EARTHWATCH INSTITUTE FIELD REPORT

Project Title: Restoring Costa Rica's Rainforests

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Position/Affiliations: [1]Professor/University of California, Santa Cruz, [2]Assistant Professor/Michigan State University, [3]Director, Las Cruces Biological Stations/Organization for Tropical Studies

Research Sites: Agua Buena, Coto Brus, Costa Rica

Local Management Status of the Research Sites: Sixteen sites owned by a range of land owners, including mostly Costa Rican farmers, a few U.S. citizens, and the Organization for Tropical Studies. All sites are in the region of La Amistad Biosphere Reserve

Scientific names of primary species being studied:

Erythrina poeppigiana, Inga edulis, Terminalia amazonia, Vochysia guatemalensis, a wide range of plant and bird species

Key Research Objectives:

- To develop tropical forest restoration strategies, which are both economically and ecologically viable.
- To test planting islands of native tree species in abandoned agriculture lands as a strategy for tropical forest restoration.
- To assess the relative importance of proximity to forest in the surrounding landscape in comparison to within site conditions (e.g. soil type, existing vegetation) on tropical forest recovery and bird use of restoration sites.
- To monitor recovery of plants and birds within the different restoration treatments.
- To assist a local coffee cooperative to establish an ecological coffee mill to facilitate community development and to help with local reforestation efforts.

Date this report was completed: August 14, 2006

Data Collection and Results

We accomplished a great deal of field work during our third field season. We completed set-up of long-term experiments to compare three different restoration strategies: 1. planting four native tree species in mixed species plantations, 2. planting native tree species in three sizes of islands, 3. no planting/control. We monitored seedling survival and growth, baseline vegetation, and bird assemblages on 13 sites planted in 2004 and 2005. We completed our side experiments at three sites to test the feasibility of planting branches of 10 different tree species as "stakes", a method commonly used by farmers

to establish “living fence posts”. Finally, we began studies of seed fate and secondary dispersal of tropical forest seeds.

Specifically, during summer 2006 we set up experimental treatments at three new sites, bringing our final total to 16 sites in locations ranging from 0 to 50% surrounding land cover. These sites are spread across an ~100 km^2 area. This large number of sites will allow us to make generalizations about the efficacy of our restoration treatments. We cleared the sites of existing vegetation and with the help of volunteers we marked the location of, planted, and measured ~1400 seedlings total on these sites. We also took soil samples and recorded locations of these plots using a GPS.

We monitored and replanted seedlings on 13 sites planted in 2004 and 2005. This included monitoring ~5200 seedlings and replanting ~700 seedlings. Seedlings planted in 2004 showed a high survival rate (93%) after one year ranging from 89.3% for Mayo to 92.2% for Guaba, and there was little additional mortality by the second year (Fig. 1). Seedlings planting in 2005 had a somewhat lower survival rate (83% not including the Solano site) ranging from 72.5% for Mayo to 94.7% for Guaba. Survival at the different sites was relatively similar for seedlings planting in 2004, but varied greatly for seedlings planted in 2005 with Melissa’s Meadow, the Reserve, and Solano having much lower survival (Fig. 2). The survival at Solano was much lower due to cows breaking in and trampling many of the seedlings.

Growth (height change) in the first year was relatively slow and showed similar rates for seedlings planted in 2004 and 2005 (Fig. 3), except for Amarillon which grew more rapidly when planted in 2005. Not surprisingly, Poro and Guaba grew most rapidly and Mayo and Amarillon grew slower. By the second year, seedlings planted in 2004 increased substantially in height, more than 230 cm for both Poro (Photo 1) and Guaba; Mayo and Amarillon grew less but much more than in the first year (Fig. 3). There was extensive tree cover in most 2-yr old sites (Photo 2). For the sites planted in 2004, growth was substantially lower at sites Bernie and Cedeño for seedlings planted in both years (Fig. 4). Of the sites planted in 2005, growth was lower at Alexis and Solano.

Photo 1 – Karen standing next to 1-yr old Poro at Bambú site.

