FIELD REPORT

**Marketing title:**
Climate Change, Canopies, and Wildlife

**PI Names:**
Dr Mika Peck

**Country:**
Ecuador

**Research site / region:**
Santa Lucía Reserve, Southern habitat corridor, NW Ecuador

**Date field report completed:**
27 Nov 2010

**Period covered:**
1 Jan 2010 to 1 Nov 2010

**Report completed by:**
Mika Peck

Dear Earthwatch Volunteers,

Firstly I would like to thank you for contributing and taking the time and effort to help with the research project at the Santa Lucía Reserve. Your contributions in 2010 have left the research team with a series of fantastic memories of the field season and we are delighted with the amount of progress we have made this year. This year has been a particularly good year as many volunteers continued to support the work in Ecuador after returning home. This means that we are now starting plans to build a dedicated laboratory at Santa Lucía to house the research centre.

Your hard work in the field has meant that we have now collected sufficient data to start to analyse and publish results. With three years of data we now have a number of articles published, about to be published and more in the pipeline. Much work is still underway and under analysis by the science team and students as part of undergraduate theses. Papers include a number of articles in herpetological journals, a paper identifying indicator bird species of habitat quality in the Andes, a paper on aerial taxonomy and a paper about to be submitted that integrates climatic information recorded by the data loggers and information on mosses and liverworts and altitude to determine whether they are sensitive enough to act as biological monitors of climate change. The camera trap website is still online and has the latest observations of wildlife. The new Reconyx cameras have proven to be a great success and we are also preparing a short publication to determine the population density of ocelots in the reserve from the dataset. You can see species caught on the cameras at www.rainforestconcern.org. This year we also carried out the first carbon assessment for the reserve with results highlighting the need to maintain intact forest as a climate change mitigation action.

Finally, the bird surveys have now generated some 10,000 individual records from the 117 sampling points distributed in the various habitats throughout the reserve. We are now combining habitat and bird survey datasets to develop indicator methods (using key bird species) to identify habitat quality. This is useful for forest restoration projects as it will provide indicators of improvement or degradation.

In conclusion, all this work could not have been carried out without your support and hard work. It is your efforts that have now established the Santa Lucía Cloud Forest Reserve as a scientific field station, ensuring its future as a destination for scientific research.

Thanks from all the Earthwatch ‘Climate Change, Canopies and Wildlife’ and Santa Lucía Cloud Forest Reserve staff.

Yours sincerely,

Dr Mika Peck
Lead Earthwatch Scientist

## SECTION ONE

### Top highlight from the past field season

This field season has seen a fantastic number of Earthwatch volunteers engage with our scientific team to provide an incredible amount of data on species diversity, abundance and the first estimate of the carbon stock of these cloud forests. A particularly exciting result is that the local community is now interested in building a dedicated research laboratory to house a permanent field scientist at Santa Lucía and to develop a permanent research station. Of particular note is that one of the 2010 Earthwatch volunteers has dedicated time and effort to raise funds for this endeavour that should be completed in 2 years time. The establishment of a permanent facility would allow national and international university students to visit Santa Lucía to carry out longer-term scientific projects to better understand the cloud forest habitat and support the creation of the next generation of conservationists.

### Non-technical overview of results

Research at Santa Lucía addresses a number of key environmental questions including:
· What species are present within the reserve?
· Can we use aerial imagery to identify canopy tree species?
· What are the impacts of environmental change on species?
· Can we monitor environmental change through change in species numbers?
· How much carbon is associated with the cloud forests?

Here we summarise the research results from information collected in 2010. Further detail of ongoing analysis of data from 2008 and 2009 can be found in the section below.

*Camera trapping:*
In 2010 we re-established the camera trap network with 14 top-of-the-range camera traps (Reconyx RC 60). These cameras have very fast trigger times and an invisible infra-red flash. These cameras have proved to be the only camera systems capable of withstanding the cloud forest environment and they also guarantee capture of imagery of all passing wildlife. Of particular interest, the cameras captured images of a Paramo Wolf (*Pseudalopex culpaeus*) descending to lower altitudes through the reserve and returning to higher ground a day later, a species normally observed only at higher altitudes. See all the images on the website at: http://www.sussex.ac.uk/Units/lifesci/rainforest/

The complete dataset is under analysis in 2011 with the aim of comparing the 2010 camera trapping season with previous camera trapping surveys in 2008 and 2009 and to determine the densities of ocelots (*Leopardus tigrinus*) within the reserve using PRESENCE software.

*Bird survey:*
To date we have recorded just short of 10,000 records of 190 bird species over three years of camera trapping. Some 50% of species recorded represent endemic species making it clear that the reserve is of extremely high conservation value. A greater species diversity was observed in primary forest, with disturbed habitats (secondary forest and silvopasture) displaying lower diversity. It is interesting to note however that 80, of the total 190 bird species observed, were actually recorded in all habitat types and we are now investigating how effective secondary forest and silvopasture are as suitable habitats for endangered, endemic and rare species.

*Herpetofauna surveys*:
Almost all aspects of herpetofaunal understanding is lacking for the area surrounding the Santa Lucía reserve. However, since we began surveys in 2008, 21 species of reptile have been identified and a number of amphibian species are still being identified at museums. We

trialled a variety of survey methods, but no single method proved particularly successful in capturing all species. Of particular interest, bromeliads have proved important microhabitats for many anuran, linking significantly to their survival. Following successful trials we have now established altitudinal transects of PVC pipe traps that mimic bromeliad habitat that will be collected in 2011 to provide information on canopy anuran species.

*Long-term monitoring of population trends*:
For projects that aim to improve forest habitat, i.e. as part of REDD+ (Reduced Emissions from Deforestation and Degradation), there is the urgent need to develop simple indicators of forest status. Preliminary results from the latest analyses of the bird monitoring dataset indicate that habitat quality indicator species need to be altitude specific in regions of extreme topography such as the tropical Andes i.e. altitude is the key explanatory variable for species presence and abundance. For birds, the key to monitor population changes depends on having sufficient replicates, or records, to carry out statistical tests to prove 'real' change. The species that provide sufficient information include the Andean Solitaire (*Myadestes ralloides*), Orange-bellied Euphonia (*Euphonia xanthogaster*), Plate-billed Mountain Toucan (*Andigena laminirostris*), Rufous-breasted Antthrush (*Formicarius rufipectus*), Sparkling Violetear (*Colibri coruscans*) and the Wattled Guan (*Aburria aburri*). The results of an undergraduate thesis based on data collected in 2008 and 2009 suggest that, although generally easy to detect, birds may not be the most sensitive group of species for monitoring change. There is a caveat to this last sentence - we are likely to be surprised by the impacts of environmental change and unexpected effects can only be identified through a monitoring programme that covers as wide a spectrum of the species present as possible.

*Bromeliad community structure and food webs*:
In 2010 several canopy bromeliad samples were taken to investigate biotic and abiotic characteristics that influence the invertebrate and vertebrate communities and food webs of bromeliad 'tank water' environments. The work is still underway as part of a thesis project at the San Franscico University (Quito) with results expected in June 2011. Preliminary results show that bromeliads sampled maintain from 70 to 150 invertebrate larvae specimens, and up to 20 adult invertebrates. Predominant orders found so far include, but are not limited to; Coleoptera, Diptera, Odonata, Blataria, Saltatoria and Annelida. A few ant colonies have been found in several samples, as well as frogs from the Pristimantis genus (Strabomantidae). These 'canopy pools' of water provide standing water habitats in a region where most water is flowing due to steep slopes and can play an important role in disease vectors, such as mosquito hosts for malaria.

*Carbon assessment of Cloud forest:*
New financing mechanisms for tropical forests are coming online that include financing forests directly for their role as carbon stores. With 1/3 of all carbon emissions associated with deforestation, it is important to provide incentives to reduce these emission sources. In 2010 we estimated carbon stocks of the forest at Santa Lucía Reserve from 30 plots and 1,320 individual tree samples. Results show an average above ground carbon stock of 143.63 (± 27.13) t C/ha (tons of carbon per hectare). We can conservatively estimate that the reserve provides carbon sequestration (through avoided deforestation alone) of approximately 1600 tons C per annum. To provide some context, this represents offset values for approximately 800 transatlantic return flights (per person calculation).

