FIELD REPORT

Marketing title

Costa Rica's Sustainable Coffee

PI name

Valerie Peters

Research site/ region

University of Georgia Ecolodge and Research Station

Research site latitude/ longitude

10° 17’ N, 84° 48’ W

Protected area status

N/A

Report completed by (name)

Valerie Peters

Country

Costa Rica

Dear Earthwatch Volunteers,

In 2009 we captured 285 birds from 56 species within the shade-grown coffee plantations where we set up mist-nets. This data, along with data collected from June and July of 2010, will allow me to analyze how important food resources (as measured by invertebrate biomass from malaise traps and fruit energy availability (FEA) from fruit counts) are to the ecosystem service of pest control by birds. In addition, 2009 was a very unusual year for precipitation in the region. February 2009 had the highest rainfall recorded in over 25 years which caused unusual flowering phenology in the coffee plants. This led to a very exciting May because of a second mass bloom in the coffee farms, coinciding with insect emergence, and bee species richness climbed from an average of 11 species during all prior coffee blooms in 2007, 2008 and 2009 to 26 species in May 2009! We now likely have over 100 bee species collected from kill jars and malaise traps, however the identification of these bee species is slow due to lack of funding to pay our Costa Rican taxonomist. I was very impressed with the volunteers during this mass bloom because of their dedication to catching some of the new bee species so that they could eventually be identified!

Finally, many volunteers in 2009 spent time trail-blazing through the forest and agricultural lands tracking individual Emerald Toucanets. In 2008, unbeknownst to me until I began to finalize this publication, the Emerald Toucanet was officially separated into 7 new species. Therefore, our Emerald Toucanet is now officially the Blue-throated Toucanet, which will likely increase its risk category determined by the IUCN (International Union for the Conservation of Nature) once they update their information. After home-range analysis we found that all individual home ranges were less than 2 hectares- this is quite surprising given that these are fairly large frugivorous (fruit-eating) birds thought to require large home ranges. This is good news for conservation, though, because it shows that even in agricultural landscapes arboreal resources can be augmented or modified to contribute to the long-term survival of frugivorous birds within the agricultural matrix.

Thank you all for your help with this project! Your contribution will hopefully lead to conservation management organizations utilizing the findings of this research throughout Latin America to improve biodiversity in managed lands.

Valerie

SECTION ONE

NON-TECHNICAL OVERVIEW OF RESULTS

Ecological studies often require several years of data collection before any results can emerge, so I will focus on merging results from the early stages of data collected with Earthwatch with what we may expect to find from this past year. Our official analysis of this year's results must wait until we have more complete data, to be collected in 2010.

Conservation planning in managed lands is relatively new despite the fact that over 85% of lands are outside of reserves or protected areas. As such, guidelines for conservation in managed lands are still in their infancy, but basically focus on plant species diversity or plant structural diversity, excluding specific goals for these. In the tropics this is especially important because tropical forests typically harbor approximately 40 up to over 100 tree species per hectare. Conservation planning guidelines often require 10 tree species per hectare, but if we are to limit our numbers to 10 , research should ask more specific questions about the species habitat requirements of biodiversity in these simplified systems.

In this context, my research has focused on asking whether differences in food resources influence biodiversity and ecosystem services in shade-grown coffee plantations (as opposed to structural diversity or plant diversity being of greater importance). The study is conducted in sites with similar plant species diversity so that the statistical factor of variation in food resources can be tested.

We first looked at whether fruit resource diversity influences bird biodiversity, and the results of this study have recently been published in the Journal of Animal Ecology. We found a very strong correlation between fruit calories or fruit energy availability at a site and the bird community richness. Furthermore, the occupancy of a shade-grown coffee plantation by birds was best determined by fruit calories. Despite the fact that our coffee plantations all had approximately 20 tree species per hectare, we found that farms with less than 500 fruit calories in any given month had higher levels of bird emigration than immigration. On the opposite end of the spectrum, we predicted that at above 12,000 fruit calories, coffee plantations would have a completely stable bird community (no emigration), as well as the highest levels of species richness (100% immigration). This prediction was based on a model, and only three coffee plantations during one month each achieved this level of fruit energy availability.