Photo 2 - The San Gabriel site after planting in 2004 (top) and after two years of growth in 2006 (bottom). The plantation plot (P) is on the left, the control plot (C) is in the center, and the island plot (I) is on the left.

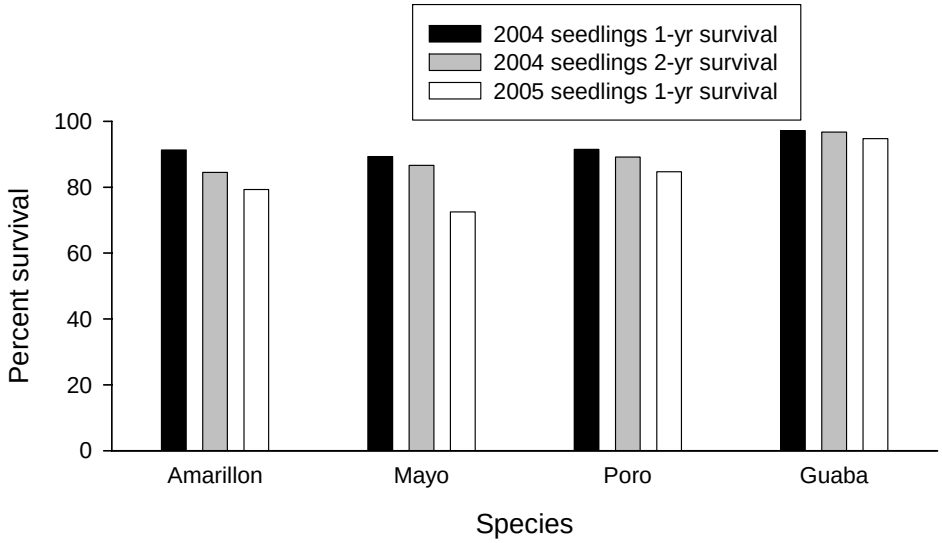

Fig. 1 Percent survival by species of seedlings planted in 2004 and 2005

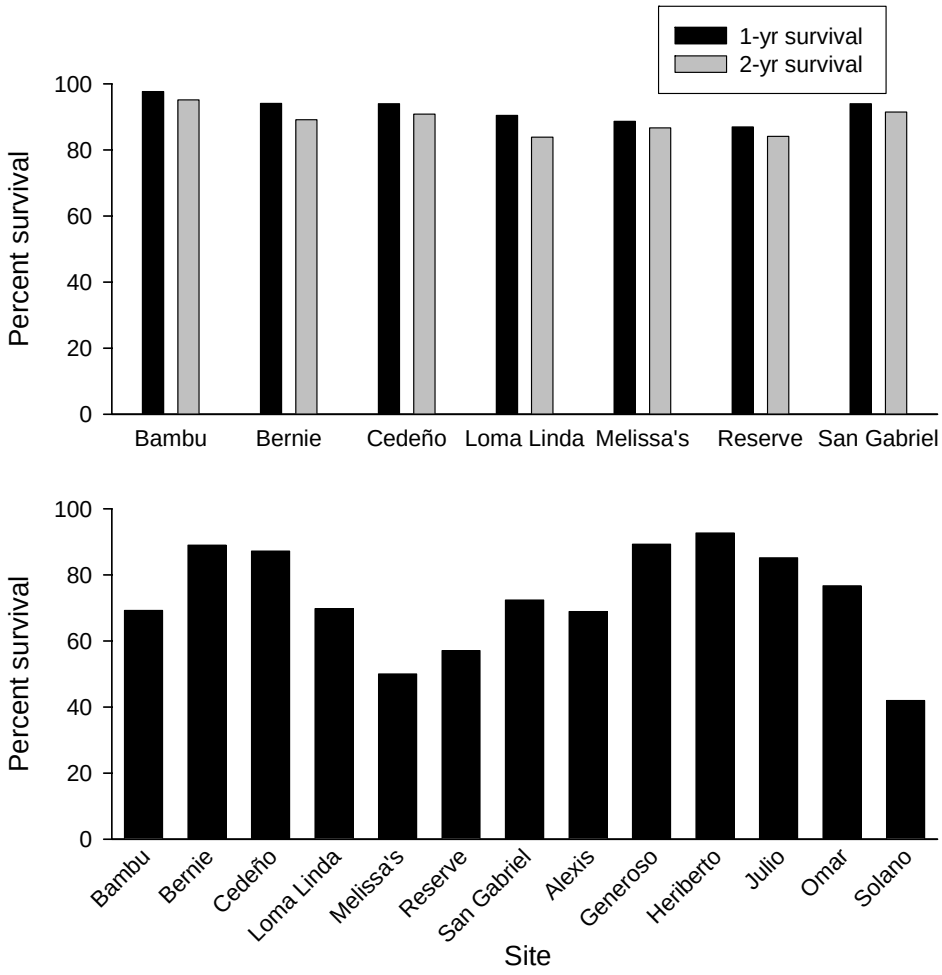

Fig. 2 - Percent survival by site of seedlings planted in 2004 (top) and 2005 (bottom)

