed to empower community members.

Third, this case does give us the opportunity to reflect on the positive outcomes of PAR, even when the project struggled over differing objectives. All the data were left with the community and the NGOs involved in the project. Access to and ownership of this data create opportunities for empowerment for these groups in future struggles over boundaries. And finally, while we did not create a map of the land use regimes within the village, we did take an initial and necessary step toward that objective by training a few NGO members in social science methods. Given the political and economic realities in Indonesia, mapping the perimeters of the village should be the first step in a long process of staking claims to land and resources. Only once these boundaries are defined can land use regimes with the territory be mapped. The villagers and NGO members that we worked with are certainly positioned to work on that mapping exercise when they feel that information would be useful.

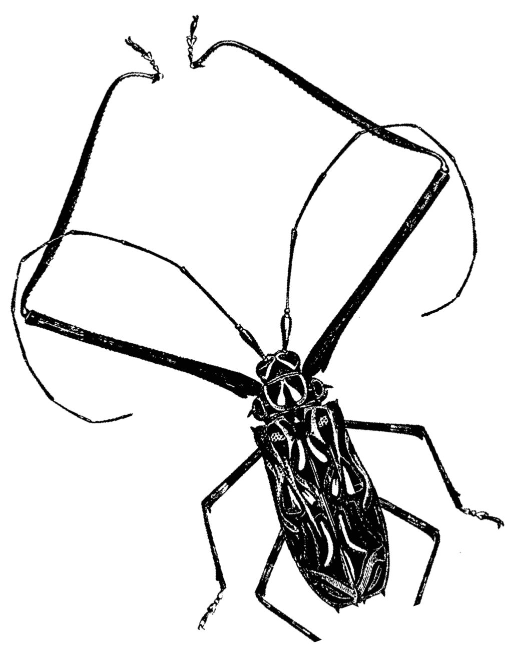
There are three broad lessons that can be drawn from this case study about PAR as a methodology. The first is the notion that PAR methodology cannot be universally applied to all research projects. Certainly many of the tools from the PAR approach can be valuable for any research project. Clearly PAR is tremendously valuable in defining community priorities when external interventions by the state, NGOs, or multi-national corporations are involved. But the commitment to facilitating the community in identifying the research objectives and engaging in research activities as partners is not always possible when the outside researcher has defined goals in mind. All researchers, however, can learn from the ideological underpinnings of PAR, by offering the community information as freely as the community shares it with them. In this way research becomes less extractive in nature and more mutually beneficial for communities that might otherwise be treated only as "subjects" in a research project.

The second important lesson from this experience touches on the length of a research project. If this mapping exercise had been a one-time, two-week long workshop, the PAR approach would clearly be a losing strategy. However, the larger project that this workshop is a part of is a three year project and, thus iterative. As researchers, we can learn from the mistakes made in this field experience and build these lessons into the next mapping exercise. This self-reflexive approach to research is crucial as we encounter events or discover knowledge in the field that challenges out assumptions.

The final lesson is that working in complex situations, with divergent objectives and time constraints requires long-term investments in sites and regions. Students from F&ES who are beginning summer research projects will experience the range of the conditions described above and need to be prepared to modify their research plans in the field. Furthermore, many students will go on to implement long-term inter-disciplinary projects for NGOs, governments and science, and all the issues raised in the article will need to be considered. Short-term experiences, such as the case described above and summer research projects, are valuable no matter what they produce - especially if one learns and incorporates those lesson in future endeavors.

Notes

1 Following anthropological conventions I am using a pseudonym for local place names.



From James Castner, 1990. *Rainforests: A Guide to Research and Tourist Facilities at Selected Tropical Forest Sites in Central and South America*. Gainesville, Florida: Feline Press.

Announcing the 2003 TRI Fellows

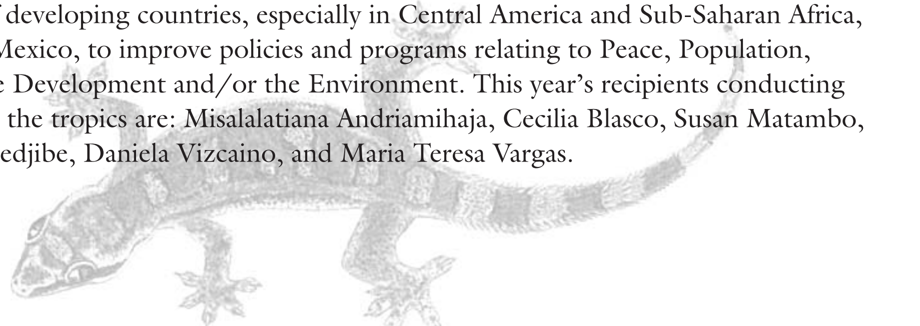
We are pleased to announce the 2003 recipients of funds for research in tropical countries. This year we have four different sources of funding for tropical research at F&ES: the **TRI Endowed Fellowship**, the **Ed Kreiser Memorial Fellowship**, the **World Agroforestry Centre African Fellowship** and the **Compton Foundation Fellowship**. All together we have 31 recipients working in 21 different countries.