Now, with data collected over the past two years, we can ask how fruit energy availability contributes to the ecosystem service of pest control by birds. In order to do this we had to exclude birds from coffee plants and measure leaf damage and insect biomass from within these areas as well as for control coffee plants. In this study we can also ask whether available insect biomass is different among coffee plantations, and whether this also contributes to bird occupancy of coffee plantations (and therefore pest control by birds). If the results from our study demonstrate this then it is a good argument for farmers to increase tree species that contribute to higher levels of annual fruit energy availability on their farms, thus increasing bird biodiversity and bird persistence in managed lands.

This story is very similar for the work we have done with bees. My research with bees has focused on floral resource availability and how this affects coffee production through the ecosystem service of pollination by bees. In 2007 we experimentally planted a steady-state floral resource, *Hamelia patens* (Firebush), in three of six coffee plantations. Over time there are several questions that we can ask through this manipulative experiment. In agricultural lands we know that space dedicated to non-focal crop plant species is limited, so it is important to understand whether plants which provide resources over time can attract more and support more abundant populations of pollinator species. It is also important to understand how this

contributes to production. If floral resources can be augmented in managed lands to maintain bees in farms, farmers may be more willing to plant other plant species in their farms, especially if this will increase their harvest.

In the first year of planting we found that our steady-state floral resource (*Hamelia patens*) competes with coffee pollination during small coffee blooms but not during the mass coffee bloom that occurs once a year and lasts for ca. 4 days. We also found that as long as bees are present, initial seed set during mass blooms remains at about 60%. In the small, early blooms however, cross-pollination (which can improve yields) is more likely (probably due to fewer coffee flowers), and therefore initial seed set increased to 74%. However, we experienced a very unusual year in 2009 due to changing patterns of precipitation:. The dry season of 2009 was not dry! We speculate that this could this be a possible indication of how precipitation patterns may be altered in the future due to climate change.

Unfortunately, the not-dry dry season of 2009 changed the flowering phenology of many plant species including the steady-state floral resources that were experimentally planted. There were virtually no flowers on these plants during these very wet months, and so pollinators could not collect resources. In this sense it was difficult to measure the effects of this resource during 2009. Despite this, we will be able to look at some taxonomic groups of insects over time (from 2008 to 2010) in response to these plantings, using data collected from malaise traps that were set up 2 to 3 times per year for two week periods. Specifically our data will tell us how the species richness, abundance and temporal stability of Lepidoptera (moths and butterflies), Diptera (flies), and Hymenoptera (both bees and wasps) is influenced by steady-state resources in shade-grown coffee farms.

SECTION TWO: TECHNICAL RESULTS

REPORTING ON RESEARCH OBJECTIVES

Objective 1
To understand how shaded coffee plantations can conserve ecosystem services

Progress towards/against objective
This objective is the overall goal of this study. The ecosystem services investigated throughout this study include pest control by birds; biodiversity; and pollination. These were all individual studies and their results will be described below under the appropriate objective.

Objective 2
Investigate how constant resource availability in shade coffee plantations affects abundance of key frugivore species

Progress towards/against objective
In order to answer this question we used occupancy modelling as a surrogate for abundance. The results from this study were published in the Journal of Animal Ecology 2010. Resource availability was measured as Fruit Energy Availability (FEA) on a monthly basis in six shade grown coffee plantations. The bird community was comprised of 14 members including:

- 1 cracid,
- 1 pigeon,
- 1 psittacid,
- 2 ramphastids,
- 1 woodpecker species,
- 2 flycatchers,
- 1 thrush species,
- 1 manakin species,
- several thraupids,
- 1 icterid,
- several emberizids

This frugivore community widely represents distinct taxonomic groups of frugivorous birds. Our occupancy model demonstrated that bird occupancy, site immigration, and site emigration are dependent upon a site's monthly FEA. In fact, the model that included FEA as an explanatory variable for each of these response variables was supported by 92% of the weight of evidence.

