The Rufford Small Grants Foundation
Final Report

Congratulations on the completion of your project that was supported by The Rufford Small Grants Foundation.

We ask all grant recipients to complete a Final Report Form that helps us to gauge the success of our grant giving. We understand that projects often do not follow the predicted course but knowledge of your experiences is valuable to us and others who may be undertaking similar work. Please be as honest as you can in answering the questions – remember that negative experiences are just as valuable as positive ones if they help others to learn from them.

Please complete the form in English and be as clear and concise as you can. We will ask for further information if required. If you have any other materials produced by the project, particularly a few relevant photographs, please send these to us separately.

Please submit your final report to jane@rufford.org.

Thank you for your help.

Josh Cole, Grants Director

Grant Recipient Details	
Your name	Esteban A. Guevara
Project title	A participative approach to study the effects of human-induced disturbance on plant – bird interactions in the Tropical Andes
RSG reference	17050-1
Reporting period	April 2015 – April 2016
Amount of grant	£4775
Your email address	eguevara@avesconservacion.org
Date of this report	May-10th 2015

1. Please indicate the level of achievement of the project's original objectives and include any relevant comments on factors affecting this.

Objective	Not achieved	Partially achieved	Fully achieved	Comments
Volunteers trained		✓		Two undergraduate students at Pontificia Universidad Católica de Ecuador, one recently graduated student from Universidad Central del Ecuador and one local member of the Alambi community and one volunteer from Quito city were trained on protocols for camera setting, video analysis and data entry. However we could not engage students from local High-schools as was originally planned. Youngsters at high-schools did not show much interest in participate.
Monitoring protocol developed			✓	Protocol for camera setting, video analyses and data entry is developed. We are currently working in protocols for flower census at study transects in a collaborative project with Stony Brook University (Graham´s Lab)
Knowledge on an endangered species is increased			✓	Some aspects of the feeding ecology of the Black-breasted Puffleg are being clarified. We know now that the species tend to use more intensively certain plant species
Scientific manuscripts submitted		✓		In progress a paper of Black-breasted Puffleg feeding Ecology.

2. Please explain any unforeseen difficulties that arose during the project and how these were tackled (if relevant).

Windy conditions - During dry season (June-August) there is a high occurrence of strong winds at our study area. This complicated camera setting and video analyses in several ways. First, once cameras were installed in front of a flowering plant there was a high probability of either the camera falling off or else branches with flowers getting out of frame. Also, under these conditions video analyses took longer periods of time, since Motion Meerkat returned a larger number of motion candidate frames

(c. 5000 frames per 5 hours video). On the other hand extreme windy conditions largely influenced hummingbird's activity.

Low interest from high-school students - High-school students were not fully interested in learning about computer vision tools. However they did show interest in hummingbird biology and ecology in general. We changed our strategy, to recruit youngsters, approaching university students instead. We currently work with two undergraduate students from *Pontificia Universidad Católica del Ecuador*. We will be working with them for at least one more year. To keep monitoring activities we will look further support from local universities and their undergraduate students. Furthermore, a third volunteer was trained and he is currently working in a separate project that also applies camera monitoring.

Sample replicates.- In order to get compelling results from our interaction data, we needed to find at least two replicates for each habitat/treatment that we considered to study plant bird interactions. The most difficult habitat to find was forest recovered from fires, since fire-affected areas are located near human settlements and hence they have a long history of habitat degradation beside forest fires, because of this is hard to separate the effects of forest fires from forest logging for instance.

3. Briefly describe the three most important outcomes of your project.

a) Characterization of plant-bird mutualistic networks.- Except for few and isolated studies (e.g. Gutiérrez et al. 2004) little is known about the structure and dynamics of mutualistic networks in Andean plant-bird assemblages. Through this study we contribute to the knowledge on the taxonomic composition of mutualistic networks and how mutualistic interactions respond to habitat loss and degradation.

We studied bird-plant interactions at communities within two elevation belts, namely 3000-3200 m a.s.l. (Alaspungo) and 3200-3500 (Yanacocha and Verdecocha), encompassing three types of habitats: forest interior (FI), forest border (FB) and forest patches (FP). Appendix 1 summarizes information on study transects and effort invested in each habitat/plant.