## SECTION TWO: TECHNICAL REPORT

## 1. REPORTING AGAINST RESEARCH OBJECTIVES

### Objective 1:

Rapid methods for determining the presence/absence and hence distribution of study species

### Progress toward/against Objective 1:

*Use of camera traps for mammal inventory:*
Following trials of cameras in 2008, the 2009 - 2010 field season was launched with the Stealth Cam, model STC-1430IR. Images from the camera trapping season are available to view at http://www.sussex.ac.uk/Units/lifesci/rainforest/ .

The information was analyzed in 2010 and is to be published in a short paper that summarises the information collected between June 2009 and February 2010 at the Santa Lucía Community Reserve. In summary, data was provided from 10 camera trap locations over 32,688 hours of total sampling time. We registered a total of 13 species from four orders, 11 families and 12 genera (Table 1.1) representing 9% of the total number of mammals present in the western subtropical region and 3% of the total number of mammals registered in Ecuador to date (382 species according to Tirira, 2007). The Shannon-Wiener's diversity index indicated that the large and mid-sized mammals of the study area represent medium levels of diversity. Felidae is the family best represented within the reserve with 3 species recorded. All other families were represented by a single species. A total of 38 individuals were photographed of which 24 were carnivores (63.16%), 6 were ungulates (15.78%), 4 were armadillos (10.53%) and 4 were rodents (10.53%).

| Order | Family | Genus | Species |
|---|---|---|---|
| Artiodactyla | Tayassuidae | 1 | 1 |
| | Cervidae | 1 | 1 |
| Carnivora | Felidae | 2 | 3 |
| | Mephitidae | 1 | 1 |
| | Mustelidae | 1 | 1 |
| | Procyonidae | 1 | 1 |
| | Ursidae | 1 | 1 |
| Cingulata | Dasypodidae | 1 | 1 |
| Rodentia | Cuniculidae | 1 | 1 |
| | Dasyproctidae | 1 | 1 |
| | Sciuridae | 1 | 1 |
| **Total 4** | **11** | **12** | **13** |

Table 1.1. Order, family and number of species of mammals registered at the Reserve between June 2009 and February 2010.

Two species had the greatest capture number; *Leopardus tigrinus* (Figure 1.1) and *Eira barbara* (Figure 1.2), in second place *Puma concolor, Tremarctos ornatus* and *Dasypus novemcintus* with four captures each; the following were captured three times; *Leopardus wiedii, Mazama americana* and *Pecari tajacu*; and in decreasing capture order we had two captures of *Dasyprocta punctata* and *Nasua narica*; finally species with only a single capture were: *Conepatus semistriatus*, *Cuniculus taczanowskii* and *Sciurus granatensis*.


**Figure 1.1** One of the most common images captured (Ocelot).


**Figure 1.2** Also a species commonly seen on camera traps in the reserve (Tayra).

In 2010 we re-established the camera trap network with 14 top of the range camera traps (Reconyx RC 60). These have a trigger time of 1/5 second and no-glow infrared flash. This has proved to be the only camera system capable of withstanding the cloud forest environment that is also guaranteed to capture all passing wildlife. Cameras were initially established in the field in August 2010 and collected at the end of September 2010. Of particular interest is the observation of a Paramo Wolf, a species normally observed at heights of 3500 m and over, descending to lower altitudes through the reserve and returning to higher ground a day later.,

The complete dataset will be under analysis in spring 2011 with the aim of comparing the 2010 Reconyx camera trapping summer season with previous camera trapping results outlined above and to determine the densities of ocelots (*Leopardus tigrinus*) within the reserve using PRESENCE software.

*Bird survey*:
The endemic species identified within Santa Lucía during the study represent 50% of the total 44 endemic species recorded within the Andean slopes of the Chocó Region. The high levels of endemic species within the reserve clearly highlight its ecological importance. In total, 190 species were identified within the reserve; 153 of these were identified in 2008, 27 additional species were identified in 2009 and a further 10 in 2010.

Areas of Santa Lucía have previously been deforested for grazing, sugarcane and coffee plantations and the reserve is now a patchwork of 3 different habitat types - primary forest, secondary forest and silvopasture. Diversity of forest-dwelling species is usually negatively affected by the removal of forest due to homogenisation of habitat and loss of canopy cover, often leading to replacement of forest-birds by open-land species (O'Dea and Whittaker, 2007). Species diversity was analysed by O'Dea and Whittaker (2007) across the different habitat types of the Santa Lucía, Maquipucuna and Mindo Valley Reserves as part of a study of habitat degradation impacts upon bird populations. O'Dea and Whittaker (2007) calculated and compared species diversity, richness and density at four different levels of habitat degradation. The study found that species richness and diversity was lowest in agricultural land and highest in secondary forest and forest-edges. The authors propose that because this area has experienced 15-20 years of secondary forest re-growth, habitat quality may be similar to that of primary forest. The study identified two main reasons for high diversity within secondary forest; firstly, many forest-birds such as Trogons, Antbirds and Manakins have adapted to intense habitat modification and gap dynamics within the 20 year re-growth period and are therefore abundant in secondary forest; secondly, edge-forest species were highly resilient to habitat modification and therefore abundant within secondary forest. Therefore secondary forest was found to have higher species richness and diversity because it can support both edge-forest species and forest-interior species. In contrast to these results; Cresswell et al (1999) surveyed cloud-forest birds in Northeast Ecuador and reported declines in species richness along a gradient of increased habitat modification between primary forest, secondary scrub (paramo), and agricultural land.

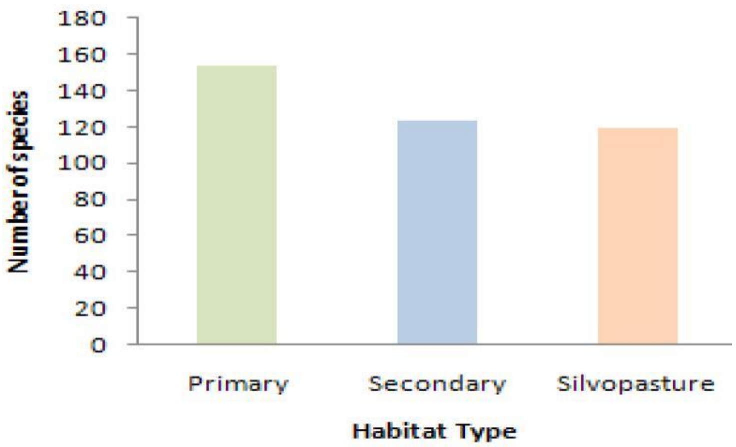


**Figure 1.3** Alpha diversity of species observed in primary forest, secondary forest and silvopasture.

Analysis of three years of our dataset showed a greater abundance of birds were observed in primary forest whilst disturbed habitats (secondary forest and silvopasture) displayed a lower diversity (Figure 1.3). 80 of the total 190 bird species observed, were recorded in all habitat types, however <23 occurred in only 2 habitat types (Figure 1.4). 36 species were only observed in primary forest, including the Andean cock-of-the-rock (*Rupicola peruviana*). Using Canoco 4.5 we carried out a direct gradient analysis (RDA) that indicated that altitude was the principal factor determining species diversity and abundance ($p<0.001$) (Lepš & Šmilauer, 2003). Eliminating altitude we still see a significant ($p<0.001$) correlation between habitat type and species diversity and abundance (Figure 1.5).

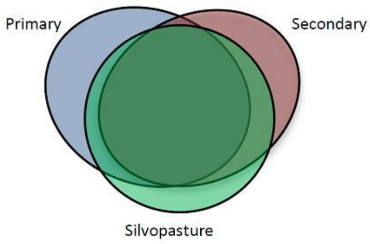


**Figure 1.4** Venn diagram indicating the extent of overlap of species between habitats.

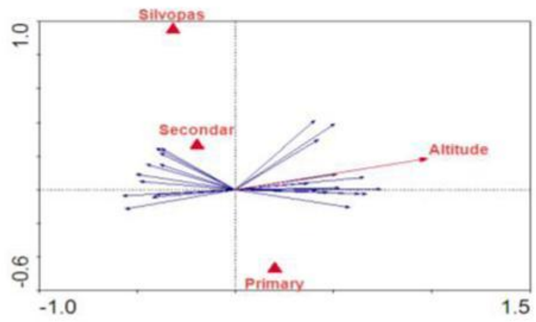


**Figure 1.5** Canoco4.5 analysis (RDA) ordination showing relationships between principal coordinate axes and altitude, habitat and species.

Using EstimateS8.2 (Colwell, 2009) to create a species abundance curve, it can be seen that an increase in sampling effort produces greater divergence of the species numbers in the three habitat types (Figure 1.6). A low sampling effort produces similar results for each habitat type whereas an increase indicates higher species diversity in primary forest.