In our best model, wind was the only other explanatory variable, and this variable influenced detection. Our best model was then used to predict site occupancy patterns with FEA as a predictor variable. The results of this have some strong implications for conservation planning in managed lands. Our model predicts that at sites where fruit provides under 500 fruit calories per month, birds will be more likely to emigrate from a site than to immigrate into a site. Empirical data collected from our farms show that despite the fact that the coffee plantations had very high shade tree diversity (ca. 20 tree species per hectare) the FEA for many months in many farms was below 500 fruit calories. Currently, guidelines for bird-friendly coffee require only 10 tree species per hectare without requirement for what types of trees should be planted. Our results indicate that a tree species contribution to annual or monthly FEA is far more important to frugivore site occupancy than the number of tree species that should be planted per hectare.

Objective 3

Investigate how constant resource availability and environmental factors affect diversity of bird species in shade coffee plantations.

Progress towards/against objective
The results of this study were quite surprising given that no previous study had detected a positive correlation between bird species diversity and fruit availability. However, we used a novel approach to determining fruit availability - Fruit Energy Availability - which includes not only the number of ripe fruits, but also the weight of the fruit and the per gram caloric value. Furthermore, by utilizing shade grown coffee plantations we could decrease the number of confounding variables in the study because coffee plantations are a bit more homogenous than natural forests. We found a strong correlation between a site's average monthly FEA and a site's average bird species richness (Pearson's product-moment correlation = 0.90) and for each individual site, month combination (Pearson's product-moment correlation = 0.55). Again, as above, this has important implications for conservation- although causality can not be shown through correlation alone, results indicate that by increasing a site's monthly FEA you can increase bird species richness. Together with the occupancy model results above, this study demonstrates that high monthly FEA can increase both the stability and species richness of the bird community in shade-grown coffee plantations.

Objective 4

Investigate how constant resource availability through planting the native shrub species *Hamelia patens* affects native bee abundance and diversity

Progress towards/against objective
Eighteen species of native social and solitary bees were collected while foraging floral resources of *Hamelia patens*. In addition, the non-native honeybee *Apis mellifera* was observed to forage occasionally at *H. patens*. A total of fifteen bee species were observed visiting *H. patens* plants in H+ plantations (plantations with the experimental plantings), and a total of eight species were observed visiting the single *H. patens* plants in H plantations (plantations without the experimental plantings). Many of these bee species were also observed during observation sessions conducted at coffee flowers in these plantations. Twelve bee species were observed foraging on potted basil flowers in H+ plantations, and ten bee species were observed in H plantations.

Species accumulation curves developed with *EstimateS* indicate significantly higher bee species richness in H+ plantations for observations conducted at both H. patens flowers and basil flowers. Combining observation sessions at both floral sources, the overall estimated bee species richness was 62.3 species (CI: 31.4 to 164.0) in H+ plantations and 19 species (CI: 14.1 to 46.6) in H plantations. In comparison, the Classic Incidence Based Coverage Estimator (ICE) estimated overall lower bee species richness in plantations, however species richness in H+ plantations remained highest with 39.6 bee species and H plantations with 21.1 bee species. Malaise traps placed in H+ plantations captured a total of 45 individuals from 14 species and in H plantations 13 individuals from 11 species were captured.

Objective 5
Investigate how constant resource availability through planting the native shrub species *Hamelia patens* affects coffee flower pollination and seed set

Progress towards/against objective
For native bee visits to coffee flowers we found a significant interaction between the coffee bloom period and *H. patens* presence ($n = 142$, $F = 6.99$, $p = 0.009$). In other words,

significantly fewer native bees visited coffee flowers during the smaller bloom periods in H+ plantations than H plantations. The mean number of native bees visiting coffee flowers during the smaller bloom periods in H+ plantations was 1.1 (SE 0.32), in comparison with 4.6 (SE 0.70) in H plantations. This difference was not significant, however, during the mass bloom period, where the mean number of native bees visiting coffee flowers during all observation periods was 2.3 (SE 0.39) in H+ plantations and 3.4 (SE 0.58) in H plantations.