To record plant-bird interactions we used Plotwatcher Pro cameras settled to take a picture every second from 06h00 to 18h30, making a pause from 12h00 to 13h00. Whenever a flowering plant was detected, a camera was settled in front of flowering branches at a distance of 50-80 cm. Cameras were taking pictures from two to five days in each plant. Cameras returned videos that were analysed using Motion Meerkat software (Weinstein 2015). Motion Meerkat is free software that detects motion candidate frames from a video stream. This computer vision tool has dramatically increased our ability to record hummingbirds in the wild. Examples of plant-bird interactions recorded in cameras are shown in Figure 1a-e

Figure 1.- Examples of bird- plant interactions captured in Plotwatcher Pro cameras and returned after Motion Meerkat screening a) Tyriant Metaltail (*Metallura tyrianthina*) feeding on *Berberis pichinchensis*, b) Saphire-vented Puffleg (*Eriocnemis luciani*) feeding on Guzmania sp., c) Collared Inca (*Coeligena torquata*) feeding on *Macleania macrantha*, d) *Eriocnemis luciani* feeding on *Palicourea fuchsioides,* d) Female Black-breasted Pufleg (*Eriocnemis nigrivestis*) feeding on *Macleania rupestris,* e) Buff-winged Starfrontlet (*Coeligena lutetiae*) feeding on *Capanea affinis.*

Herewith we report the topology of three mutualistic networks at two habitats namely, forest interior and forest border at Verdecocha/Yanacocha Area. We used the bipartite package (Dormann et al., 2008) in R software to visualize mutualistic networks. Network structure of both forest interior and forest border are shown in Figures 2 and 3.

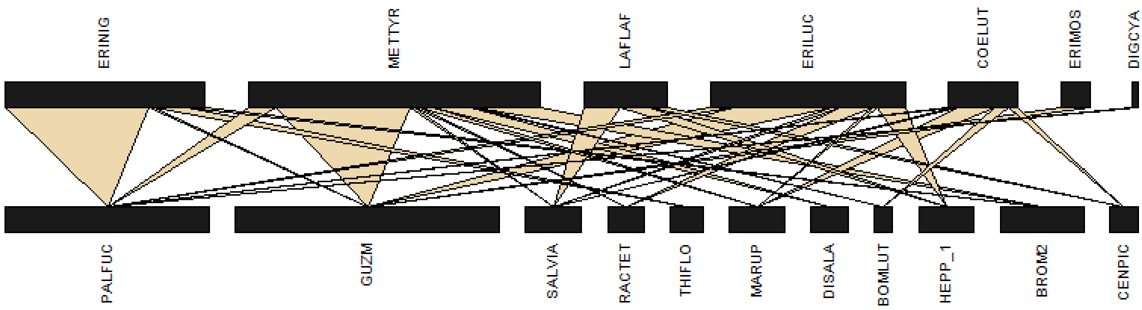

Figure 2. Pollination network structure in forest habitat. Bipartite network consist of higher trophic level species (birds/pollinators) in the upper side, and lower trophic level species (plants) at the bottom of the figure. Species code, birds: ERINIG (*Eriocnemis nigrivestis*), METTYR (*Metallura tyrianthina*), LAFLAF (*Lafresnaya lafresnayi*), ERILUC (*Eriocnemis luciani*), COELUT (*Coeligena lutetiae*), ERIMOS (*Eriocnemis mosquera*) and DIGCYA (*Diglossopis cyanea*). Plants: PALFUC (*Palicourea fuchsioides*), GUZM (*Guzmania* sp.), SALVIA (*Salvia sp.*), RACET (*Racinea tethranta*), THIFLO (*Thibaudia floribunda*), MARUP (*Macleania rupestris*), DISALA (*Disterigma alalternoides*), BOM_Y (*Bomarea* sp.), HEPP_1 (*Heppiella* sp.) and BROM2 (Bromealiacea, unknown species), CENPIC (*Centropogon pichinchensis*).