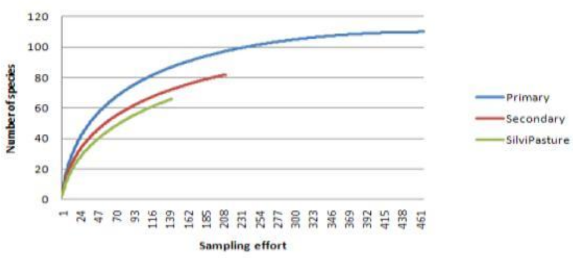


**Figure 1.6** Species accumulation curves for the three habitat types showing higher species diversity for primary forest.

Initial analysis of the data gives a clear indication that primary forest has a significantly higher species diversity and abundance. These results are contrary to previous studies with low sampling effort (Mordecai et al., 2009; Johns, 1991). Primary forest species diversity is expected to continue to grow incrementally due to the presence of rare species (O'Dea & Whittaker, 2007). A plateau is yet to be achieved in species abundance data for disturbed habitats, however, it is expected to level off at a higher sampling rate as there are fewer rare species. Further work in this area will look at diversity indices at different sampling efforts, in order to illustrate how a low sampling effort reduces accuracy. Following this investigation of the data will ascertain as to how effective secondary forest and silvopasture are as suitable habitats for endangered, endemic and rare species. From Figure 1.4 it can be seen that many of the bird species were found in all habitats indicating that the two disturbed habitats provide sufficient habitat to support many species, at least within the habitat mosaic seen at Santa Lucía. This will be investigated further.

As a protected reserve with 80% undisturbed primary forest and a large proportion of regenerating secondary forest and silvopasture, Santa Lucía evidently provides an important habitat for montane bird species. Further sampling within the reserve may identify more endemic species which are known to exist within the Chocó-Andean Corridor. We continue to analyse the dataset in 2010/2011 and aim to publish a paper identifying bird species as habitat quality indicators for the various forest types throughout the altitudinal range represented by our monitoring programme.

*Herpetofana surveys:*
Almost all aspects of herpetofaunal understanding is lacking for the area surrounding the Santa Lucía reserve. Due to the difficulty of working in such an environment and low population densities of study species the focus has long been on lowland sites. Thus all information gathered during our research will prove to be a valuable resource for future studies in the local area or further afield.

An inventory of the herpetofauna in the reserve has been carried out since the start of the 'Climate Change, Canopies and Wildlife' expeditions began in 2008. To date we have recorded 21 species of reptile (Table 1.2) and, due to the inherent difficulties, the amphibian species are still being identified - so an accurate account cannot be provided at present. However, almost all species found on the reserve belong to the Pristimantis genus with *Pristimantis achatinus* and *Pristimantis w-nigrum* being the most abundant.

| | Altitude (m/asl) | | | | Habitat | | |
|---|---|---|---|---|---|---|---|
| **Species** | 1400-1700 | 1700-2000 | 2000-2300 | 2300-2600 | Primary | Secondary | Tertiary |
| **Lizards** | | | | | | | |
| *Anolis aequatorialis* | - | + | - | - | + | - | - |
| *Anolis fraseri* | - | + | - | - | - | + | - |
| *Anolis gemmosus* | - | + | - | + | + | + | - |
| *Cercosaura vertebralis* | + | + | - | - | - | + | + |
| *Riama oculata* | + | + | - | - | + | + | + |
| *Riama unicolor* | - | + | + | - | + | + | + |
| *Riama spp.* | + | - | - | - | + | + | - |
| *Stenocercus varius* | - | + | - | - | - | - | + |
| *Echinosaura brachycephala* | - | + | - | - | + | - | - |
| *Enyalioides oshaugnessyi* | - | - | + | - | + | - | - |
| *Lepidoblepharis spp.* | + | + | - | - | + | + | - |
| | | | | | | | |
| **Snakes** | | | | | | | |
| *Atractus dunni* | - | + | - | - | - | - | + |
| *Atractus gigas* | - | - | - | + | + | - | - |
| *Atractus spp.* | - | + | - | - | - | - | + |
| *Chironius monticola* | - | + | - | - | + | - | - |
| *Coniophanes fissidens* | - | - | + | - | + | - | - |
| *Dendrophidion dendrophis* | - | + | - | - | - | - | + |
| *Dendrophidion nuchalis.* | - | + | - | - | - | - | + |
| *Dipsas oreas* | - | + | - | - | - | + | - |
| *Tantilla melanocephala* | + | + | + | - | + | + | + |
| *Bothriechis schlegelii* | + | - | + | - | + | - | - |

**Table 1.2**. Reptile species recorded from the Santa Lucía community cloud-forest reserve with collection data: altitudinal bands, and habitat type for respective species. Tertiary habitat refers to any habitat type that does not qualify for primary or secondary forest: silvopasture, plantations, and human habitation areas.

A variety of methods were employed to collate the inventory presented herein and no single method proved particularly successful in capturing all species. A total of nine methods were used: pitfall traps with drift fences, 'pole and noose', excavation, line transects, grid transects, active searches, pipe traps, bromeliad patch sampling, incidental sightings and capture by staff and volunteers. Line and grid transects were 'axed' after the July - September 2008 sampling period as very few specimens were recorded comparative to sampling effort. However, opportunistic searches across the entire reserve proved successful so were implemented extensively through all field expeditions.

Bromeliads have proved important microhabitats for many aspects of anuran biology, linking significantly to their survival. It is unsurprising therefore that several species that were not documented by utilizing other techniques were collected from bromeliads in both 2009 and 2010. The implementation of PVC pipe traps (see Fig 1.7) proved successful in capturing a currently unidentified species of Pristimantis that was only found within bromeliads on the reserve. This indicates that the pipe traps act as artificial refuges for arboreal species that would usually sleep in bromeliads during daylight hours. The arboreal placement of the traps also provides a good picture of the species that may otherwise be missed or an alternative to the very time consuming procedure of bromeliad patch sampling - particularly if canopy access techniques are required to collect the bromeliads. Pipe traps have been set up across the reserve with four sizes trialled: 5cm x 50cm, 5cm x 100cm, 7.5cm x 50cm, and 7.5cm x 100cm. Pipe traps that were located above 2m were set up using a Buckingham Big Shot catapult and have been left up for collection by the 2011 Earthwatch expedition teams for further analysis.

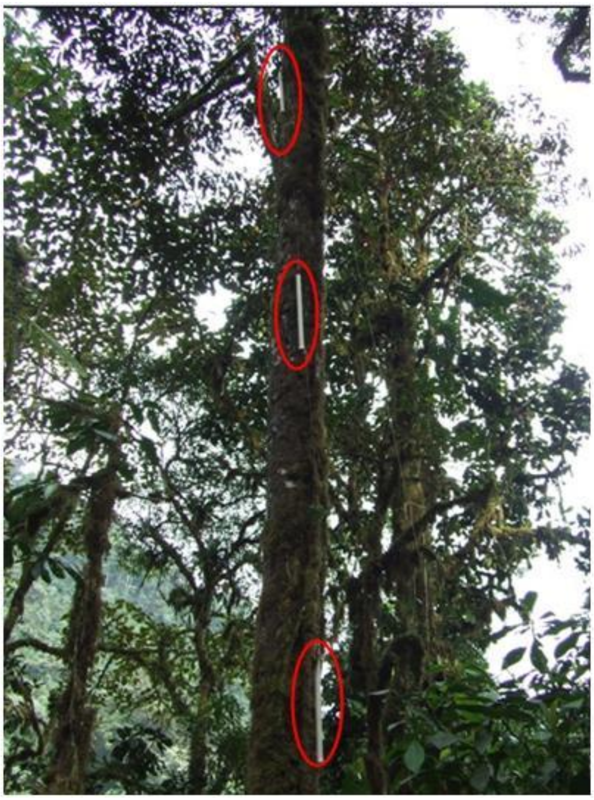

**Figure 1.7** Pipe trap setup at Santa Lucía.

**Objective 2:**

Estimates of population density of study species allowing long-term monitoring of population trends

**Progress toward/against Objective 2:**

For projects that aim to improve forest habitat, i.e. as part of REDD+, there is the urgent need to develop simple indicators of forest improvement or degradation. The ability to detect environmental change is also important in the context of habitat degradation and climate change. The bird survey dataset has been established to determine whether presence/absence and change in abundance of bird species can indicate environmental change. In May 2010 a preliminary analysis of two years of bird data was undertaken to detect significant change in species populations over a two year period of the dataset. In 2010/2011 we continue to analyse the dataset using multivariate statistical techniques with the aim of identifying habitat indictors. Preliminary results from the latest analyses indicate that habitat quality indicator species need to be altitude specific in regions of extreme topography such as the tropical Andes i.e. altitude is the key explanatory variable for species presence and abundance.