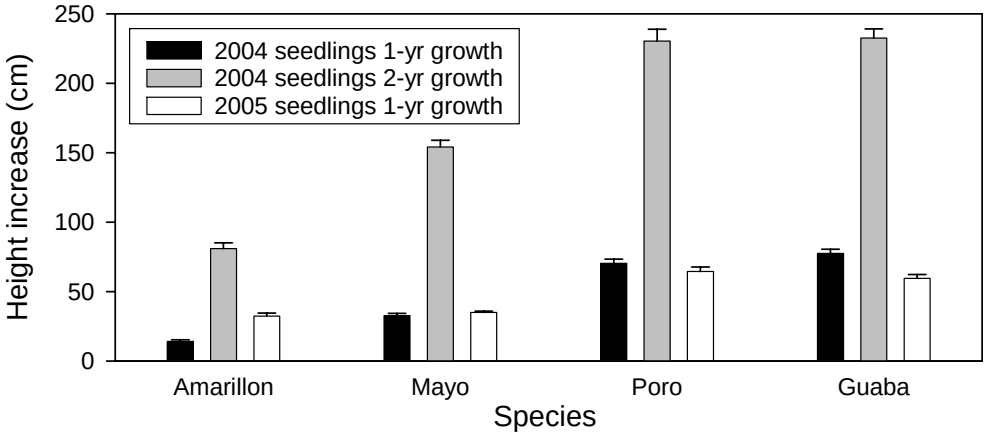

Fig. 3 - Height increase by species of seedlings planted in 2004 and 2005

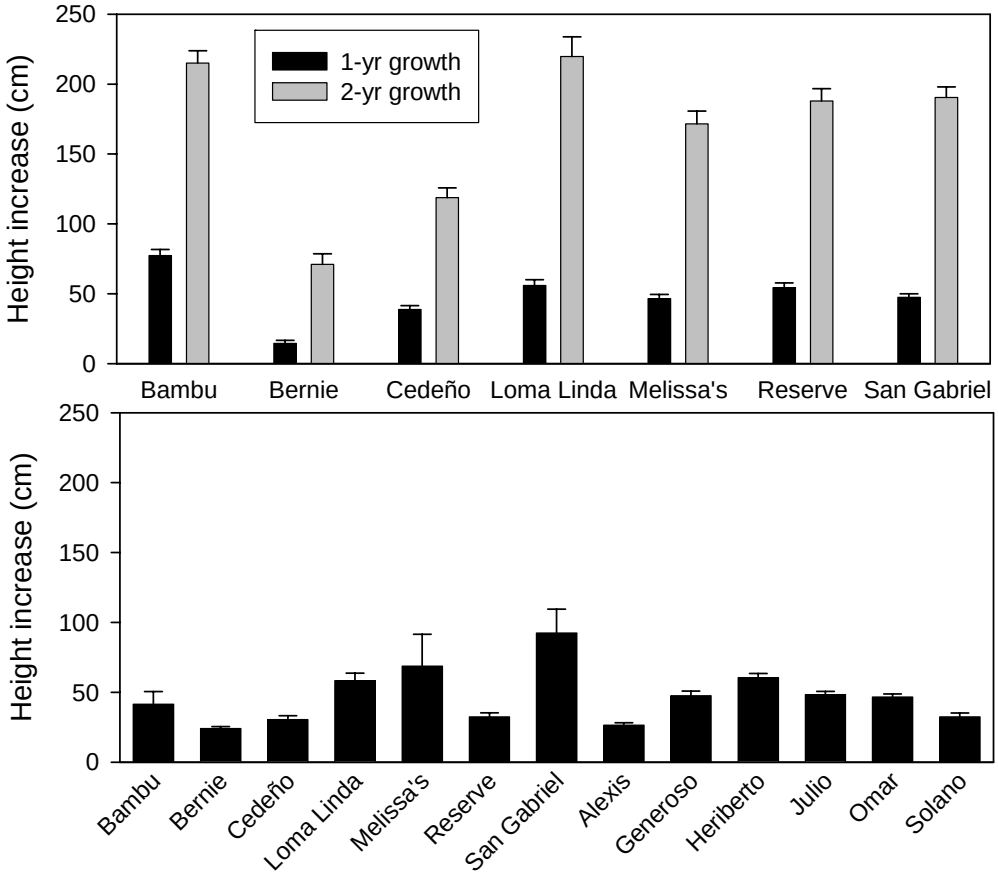

Fig. 4 - Height increase by site of seedlings planted in 2004 (top) and 2005 (bottom)

During summer, 2006 we marked permanent vegetation sampling quadrats in the sites established in 2005 and measured existing vegetation in the 13 sites planted in 2004 and 2005. We recorded herbaceous vegetation cover and composition in 1×1 m quadrats and shrub cover in 2×4 m quadrats. The vegetation is currently dominated by pasture grasses, bracken fern, and a number of early-successional species in the sunflower family. These data will serve as a baseline for comparisons as forest vegetation begins to establish in these plots. In January 2007, we will stop clearing vegetation in the plots planted during summer 2004 and will then begin to monitor establishment of forest seedlings.

We monitored the survival and growth of tree stakes planted in 2004 and 2005. We also measured the above- and below-ground biomass of two species planted as both seedlings and stakes, in order to assess differences in these two replanting approaches. This meant doing extensive root excavations, as the roots of the stakes often grew several meters within a year! Preliminary results show that belowground biomass of stakes was on average an order of magnitude greater than that found for seedlings, and this result was consistent across sites and species.

Volunteers assisted graduate student, Rebecca Cole, in setting up seed predation experiments that will comprise part of her dissertation. In addition to studying seed predation and dispersal in our experimental plots, Rebecca is also studying of the fate of larger seeded species and "secondary dispersal" in primary forest, secondary forest, and abandoned pasture. The majority of seed fate studies have assumed that if seeds are removed they have been eaten by animals. In fact, some mammals such as agoutis and spiny mice may move and bury seeds, some of which successfully germinate and establish. This type of "secondary dispersal" may be a critical mechanism for the establishment of some larger-seeded tree species, yet little is known about what role secondary dispersal might play in the recovery of these species in secondary forests and abandoned agricultural land. Initial results suggest that seeds in primary forests are frequently buried and left uneaten while seeds in secondary forests are consumed immediately. Seed germination in forests and secondary forests is much higher than in pastures.

Volunteers also assisted Rebecca Cole and student assistant Sarah Abel to set up a seed removal study in the experimental sites. This study tests the effects of proximity to forest on the removal of small-seeded primary and secondary trees likely to be dispersed into recovering areas. The study also tests the effects of "linear forests", or narrow strips of trees along streams, on rates of seed removal. These linear forests are common in agricultural landscapes and may act as starting points for forest regeneration.

Undergraduate student Megan Deffner studied levels of insect damage (herbivory) to leaves of the plants at two sites, Melissa's Meadow and Bambu. She found that overall herbivory levels are relatively low, but that Amarillon and Mayo suffer more herbivory. Another undergraduate, Monica Panamaska documented a number of different insect species using the nectaries (nectar producing organs) on the Guaba seedlings planted at our sites.