For *Apis mellifera* visits to coffee flowers we found no significant interaction between bloom period and H. patens presence. However, there was a significant effect of both bloom period ($n=124$, $F=86.81$, $p<0.0001$) and H. patens presence ($n = 124$, $F = 14.75$, $p = 0.0002$) on the *A. mellifera* visits to coffee flowers. *A. mellifera* visitation rates were higher in the mass bloom than in the smaller bloom. In addition, *A. mellifera* visits to coffee flowers were higher in H+ plantations for both the small (2.9 ± 0.49 SE) and mass (9.19 ± 0.96) bloom periods than in H farms for the small (1.25 ± 0.34) and mass (7.03 ± 1.07) blooms.

Coffee initial seed set rates were not significantly different between H+ plantations and H plantations, though, for either the small or the mass bloom periods, although there was a trend for decreased seed set during the small bloom period in H+ farms. Coffee initial seed set rates in the small bloom period in H+ and H plantations were 0.70 and 0.78 respectively ($t123 = 1.82$, $p = 0.07$). Coffee initial seed set rates from the mass bloom period were 0.56 in H+ plantations and 0.62 in H plantations ($t138 = 1.41$, $p = 0.16$). Pollen deposition on coffee stigmas was not significantly different between H+ and H plantations during the mass bloom period ($t134 = 0.87$, $p = 0.192$) and was not measured during the small bloom periods.

Objective 6
Investigate how resource availability in shade coffee plantations affects MCP and breeding success of Emerald Toucanets

Progress towards/against objective
In the middle of this project the Emerald Toucanet was officially divided into seven species, so the correct name, now, for the bird which we were working with is the Blue-throated Toucanet, which ranges from Costa Rica to Panama.

We found that Blue-throated Toucanets have an extremely small home range in the shade grown coffee plantations and which was not different from birds captured in the forest (< 2 hectares). We captured and radio-tracked 10 individuals over two years; the low number is due to the difficulty in capturing these mainly canopy-dwelling birds. Through occupancy modeling we found that Toucanets are strongly associated with Fruit Energy Availability (FEA), and farms with more *Ficus pertusa* trees also supported more Toucanets. 39% of all observations of tracked birds included foraging fruit, and that was the most common activity observed. This research highlights the importance of fruit security in the managed tropical landscape to support populations of frugivorous animals. Some birds spent almost 100% of their time in coffee plantations despite the fact that plantations were surrounded by patches of forest, but only when these plantations had higher levels of FEA.

PARTNERSHIPS

University of Georgia's Research Station
The UGA ecolodge and research station provided all logistical support for the Earthwatch teams including hotel reservations in the rendezvous site, transportation to the field site, housing and food during the entire field season, reservations for volunteers at various tourist destinations for time off, free-time activities such as lectures, hiking, or horse-back riding, and return transportation to the airport.

Finca la Bella
The farmers comprising Finca La Bella graciously allowed all the Earthwatch groups to descend upon their homes and backyards for two week periods. The farmers really enjoyed this experience and I believe they were sad to see the volunteers go. It was amazing to me that the farmers allowed us to spend so much time on their farms, inviting us into their homes, giving us coffee and snacks, allowing us to use their bathrooms and invade all aspects of their lives. There is no way that this research could have been conducted without the kindness of these farmers. One farmer family especially, the Salazars, would bring us coffee and snacks every day that we spent on their farm- even if we were there for two weeks mist-netting every day!

Costa Rica National Institute of Biodiversity
Manuel Solis at INBio has graciously offered to identify many native bee species for this project.