*DISTANCE analysis and power analysis:*
On the first two years of data we carried out DISTANCE analysis (Buckland, 2001) to produce mean density estimates and upper and lower 95% confidence limits for each bird species with greater than 30 observations (considered a minimum for this type of analysis). Of 180 recorded species only 44 satisfied this criterion. As it is particularly important in this type of study to minimise type II statistical errors (i.e. a false negative), we carried out a power analysis based on mean densities and confidence intervals for the two years setting alpha to 0.05 and beta to 0.8 (accepting a 20% chance of type II error). No 'seen' species showed statistical significant differences in density between the two years sampled. However, a few 'heard' species did produce statistically significant differences as they had the largest sample sizes and, following power analysis, had significant power to detect a change in population.

| Species | Mean 2008 - Mean 2009 | Effect Size | Power | Sample size required if power is<0.8 | Sample size required per year. | Compromise Analysis: α-level | Compromise Analysis: β-level |
|---|---|---|---|---|---|---|---|
| **Andean Solitaire** | **0.253** | **0.229** | **0.855** | **N/A** | **N/A** | **N/A** | **N/A** |
| Andean Cock-of-the-Rock | -0.187 | -0.036 | 0.111 | 19082 | 9541 | 0.407 | 0.593 |
| Booted Racket-Tail | 5.141 | 0.133 | 0.47 | 1400 | 700 | 0.192 | 0.808 |
| Brown-capped Vireo | 0.018 | 0.047 | 0.138 | 11198 | 5599 | 0.379 | 0.621 |
| Dusky Bush-Tanager | 0.563 | 0.109 | 0.36 | 2084 | 1042 | 0.237 | 0.762 |
| Golden-crowned Flycatcher | 0.014 | 0.058 | 0.168 | 7354 | 3677 | 0.352 | 0.648 |
| Golden-headed Quetzal | 0.011 | 0.031 | 0.1 | 25736 | 12868 | 0.42 | 0.58 |
| Gray-breasted Wood-Wren | -0.329 | -0.117 | 0.396 | 1808 | 904 | 0.222 | 0.778 |
| Narino Tapaculo | 0.017 | 0.04 | 0.12 | 15458 | 7729 | 0.397 | 0.603 |
| **Orange-bellied Euphonia** | **0.633** | **0.568** | **1** | **N/A** | **N/A** | **N/A** | **N/A** |
| **Plate-billed Mountain Toucan** | **-0.028** | **-0.434** | **0.999** | **N/A** | **N/A** | **N/A** | **N/A** |
| Plumbeous Pigeon | 0.051 | 0.208 | 0.791 | 574 | 287 | 0.087 | 0.913 |
| **Rufous-breasted Antthrush** | **0.182** | **0.327** | **0.987** | **N/A** | **N/A** | **N/A** | **N/A** |
| Russet-crowned Warbler | -0.1 | -0.15 | 0.55 | 1102 | 551 | 0.163 | 0.837 |
| Slate-throated Whitestart | 0.162 | 0.142 | 0.51 | 1228 | 614 | 0.176 | 0.824 |
| **Sparkling Violetear** | **0.216** | **0.218** | **0.823** | **N/A** | **N/A** | **N/A** | **N/A** |
| Toucan Barbet | 0.014 | 0.052 | 0.151 | 9148 | 4574 | 0.367 | 0.633 |
| Violet-tailed Sylph | 0.256 | 0.162 | 0.605 | 944 | 472 | 0.144 | 0.856 |
| Wattled Guan | 0.019 | 0.636 | 1 | N/A | N/A | N/A | N/A |

**Table 2.1** Table of power values of density estimates for heard species. The sample size required to achieve 0.8 for all species with a power value below 0.8 is provided. This is then divided by two to give the required sample size per year. Finally, the table shows the compromise analysis results for species where the required sample size is unrealistic for a 3 month survey. Species providing adequate power are highlighted in bold.

Species providing sufficient replicates from existing samples to detect significant change are shown in bold in table 2.1. Through DISTANCE sampling and analysis, statistical testing and power analysis, a number of species have been identified for future monitoring of population density changes. These species are; Andean Solitaire, Orange-bellied Euphonia, Plate-billed Mountain Toucan, Rufous-breasted Antthrush, Sparkling Violetear and Wattled Guan. Species which would be useful if a-level was compromised to 0.15 are: Plumbeous Pigeon (*Patagioenas plumbea*) and Violet-tailed Sylph (*Aglaiocercus coelestis*). Many of these species have been described as inconspicuous and difficult to spot, such as Wattled Guan, Rufous-breasted Antthrush and Andean Solitaire (Ridgely and Greenfield, 2001a; 2001b) and all potential indicator species were recorded as heard except for the Violet-tailed Sylph (high power value for both seen and heard).

The Distance Sampling and Power analysis methods are useful for confidently detecting changes in species density estimates; however large sample sizes are required for this method which leads to a large amount of information loss during the screening processes. It should be noted that sampling was carried out at slightly different times in 2008 and 2009; therefore species density changes detected within this survey may not be due to climatic change, but seasonality and migration. Another drawback of this approach is the need to have a sufficiently large sample size that means that the indicator species tend to be the most common species within the area because they have highest sample sizes; it may be that the most common species are also the hardiest of bird species within the reserve. Environmental change might impact more significantly on the rarer more specialised species, but changes in these populations will not be detected due to smaller sample sizes. As such environmental change impacts may manifest within the indicator species at a slower rate than for more threatened species, and detection of population change within the indicator species may come too late for threatened species. Although generally easy to detect it might be that birds may not be the most sensitive group of species for monitoring change due to the risks outlined above. There is a caveat to this last sentence - we are likely to be surprised by the impacts of environmental change and unexpected effects can only be identified through a monitoring programme that covers as wide a spectrum of the ecosystem as possible.

For future studies, one recommendation is that call survey points be distributed equally between habitat types (although this is complicated by the fact that the habitat types make up significantly different areas within the reserve) and a standard sampling effort is carried out within these habitat types. This would reduce bias and increase the confidence of diversity estimates. It is also recommended that the standard sampling effort be greater than 50, perhaps a minimum of 100 samples per habitat, in order to determine more accurate species numbers per habitat and to account for the slower accumulation of species observations within primary forest. More than 2 years of data is required for effective comparison of population changes within the reserve and sampling should be carried out at a standard time of year to avoid seasonal and migratory variation. An analysis of community structure may also provide further insight into population changes and improve long-term monitoring.

**Objective 3:**

Information on the status of food webs and habitat of study species

**Progress toward/against Objective 3:**

*Bromeliads:* The Bromeliad Project began in 2009, when several canopy bromeliad samples were taken from the reserve to assess herpetofauna diversity and occurrence. Positive results have initiated an investigation into biotic and abiotic characteristics that influence the invertebrate and vertebrate communities and food webs of bromeliad 'tank water' environments.

*Altitude:* During the 2010 sampling season the differences in the invertebrate community within bromeliads with altitude were also investigated. This study is currently an ongoing research project that will form the part of an undergraduate BSc. thesis by an Ecuadorian research student based at the San Francisco de Quito University, Ecuador. Six altitudinal range plots were sampled (plots: 1400m - 1600m, 1600m - 1800m, 1800m - 2000m, 2000m - 2200m, 2200m - 2400m, 2400m - 2600m). Five Bromeliaceae samples were taken from each plot focusing on a standardized size for each collected plant; approximately 80cm of height vs. 20cm at base width. The height at which the sample rested was also standardized, keeping all samples between 0 - 3 meters. We kept a tally of how many live leaves each sample had as a secondary size indicator. The bromeliad, with its water tank intact, was collected in a plastic bag and processed to sort invertebrates and vertebrates. Samples in 90% alcohol were transported to the University in Quito for identification.

*Canopy Height:* Using canopy access techniques fifteen Bromeliaceae samples were collected from the Santa Lucía reserve at an average height of 14 meters above ground level. The samples were collected from a similar altitude (1800 - 2000 meters above sea level); each plant was evaluated for sampling based on size (height vs. width at base: 70cm x 20cm approximately) and on safety conditions, which included individual evaluations of the safety conditions provided by the tree on which a sample was located. Given the study area, high humidity conditions and presence of Cecropia (balsa) trees, sampling was not randomized but restrained to a few samples. Once collected, samples were processed as above.