The Tropical Resources Institute Endowed Fellowship is designed to support Master's and Doctoral students interested in conducting research in tropical countries. This year's recipients are: Nikhil Anand, India; Jennifer Balch, Venezuela; Avery Cohn, El Salvador; Jonathan Cook, Ecuador; Sarah Davidson, Mexico; Raji Dhital, Nepal; Margarita Fernandez, Cuba; Libby Jones, Papua New Guinea; Helen Mills, Mexico and USA; Jonathan Padwe, Cambodia; Christian Palmer, Brazil; Alexandra Ponette, Mexico; Fulton Rockwell, India; Kenichi Shono, Belize; Corrina Steward, Brazil; Yusuke Taishi, Madagascar; Jennifer Vogel, Madagascar; Kevin Woods, Burma; Heather Wright, Peru; Hillary Young, Peru.

The Edmund Kreiser Memorial Fund was initiated by members of the 1994 Masters' class and an anonymous donor in honor of their classmate and friend Edmund Kreiser. These funds are specifically targeted to support Masters' students who are interested in research in Africa. There are three recipients of this award, all of whom will be returning to their home countries: Misalalatiana Andriamihaja, Madagascar; Susan Matambo, Zambia; Vincent Medjibe, Central African Republic.

World Agroforestry Centre, Africa (formally the International Centre for Research in Agroforesty or ICRAF) has dedicated funds for Masters' students who are interested in conducting collaborative research with the World Agroforestry Centre. This years receipt is Robin Barr who will be working in Kenya.

The Compton Foundation's Fellowship Program's goal is to contribute to the capacity of developing countries, especially in Central America and Sub-Saharan Africa, as well as Mexico, to improve policies and programs relating to Peace, Population, Sustainable Development and/or the Environment. This year's recipients conducting research in the tropics are: Misalalatiana Andriamihaja, Cecilia Blasco, Susan Matambo, Vincent Medjibe, Daniela Vizcaino, and Maria Teresa Vargas.



Hemidactylus mabouia
Watercolor by James Chapin
Congo Expedition 1909-1915
American Museum of Natural History Library

Errata

Omission: Our apologies to Jeffrey Luoma, whose table (see below) was omitted from the 2002 bulletin. For the article, refer to Luoma, J. 2002. Understory vegetation characteristics along (*Tectona grandis*) plantation/natural forest ecotones. *Tropical Resources: The Bulletin of the Yale Tropical Resources Institute* 21:11–16.

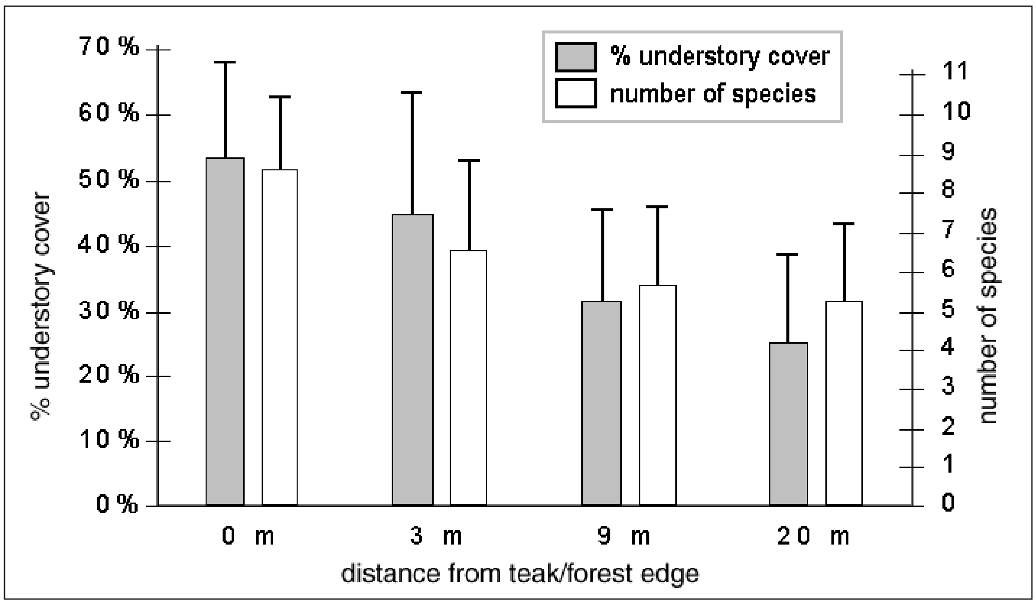


Figure 1 *Graph of percent understory cover and number of species per square meter versus distance from the edge of the teak plantation into the teak. Parrita, Costa Rico.*

Tropical Resources

The **Bulletin of the Tropical Resources Institute** is a student-edited bulletin where Masters and PhD candidates from the Yale School of Forestry and Environmental Studies publish the results of their TRI-funded independent research.

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The mission of the **Tropical Resources Institute** is to provide a forum to support and connect the initiatives of the Yale community in developing applied research, partnerships, and programs in the tropics. We support projects and research that aim to develop practical solutions to issues relating to conservation and management of tropical resources.

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