PROJECT DEVELOPMENT
n/a

DISSEMINATION

Print

- Peters, V.E., Mordecai, R., Carroll, C.R., Cooper, R.J., and Greenberg, R. (2010). Bird community response to fruit energy. *Journal of Animal Ecology* 79: 824-835. (*Earthwatch was acknowledged*)
- Peters, V.E., Solis, M., Carroll, C.R., Cooper, R.J. and Greenberg, R. *Season dependant effects of steady-state floral resources on coffee pollination*. (In review).
- Peters, V.E. and Nibbelink, N. *The importance of fruit security in the Neotropical managed landscape. A case study with Blue throated Toucanets*. (In review).
- Peters, V.E. and Carroll, C.R. *Climate changed induced phenology shifts and the coffee harvest*. (In review).
- Peters, V.E. (2009) Not all coffee is created equal: resource constancy and ecosystem services in shade-grown coffee plantations. *Ph.D. dissertation*. University of Georgia, Athens, GA.

Conference presentations
Coffee flower phenology changes and pollinator response in strong El Nino year. *Ecological Society of America annual meeting 2010*. Pittsburgh, PA, 01/08/2010 to 06/08/2010.

CAPACITY DEVELOPMENT AND EDUCATION

Martha Garro Cruz
Martha was my field assistant throughout 2009 and due to her education with my project on field techniques and proper data collection she is now employed full-time by another research project in the area.

Local Community
The sustainable coffee project directly involves farmers and their families, but in addition, after each Earthwatch group they are offered a seminar on the project, each time covering different aspects in order to fully educate the farmers. In response to many of these seminars and to what the farmers have learned throughout the project, the farmers have implemented new management actions such as incorporating different trees into their farms.

CONTRIBUTIONS TO INTERNATIONAL CONVENTIONS, AGENDAS, POLICIES, MANAGEMENT PLANS

A small part of my research was intended to modify the guidelines for bird-friendly coffee certification, and the management of shade-grown coffee farms in general. The SMBC (Smithsonian Migratory Bird Center) who oversees the distribution of criteria for bird friendly coffee certification materials does have the results of my research. However, due to publication costs I am not sure when they will add the new findings into their materials.

CONTRIBUTIONS TO LOCAL, NATIONAL AND REGIONAL CONVENTIONS, AGENDAS, POLICIES, MANAGEMENT PLANS

On a local scale, the farmers have implemented management practices to promote biodiversity and ecosystem services, but the results of my research have not yet been distributed widely within the country (Costa Rica) and to the National coffee organization.

ACTIONS OR ACTIVITIES THAT ENHANCE NATURAL AND SOCIAL CAPITAL

Land (species) Management by local people
In Finca la Bella farmers planted resources which would benefit native bees, either specifically for the research or because I had educated them about the value of native bees for crop pollination.

LONG TERM IMPACT OF PROJECT

Taxa of conservation significance enhanced, restored or maintained
The research in my project focused mainly on biodiversity, not on single species, and so it is difficult to assess this question. In addition, one portion of my research focuses on bee species in the neotropics and we are only beginning to assess the status of bee populations. There are only two species on the IUCN red list and they are both from North America. Many of the neotropical bee species are not even named, so we don't really know the status of their populations- if they are declining or stable. If bee populations depend on floral resources then through floral resource plantings during the project, bee species were restored and maintained in the area through this project. It seems likely that this is the case, however, nest sites are l also likely to be important for the status of bee species and we did not modify nest sites during our project. We did find many bee species in the coffee farms, and I have heard that in other regions of Costa Rica bees are absent from coffee farms, so the Monteverde farms could be seen as a goal or model farm for other coffee farms in Costa Rica for maintenance or restoration of native bee species.

Ecosystem services enhanced, restored or maintained
My research specifically asked questions about how habitat factors can support the provisioning of ecosystem services: seed dispersal, biodiversity, pest control, and pollination. Hopefully the results from this research will now be utilized by conservation non-profit organizations to enhance, restore and maintain ecosystem services. I know the farmers are using the knowledge gained but the results still need to be widely disseminated and implemented. Many of Costa Rica’s national organizations (including agricultural organizations) are not yet working with this type of management practice.