Preliminary results: 10 out of 30 samples from the “altitude” variable and 12 out of 14 samples from the “height” variable have been processed so far. Invertebrates from 7 samples (altitude) and from 6 samples (height) have been identified (to family level). From processed samples, each bromeliad has been shown to maintain from 70 to 150 invertebrate larvae specimens, and up to 20 adult invertebrates. Predominant orders found so far include, but are not limited to: Coleoptera, Diptera, Odonata, Blataria, Saltatoria and Annelida. A few ant colonies have been found in several samples, as well as frogs from the Pristimantis genus (Strabomantidae).

Several different indices will be used in order to identify differences between each sample with altitude, in terms of diversity and community composition. These include the Shannon diversity index and the Community Composition Comparison Index, which will reveal how different each plot is from other. Also, Chi square analysis and Contingency tables will be used as statistical tools to establish different distribution patterns of invertebrates throughout the reserve.

*Bird survey & habitat dataset:* The bird survey dataset now consists of just fewer than 10,000 records of 190 species from 123 point distance survey locations covering the habitat and altitudinal range of the reserve. Integration of the bird survey dataset with a micro-scale habitat assessment is currently underway (expanding on work in 2010) for an undergraduate thesis at the University of Sussex to identify key habitat quality indicators. The aim is to identify simple structural measures to provide an indication of forest status allowing simplified analysis of habitat quality monitoring.

*Camera traps:* With information from the 2010 camera trapping season we have reliable estimates of abundance of prey species (i.e. agouti, peccary, etc.) and their feline predators (Puma, Ocelots). This provides the opportunity to develop indices of prey base and carnivore carrying capacity of the reserve. Information will be integrated within studies of feline population densities.

*Snakes and predation*: To test for the long suspected aposematism (warning colouration) that occurs within the highly venomous snake genus Bothrops plasticine snakes were set up at the lower altitudes on the reserve. Eight snake variables were utilised: small Bothrops, small Bothrops on paper, large Bothrops, large Bothrops on paper, small non-venomous snake, small non-venomous snake on paper, large non-venomous snake, and large non-venomous snake on paper. The use of paper was to test for the possibility of whether the Bothrops pattern and colouration is for crypsis rather than aposematism.

Almost all recorded attacks were from small mammals (generally in the form of scratch marks). It is likely that these attacks are erroneous and only represent curiosity on close examination by the small mammals. There were however several documented attacks by avian predators during the test period but no conclusive results could be made due to such a small number.

Snakes will be set up again with additional replicates during the Earthwatch expeditions in 2011 to provide us with a clear picture of the patterning exhibited by many of the Bothrops species.

**Objective 4:**

A novel remote sensing based methodology for habitat assessment metrics of canopy tree species in Andean mountain environments

**Progress toward/against Objective 4:**

Analysis of data collected from 2008 and 2009 field seasons is underway with the aim of submitting a paper in spring 2011. To date 278 replicates from 91 crown images from primary forest have been analysed and multivariate redundancy analysis (RDA) of the distribution of spectral intensity (for red and blue bands in imagery) of aerial imagery of crowns was found to be statistically significant at the level of genus (Monte Carlos simulation p=0.002) (Figure 4.1). This provides the evidence required to proceed with the methodology and apply pattern recognition software to the datasets. The result would be a tool providing information at the landscape level from high resolution aerial imagery. In addition to opening up studies at the landscape scale it would also be useful in identifying endangered canopy species for distribution mapping and identification of priority forest areas for conservation action.

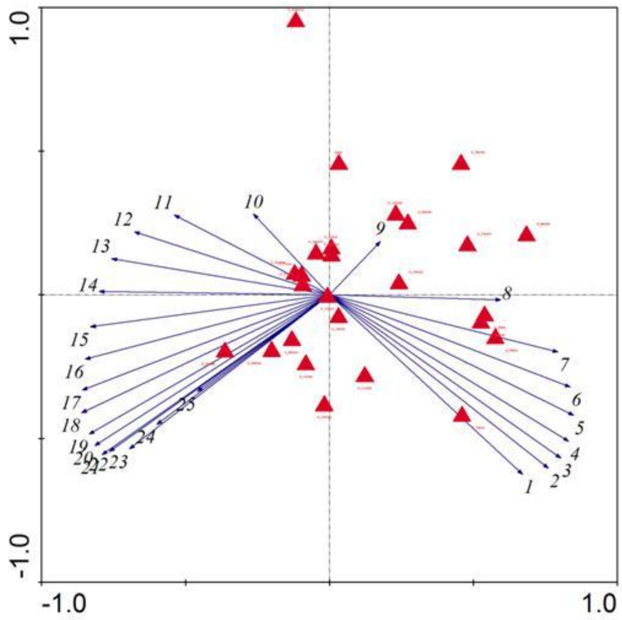


Figure 4.1. PCA analysis of Red band with overlay of genera as nominal categorical variables. Genera are significant in explaining the spectral distributions (based on RDA analysis, p=0.002).

**Objective 5:**

Monitoring climate change – data loggers and bryophytes

**Progress toward/against Objective 5:**

*Data Loggers:* Data was downloaded from the 46 data loggers installed across the Santa Lucía Reserve that record temperature and humidity at 45 minute intervals throughout the year. Preliminary analysis has shown a lapse rate of 0.493°C per elevation of 100m based on the annual mean temperature readings from 17 under canopy data loggers spread across the altitude 1400 - 2500m. This is consistent with wet adiabatic lapse rates occurring in moist air masses and is approximately half that of dry adiabatic lapse rates. Our plans are for dissemination of the dataset online in 2011 after 4 years of data has been recorded - the information is useful for calibrating regional climate models. We are currently analysing the dataset with the bryophyte data to determine the potential for monitoring climatic trends using moss and liverwort communities.

*Bryophytes:* Mosses and liverworts were sampled from 20 points through an altitudinal range of 1412m to 2521m above sea level. At each sampling point 20 trees with similar diameters were selected and bryophytes collected at a height of approximately 1.4 m. Multivariate analysis shows altitude as a highly significant environmental predictor of bryophyte genus ($p<0.002$ for RDA). It is interesting to note that for genera for which the first principal axis explains at least 25.8%, liverworts are associated with higher altitudes and mosses with lower altitudinal samples. This is likely to reflect the higher atmospheric moisture levels at higher altitude but we await further analysis from datalogger information. Our aim is to identify altitudinal zones within the study transect where species turnover might provide particular information on climatic change.

**Objective 6:**

Integrate methods and results for biodiversity and carbon within a framework to estimate ecosystem services.

**Progress toward/against Objective 6:**

New financing mechanisms for tropical forests are coming online and include finance from REDD+ (Reduced emissions from deforestation and degradation). Scientific information that underpins any REDD project includes standing stock of carbon for the various forest types. At present there is little information on the standing carbon stock of cloud forests and none for the Santa Lucía Reserve. In 2010 we undertook a field sampling programme to provide information on the above-ground carbon stocks of Santa Lucía Reserve. This information, with further data on local rates of deforestation, forms the basis of financing mechanisms for REDD projects.

*Estimate of carbon stock at Santa Lucía Reserve*: In order to estimate the carbon stocks we used a random sampling strategy in accordance with IPCC Good Practice Guidelines for Land Use, Land-Use Change and Forestry (IPCC 2003), Penman et al. (2003) and Pearson et al. (2005). 30 plots (Figure 6.1) were established throughout the reserve.