We collected data on bird assemblages at nine of the sites in February 2006 with Team 1 and at eleven of the sites in July 2006 with Team 4. We used mist nets to capture birds that were then marked, measured, and released. In February, 144 individual birds

of 47 different species were captured. In July we captured 384 birds of 52 different species. Already, it appears that the value of the sites as habitat for birds will increase rapidly over time because, based on the July data, the sites that were planted in 2004 averaged 18.8 species and 47.3 birds captured (controls, islands, and plantations combined) whereas the sites planted in 2005 averaged 10.2 species and 20 birds captured. The sites planted in 2004 also are beginning to show differences in the numbers of birds captured in the different plot types, compared to the sites planted in 2005. The 2004 sites had an average of 9.3, 16.8, and 21.2 birds captured in the controls, islands, and plantations, respectively, while the comparable numbers for the sites planted in 2005 are 6.4, 8.0, and 5.6. We are also beginning to see patterns in the types of species captured in the different plot types. Tanagers, a group of birds that are dependent on shrubs and trees, as opposed to grasses, and that eat many fruits and so are important seed dispersers, were captured more often in the islands and plantations than in the controls in July (2 tanagers in the controls, 13 in the islands, and 7 in the plantations). These data will allow for comparisons in the numbers and types of species detected in the sites over time.

Emily Morrison, a graduate student, and Becca Fink, an undergraduate, who both assisted with the mist netting, conducted preliminary studies in the sites this summer. Emily documented the behaviors the birds use to catch prey, and how successful they are, in the islands and plantations. Becca collected data on the amount of time birds spend in the plantations and different-sized islands. These studies will provide additional measures of the quality of the habitat from the birds' perspectives.

Photo 3 – A Baltimore Oriole caught in mist nets at restoration sites in February 2006.

Significance/Benefits of Research

A major goal of our research is to inform regional reforestation efforts. As we are at an early stage in the research it is too soon to have achieved this goal, but we are working with the local community in various ways. This year volunteers helped to plant seedlings on a couple farmers' lands who wanted to reforest (not part of our scientific experiments). Over time we anticipate that our results will inform forest restoration efforts locally and regionally. Also, by employing Costa Ricans to help with our research we provide income and training to people in the community.

We are continuing to work with farmers who use sustainable coffee farming practices to direct market their coffee to consumers to gain a price premium. We have been working closely to aid the formation of a new, small coffee cooperative in the region, CoopePueblos, which is committed to sustainable farm management: conserving soils, promoting biodiversity, protecting their watershed, and reducing agrochemical use. We,

along with some this and past year's volunteers, are helping with fundraising for the ecological coffee mill they will be installing in the next month. This coffee mill will allow them to process their coffee locally, ensure long-term sustainability of the coffee processing, and bring income back to the community. Team leader Rebecca Cole is starting interviews with farmers to determine what sort of incentives are necessary for them to both diversify the tree species within their coffee plantations, and set aside land for reforestation for timber or conservation.

Dissemination of Results

Because we are at an early stage of the project, we are just beginning to disseminate our results. We are presenting a poster at the CoopePueblos cooperative in August to inform more people in the community of our research plans and results. The cooperative will be presenting information about the project to their members and partner organizations in September. We will also write a brief summary of our work from this year in Spanish for people in the Agua Buena community.

Karen Holl wrote a book chapter on tropical forest succession in abandoned agricultural lands which draws on this and her past research on tropical forest restoration (Holl, K.D. In press. Old field vegetation succession in the neotropics. In *Old fields: Dynamics and restoration of abandoned farmland*. Eds. V.A. Cramer and R.J. Hobbs. Island Press). Karen also gave five presentations on this research during the 2005-2006 academic year, to audiences at the University of California - Santa Cruz, California State University – Chico, University of Santa Clara, and the University of Xalapa in Mexico. Catherine Lindell gave a presentation on this work to the Zoology Dept. at Michigan State University and will be posting this report on Center for Global Change and Earth Observations web site at Michigan State University. Zak Zahawi spoke on this research to a number of field courses and natural history visitor groups that visit the Las Cruces Botanical Garden and on three occasions took courses into the field to see the research first hand.
Zak will be writing up the results of the stake experiment during fall 2006.