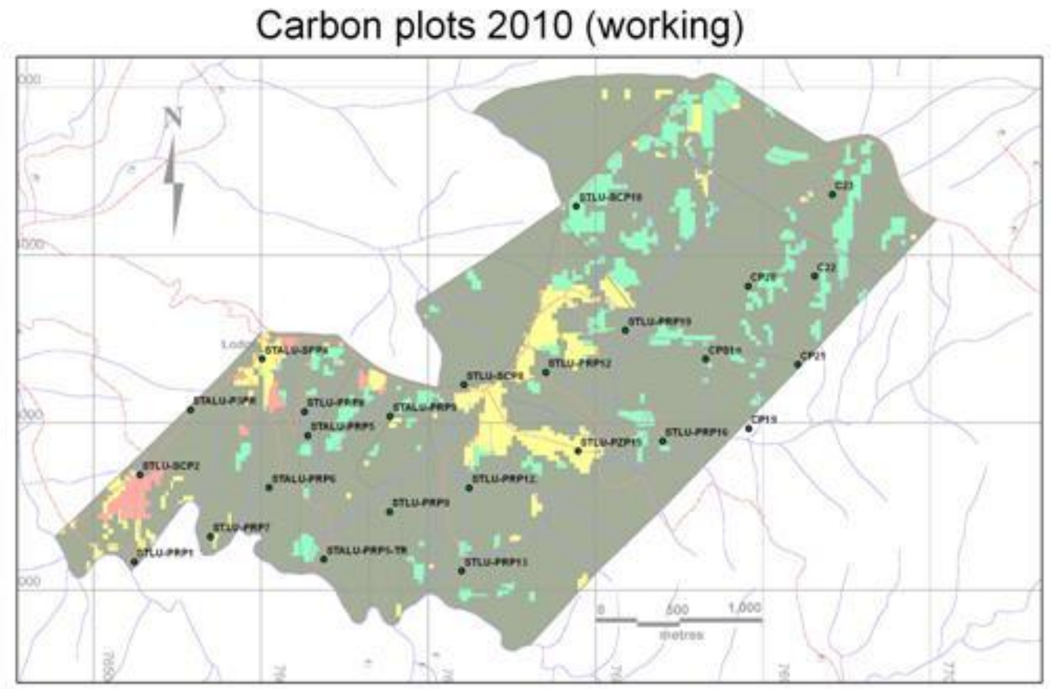


Figure 6.1. Map of 2010 carbon plots used for estimating forest carbon at Santa Lucía Reserve.

At each plot permanent square, nested sample plots were established. Plot locations were marked with a hand held GPS, and a metal stake embedded in the ground at the south west corner. In the largest subplot (0.10 ha) trees of >50 cm diameter at breast height (DBH) were recorded, in the medium subplot (0.05 ha) trees of DBH 20 - 50 cm were recorded and in the smallest subplot trees of 5 - 20 cm DBH were recorded. Above and below ground woody biomass was sampled within the sample plots, by recording DBH at 1.3m, for all trees with a DBH = 5cm. Standardised methods were applied for determining the point of measurement for trees whose diameter at 1.3 m was not representative of the tree as a whole (Pearson et al. 2005). For each tree full species ID was recorded where possible, with local names or classification by genus or family used when full identification was not feasible. In addition to DBH and species, height was estimated and the location of each tree within the sample plot was recorded so that trees could be relocated at a later date.

Standing dead trees were also recorded within the plots. These were categorised according to a 4 point scale: 1) With branches and twigs remaining; 2) Small and large branches remain but twigs are absent; 3) Only large branches remain; 4) No branches. The height and diameter of the stem at the top of the tree was estimated for trees in classes 2, 3, and 4.

For coarse woody debris, surveyed along the external perimeter, the diameter of all fallen dead wood = 5 cm diameter at the point at which it intercepted the transect for coarse woody debris was recorded, and any hollows were noted. Coarse woody debris was categorised as: 1) Sound - firm to the touch; 2) Intermediate - possible to push a sharp object into the wood; or 3) Rotten - crumbles to the touch.

*Calculation of carbon stocks:*
From a total of 1320 individual tree samples we used allometric equations to estimate the above ground and below ground biomass of each live tree. Allometric equations for wet tropical forest (Chave et al. 2005) and Cairns (1997) for below ground biomass were used for all trees.

Species specific wood density values were obtained from the Global Wood Density Database (Zane et al. 2009). An average value was used when there was more than one entry for a species. When species specific information was not available, or when species were identified to genus or family level only, an average wood density of tropical South American species in that genus or family was applied. For species where family was not identified, the average wood density for tropical South American species in the Wood Density Database (Zane et al. 2009) was applied.

Results: Above ground carbon stock with 95% confidence intervals (Live + deadwood) = 143.63 (± 27.13) t C/ha and below ground carbon stock = 19.38 (±4.09) t C/ha.
This estimation of carbon stock for the reserve is vital should Santa Lucía decide to explore REDD as a financing mechanism. For the Earthwatch project, it represents the start of a research programme that aims to provide greater scientific understanding of carbon in cloud forest systems. In 2011 we aim to investigate the carbon associated with epiphytes (a component that remains missing using standardised methods for carbon pool assessment and a potentially significant pool in neotropical mountain regions). In addition we aim to standardise our methodology to allow cross comparison to other Earthwatch field sites globally.

**Updates to Objective 6:**

Objective 6 is ongoing with 2011 fieldwork focusing on:
· Harmonization of field measurements based on the Smithsonian Tropical Research Institute protocols to allow comparison with other Earthwatch HSBC Climate partnership sites.
Protocols: http://www.ctfs.si.edu/group/11/?viewId=49
· Field estimation of contribution of epiphytes to carbon stock of neotropical cloud forests.
· Canopy - atmosphere functions: fieldwork will answer the question `Does forest degradation alter evapotranspiration?'

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## 2. PARTNERSHIPS

Project success has been based on partnerships with:

1. *Holly Hill Trust*: whose ongoing financial support of researchers has ensured the camera trap system ran for an extended field season and who provided a number of grants to support UK thesis students, principal investigator salary and funding for the new RECONYX camera traps;

2. *Rainforest Concern* who supported the development of the bespoke camera trap database;

3. *The National Herbarium Quito (QNCE)* who provide ongoing botanical expertise in plant identification

4. *Pontificía Universidad Católica del Ecuador (PUCE)* has provided help in identification of reptiles and amphibians.

5. *Santa Lucía Cloud Forest Reserve* - through provision of excellent infrastructure and personnel.

## 3. CONTRIBUTIONS TO CONVENTIONS, AGENDAS, POLICIES, MANAGEMENT PLANS

### International

At the international scale the project contributes to the Ecuadorian government's obligations under the Convention on Biological Diversity, in particular to Article 7 (Identification and monitoring), Article 8 (In-situ conservation), and Article 12 (Research and Training).

### National or regional

Regionally the project contributes to the establishment of the Choco-Andean corridor. This network of protected areas connects forest in Ecuador through to Colombia. The Santa Lucía Reserve is a key linkage connecting forest starting at Mindo through to the Cotacachi-Cayapas Ecological Reserve.

The plans to build a research laboratory at Santa Lucía will also provide the facilities for universities (local and national) to run field courses close to the capital Quito, in the distinctive Andean forests.

### Local

The project directly supports the existence of the Santa Lucía Cloud Forest Reserve. As a financial input, the annual contribution makes the community-based reserve financially sustainable resulting in the protection of 700 hectares of forest within a biodiversity hotspot. Baseline data set (completed end of 2011) will provide a basis from which to develop the Santa Lucía Reserve management plan by incorporating species conservation management criteria.

## 4. DISSEMINATION

**Peer reviewed publications:**

1. Tolhurst B., Peck M., Morales J.N., Cane T., & Recchio I. (2010) Extended distribution of a recently described dipsadine colubrid snake: *Atractus gigas*. Herpetology Notes (3): 73-75

2. Maddock S.T, Tolhurst B., Peck M.R. , Morelos J. (2010). *Chironius monticola* (Mountain Sipo). Body bending behaviour. Herpetology Notes (Submitted)

3. Maddock S.T, Tolhurst B., Peck M.R. , Morelos J. (2010). *Riama oculata* - prehensile tail and new habitat type. Herpetology Notes (Submitted)

4. Cueva X.A., Morales N., Brown M. & Peck M (2010). Macro y mesomamíferos de la Reserva Comunitaria Santa Lucía, Pichincha – Ecuador. BOLETIN TECNICO, SERIE ZOOLOGICA, Ecuador (Submitted).

5. Maddock S.T, Tolhurst B., Morales J.N., & Peck M. (2010) The reptiles of the Santa Lucía Cloud Forest Reserve, Province of Pinchincha, Ecuador. Herpetological Conservation and Biology (Submitted).

Note: 3 papers in preparation for 2011 covering camera trapping, bryophytes and altitude and aerial taxonomy.

**Academic dissertations:**

1. Nicola Fry (2010) Monitoring Population Change of Bird Species within a Tropical Montane Cloud Forest, Ecuador. BSc thesis. University of Sussex, UK.

2. Nicholas Biddiscombe (2010) The Abundance and Diversity of Bromeliad-inhabiting Fauna in an Ecuadorian Cloud Forest, in Reference to the Theory of Island Biogeography. BSc thesis. University of Sussex, UK.

3. James Duffy (2010) More than just timber. Exploring the hydrological values of two tree species in a tropical montane cloud forest, Ecuador. BSc thesis. University of Sussex, UK.

4. Martin Padbury (2009) An Investigation into Developing Aerial Taxonomic Keys for Remote Identification of Canopy Trees in Aerial Photographs. BSc thesis. University of Sussex, UK.

5. Matthew Brown (2009) Testing the effectiveness of camera trapping as a surveying method for mammals in a cloud forest environment. BSc thesis. University of Sussex, UK.

**Digital:**

Online Camera Trap database: www.sussex.ac.uk/Units/lifesci/rainforest/
The online camera trapping database continues to be updated from imagery collected from the network of cameras from the reserve and is available to the general public.

**Media:**

New Scientist 30 March 2009: Rare animals to feature on Google Earth. http://www.newscientist.com/article/mg20127015.500-rare-animals-to-feature-on-google-earth.html

Daily Telegraph 14th April 2009: Remote Controlled Helicopters in Rainforest used to Monitor Global Warming
http://www.telegraph.co.uk/earth/earthnews/5149137/Remote-controlled-helicopters-in-rainforest-used-to-monitor-global-warming.html

**Meetings and conferences:**

Earthwatch Lectures: Forests and Climate, 26th March 2009 RGS.

In 2010 a meeting to discuss the future of work at Santa Lucía took place with the communities representing Santa Lucía Reserve. The role of scientific research was clearly recognized both due to the scientific information generated and through its potential to raise funds to maintain the reserve. As a result the Santa Lucía Reserve community has agreed to build a research station to house a new laboratory and space to allow Ecuadorian students to be accommodated at low costs at the reserve. This is a major step in plans to establish a permanent field station at Santa Lucía to allow study of the cloud forest environment of the Western Andes. The build is expected to take 18 - 24 months and will include accommodation for a full time field scientist at the reserve to develop and coordinate scientific research at the reserve. Funds are being raised by a 2010 volunteer.

**Educational resources:**

Camera trapping handbook (Santa Lucía staff)

**Visual:**

One of the field teams (18th - 28th July 2010) was documented by Dorota Laughlin from Australia Earthwatch office, and is now available online as an 'online coffee table book' at: http://www.earthwatch.com.au/Ecuador/

## 5. DEVELOPING ENVIRONMENTAL LEADERS

Youth Training programme: As part of a programme to identify future staff from the communities surrounding the Santa Lucía reserve we continued to invite two youth members to join each Earthwatch team. The aim is to identify future guides for the reserve and provide an outreach to the local community.

Camera trapping: Staff at the reserve have received ongoing training in maintenance of the camera trap network and use of the internet-based database.

## 6. LONG TERM IMPACT OF PROJECT

### 6.1. Taxa of conservation significance enhanced, restored or maintained

Datasets for birds, mammals and reptiles and amphibians form a baseline dataset for the reserve from which to monitor environmental change. See field report above for results of population change monitoring for bird species based on 2 years of EW data.

Bird species recorded in field surveys are shown below with Latin name and IUCN category (Critically Endangered: CE, Endangered: EN, Vulnerable: VU, Near Threatened: NT, Least Concern: LC, Data Deficient: DD, Not Evaluated: NE).

Ochre-breasted antpitta LC Grallaricula flavirostris
White-rumped Hawk LC Buteo leucorrhous
Russet-backed oropendola LC Psarocolius angustifrons
Smoky-brown woodpecker LC Veniliornis fumigatus
Pale-Vented Thrush LC Turdus obsoletus
Rufous Wren LC Cinnycerthia unirufa
Yellow-bellied Chat-Tyrant LC Ochthoeca diadema
Semicollared Hawk NT Accipiter collaris
Plumbeous pigeon LC Patagioenas plumbea
Gray-breasted wood-wren LC Henicorhina leucophrys
Booted racket-tail LC Ocreatus underwoodii
Andean Solitaire LC Myadestes ralloides
Toucan barbet NT Semnornis ramphastinus
Dusky bush-tanager LC Chlorospingus semifuscus
Wattled guan NT Aburria aburri
Golden-headed quetzal LC Pharomachrus auriceps
Orange-bellied euphonia LC Euphonia xanthogaster
Rufous-breasted antthrush LC Formicarius rufipectus
Slate-throated white start LC Myioborus miniatus
Violet-tailed sylph LC Aglaiocercus coelestis
Andean cock-of-the-rock LC Rupicola peruvianus
Sparkling violet-ear LC Colibri coruscans
Red-billed parrot LC Pionus sordidus
Golden tanager LC Tangara arthus
Russet-crowned warbler LC Basileuterus coronatus
Crimson-rumped toucanet LC Aulacorhynchus haematopygus
Nariño tapaculo LC Scytalopus vicinior
Beryl-spangeled tanager LC Scytalopus vicinior
Tawny-bellied hermit LC Phaethornis syrmatophorus
Brown-capped vireo LC Vireo leucophrys
Smoke-collored pewee LC Contopus fumigatus
Dark-backed wood-quail VU Odontophorus melanonotus
Plate-billed mountain toucan NT Andigena laminirostris
Blue-winged mountain tanager LC Anisognathus somptuosus
Scaly-naped amazon LC Amazona mercenaria
Club-winged manakin LC Machaeropterus deliciosus
Pale-eyed thrush LC Platycichla leucops
Golden-crowned flycatcher LC Myiodynastes chrysocephalus
Tricoloured brush-finch LC Atlapetes tricolor
Scale-crested pygmy-tyrant LC Lophotriccus pileatus
Band-tailed pigeon LC Patagioenas fasciata
Brown Inca LC Coeligena wilsoni
Red-headed barbet LC Eubucco bourcierii

Golden-winged manakin LC Masius chrysopterus
Three-striped warbler LC Basileuterus tristriatus
Andean pygmy owl LC Glaucidium jardinii
Azara's spinetail LC Synallaxis azarae
Glossy-black thrush LC Turdus serranus
Powerful woodpecker LC Campephilus pollens
Ruddy foliage-gleaner LC Automolus rubiginosus
Flame-faced tanager LC Tangara parzudakii
Golden-naped tanager LC Tangara ruficervix
Spillmann's tapaculo LC Scytalopus spillmanni
Moustached antpitta VU Grallaria alleni
Spotted barbtail LC Premnoplex brunnescens
Long-tailed antbird LC Drymophila caudata
Masked trogon LC Trogon personatus
Olive finch LC Arremon castaneiceps
Rufous-collared sparrow LC Zonotrichia capensis
Immaculate antbird LC Myrmeciza immaculata
Streaked-capped treehunter LC Thripadectes virgaticeps
Uniform antshrike LC Thamnophilus unicolor
Green-and-black fruit-eater LC Pipreola riefferii
Black-capped tanager LC Tangara heinei
Olive-crowned yellowthroat LC eothlypis semiflava
White-sided flowerpiercer LC Diglossa albilatera
White-tailed tyrannulet LC Mecocerculus poecilocercus
Yellow-breasted antpitta LC Grallaria flavotincta
Blue-and-white swallow Notiochelidon cyanoleuca
Gorgeted sunangel LC Heliangelus strophianus
Cinnamon flycatcher LC Pyrrhomyias cinnamomeus
Crimson-mantled woodpecker LC Colaptes rivolii
Glistening-green tanager LC Chlorochrysa phoenicotis
Masked flower-piercer LC Diglossopis cyanea
Mountain woodcreeper LC Lepidocolaptes lacrymiger
Scaled fruit-eater LC Ampelioides tschudii
Blue-and-black tanager LC Tangara vassorii
Brown violet-ear LC Colibri delphinae
Chestnut-crowned antpitta LC Grallaria ruficapilla
Metallic-green tanager LC Tangara labradorides
White-capped parrot LC Pionus tumultuosus
Lineated foliage-gleaner LC Syndactyla subalaris
White-collared swift LC Streptoprocne zonaris
Barred forest-falcon LC Micrastur ruficollis
Red-faced spinetail LC Cranioleuca erythrops
Collared forest-falcon LC Micrastur semitorquatus
Crested quetzal LC Pharomachrus antisianus
Strong-billed woodcreeper LC Xiphocolaptes promeropirhynchus
White-bellied woodstar LC Chaetocercus mulsant
Barred becard LC Pachyramphus versicolor
Black-winged saltator LC Saltator atripennis
Empress brilliant LC Heliodoxa imperatrix
Golden-olive woodpecker LC Colaptes rubiginosus
Mountain wren LC Troglodytes solstitialis
Roadside Hawk LC Buteo magnirostris
Tropical parula LC Parula pitiayumi
White-whiskered hermit LC Phaethornis yaruqui
Beautiful jay NT Cyanolyca pulchra

Black-chinned mountain-tanager LC Anisognathus notabilis
Broad-billed motmot LC Electron platyrhynchum
Chestnut-capped brush-finch LC Arremon brunneinucha
Choco tapaculo LC Scytalopus chocoensis
Giant antpitta VU Grallaria gigantea
Grass-green tanager LC Chlorornis riefferii
Lemon-rumped tanager LC Ramphocelus flammigerus
Silver-throated tanager LC Tangara icterocephala
Yellow-throated bush-tanager LC Chlorospingus flavigularis
Fawn-breasted brilliant LC Heliodoxa rubinoides
Purple-bibbed whitetip LC Urosticte benjamini
Rufous-headed pygmy tyrant LC Pseudotriccus ruficeps
Squirrel Cuckoo LC Piaya cayana
Three Striped Warbler LC Basileuterus tristriatus
White-throated quail-dove LC Geotrygon frenata
White-winged tanager LC Piranga leucoptera
Yellow-vented woodpecker LC Veniliornis dignus
Collared Inca LC Coeligena torquata
Esmereldas Antbird LC Myrmeciza nigricauda
House wren LC Troglodytes aedon
Lineated woodpecker LC Dryocopus lineatus
Olive-striped flycatcher LC Mionectes olivaceus
Ornate flycatcher LC Myiotriccus ornatus
Sickle-winged guan LC Chamaepetes goudotii
Slaty antwren LC Myrmotherula schisticolor
Slaty spinetail LC Synallaxis brachyura
Speckled hummingbird LC Adelomyia melanogenys
Swallow-tailed kite LC Elanoides forficatus
Wedge-billed hummingbird LC Schistes geoffroyi
White-faced nunbird LC Hapaloptila castanea
White-tailed hillstar LC Urochroa bougueri
Barred fruiteater LC Pipreola arcuata
Barred Hawk LC Leucopternis princeps
Barred parakeet LC Bolborhynchus lineola
Black-chested buzzard-eagle LC Spizaetus melanoleucus
Black-solitaire LC Entomodestes coracinus
Clay-breasted wood wren
cloud forest pygmy owl VU Glaucidium nubicola
Dusky-faced tanager LC Mitrospingus cassinii
Golden Naped Tanager LC Tangara ruficervix
Golden olive woodpecker LC Colaptes rubiginosus
Great thrush LC Turdus fuscater
Green-crowned wood nymph LC Thalurania fannyi
Green-fronted lancebill LC Doryfera ludovicae
Hooded mountain tanager LC Buthraupis montana
Pearled treerunner LC Margarornis squamiger
Pearl-eyed thrush
Ruddy Forest Wren
Rufous-crowned tody-flycatcher LC Poecilotriccus ruficeps
Rufous-crowned warbler LC Basileuterus rufifrons
Rufous-tailed hummingbird LC Amazilia tzacatl
Scaled Antpitta LC Grallaria guatimalensis
Scarlet-bellied mountain-tanager LC Anisognathus igniventris
Sepia-brown Wren LC Cinnycerthia olivascens
Spectacled Whitestart LC Myioborus melanocephalus

Spotted nightingale-thrush LC Catharus dryas
Tyrannine woodcreeper LC Dendrocincla tyrannina
Undulated antpitta LC Grallaria squamigera
Unicolor tapaculo LC Scytalopus unicolor
Wedge-billed woodcreeper LC Glyphorynchus spirurus
White-capped dipper LC Cinclus leucocephalus
White-necked jacobin LC Florisuga mellivora
Yellow-bellied Siskin LC Carduelis xanthogastra
Yellow-breasted woodpecker
Mammals recorded from camera traps are listed below with IUCN status where applicable:
Spectacled bear VU Tremarctos ornatus,
Ocelot LC Leopardus pardilus
Red brocket deer DD Mazama Americana ,
Nine banded armadillo Dasypus novemcintus
Puma LC/VU ICUN Ecuador Puma concolor
Skunk Conepatus semistriatus
Coati Nasua narica
Peccary Pecari tajacu
Tayra Eira Barbara
Margay NT Leopardus wiedii

The following genera of reptiles and amphibians have been collected in the reserve from 2008 to 2009:
Lizards: Anolis aequatorialis, Anolis fraseri, Anolis gemmosus, Cercosaura vertebralis, Riama oculata, Riama unicolor, Riama spp., Stenocercus varius, Echinosaura brachycephala, Enyalioides oshaugnessyi, Lepidoblepharis spp.

Snakes: Atractus dunni, Atractus gigas, Atractus spp., Chironius monticola, Coniophanes fissidens, Dendrophidion dendrophis, Dendrophidion nuchalis, Dipsas oreas, Tantilla melanocephala, Bothriechis schlegelii

Anurans (Genera): Bufo, Centrolene, Pristimantis.

Caecelians (Genera): Caecilia.

**6.2 Habitats enhanced, restored or maintained**

The Earthwatch Project provides a regular income to support the sustainable development of the Santa Lucía Cloud Forest Reserve whose income is generated from ecotourism and the growing scientific tourism revenues.

The cloud forest habitat (a biodiversity hotspot) of 700 hectares is directly maintained by the financial support generated by the Earthwatch project. The project acts as a sustainable livelihood option for the community with sustainability built on three foundations: financial, environmental and social. The project contributes to all three by providing funds to the lodge and reserve, generating scientific data for habitat management, and through educating local staff accompanying volunteers and scientists into the field. The project has been a key factor in the financial success of the reserve over the last two years.

Plans to build a dedicated laboratory space to establish a permanent research station for Ecuadorian and international volunteers and universities to carry out research is now underway as a direct result of the Earthwatch project.

### 6.3 Ecosystem services enhanced, restored or maintained

The project supports the maintenance of the pristine Andean cloud forest and as such contributes to the following environmental services: carbon sequestration (thorough avoided deforestation and flux), watershed protection and provision of water supplies, biodiversity conservation (and all associated ecosystem services including pollination and seed dispersal) and erosion regulation.

From data generated by the 2010 Earthwatch field season we can conservatively estimate that the reserve provides carbon sequestration (through avoided deforestation alone) of approximately 1600 tons C per annum*. To provide some context, this represents approximately 800 transatlantic return flights (per person calculation).
* Calcluation: Avoided deforestation per annum (tons C/year) = primary forest area in hectares x carbon per hectare x local deforestation rate (Cotacachi County rates from Peck 2010)

### 6.4 Cultural heritage enhanced, restored or maintained

The project focuses on the maintenance of natural heritage but also keeps local skills alive including:
1. Sugar production (with a small sugar cane press at the reserve)
2. Local shade grown coffee (with Santa Lucía coffee grown within an agroforestry matrix)

### 6.5 Livelihood assets enhanced, restored or maintained

1) Direct financial support of staff and reserve infrastructure from approximately 80% of funds from Earthwatch going directly to the Santa Lucía Cooperative.
2) Local employment during the project period of guides and support staff
3) Guaranteed income allowing reserve to undertake infrastructure development

As the 'Climate Change, Canopies and Wildlife' project sits within a participatory, community-run reserve there is a close relationship between the Earthwatch project and all local staff engaged in running the project. In addition the outreach programme that includes inviting youth members from the local community to join Earthwatch teams, at no cost to themselves, provides the mechanism through which conservation and training are disseminated directly at a community level.

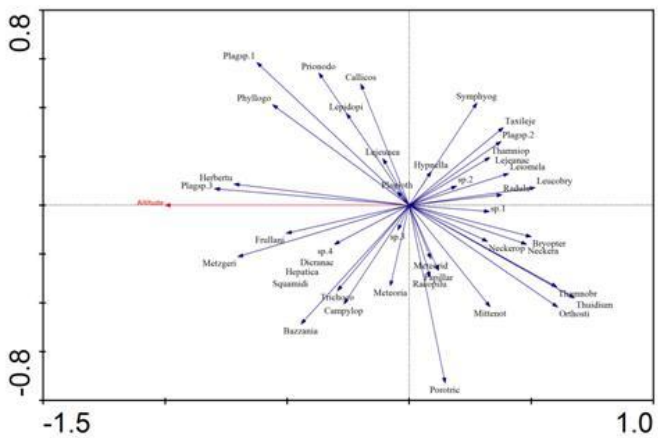


Figure 5.1.Bryophyte genera with altitude as the principal axis in a RDA analysis.