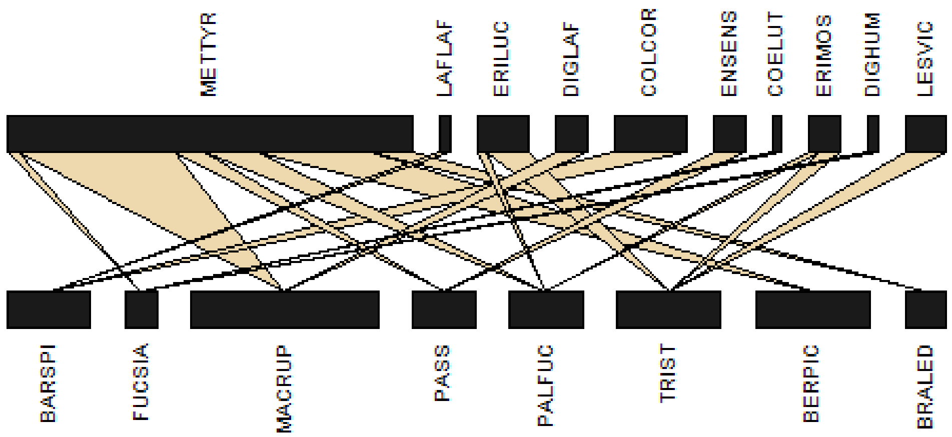

Figure 3. Pollination network structure in forest border habitat. Bipartite network consist of higher trophic level species (birds/pollinators) in the upper side, and lower trophic level species (plants) at the bottom of the figure. Species code, birds: METTYR (*Metallura tyrianthina*), LAFLAF (*Lafresnaya lafresnayi*), ERILUC (*Eriocnemis luciani*), DIGLAF (*Diglossa lafresnayi*), COLCOR (*Colibri coruscans*), COELUT (*Coeligena lutetiae*), ERIMOS (*Eriocnemis mosquera*), DIGHUM (*Diglossa humeralis*) and LESVIC (*Lesbia victoriae*). Plants: BARSPI (*Barnadesia spinosa*), FUCSIA (*Fucsia sp.*), PASS (*Passiflora cumbalensis*), PALFUC (*Palicourea fuchsioides*), TRIST (*Tristerix sp.*), BERPIC (*Berberis pichinchensis*), BRALED (*Brachyotum ledifolium*).

Several topological measures of network structure were obtained using the function "networklevel" in the bipartite package. Nestedness related indices reveal higher nestedness patterns in Forest Interior networks as is shown in Table 1

Table 1. Network metrics of two mutualistic assemblages studied in both Forest Interior and Forest Border.

Index	**Forest Interior**	**Forest Border**	**Index explanation**
connectance	0,37	0,21	Realized proportion of possible links.
web asymmetry	-0,18	0,11	Balance between numbers of the two trophic levels, higher numbers indicates more species of higher trophic level (pollinators) present in the network
weightednestedness	0,39	0,2	Nestedness weighted by frequencies: 1= perfect nestedness, 0=perfect chaos
weightedNODF	27,90	7,53	Higher values indicates higher nestedness patterns

The application of network theory to the analysis of ecological interactions has allowed the description of general principles intrinsic to mutualistic networks such as nestedness and modularity. In mutualistic networks specialist species interact only with a subset of species that in turn could interact with the more generalist species, giving rise to a nested pattern (Bascompte et al 2003). The nested pattern is a common attribute of mutualistic networks and has been proposed that it is responsible of network resilience to species extinction (Memmott et al. 2004, Lewinsohn and Prado 2006). Since specialist species are more prone to extinction, the disappearance or low abundances of specialist species would not affect the overall interaction patterns of the generalist species linked to specialist species (Tylianakis et al., 2010). Our preliminary results show that there might be a decrease in the nested pattern in pollination networks at Forest Border, as shown by nestedness metrics in Table 1. To assert this conclusion further sampling in habitat replicates is needed.

On the other hand, we explored which bird species might be the most important contributors to sustain nestedness patterns in pollination networks. To achieve this we applied the "nestedcontribution" function in bipartite package (Dormann et al., 2008). This function estimates the degree to which the interactions of each row (plants) and column (birds) species increase or decrease community nestedness by comparing observed contribution to those obtained from null models (obtained through a randomization of interaction matrix). Hummingbirds that contribute the most to nested patterns where *Mettalura tyrianthina* (z-score = 1,66), *Eriocnemis mosquera* (z-score = 0.022) in Forest Borders and *Metallura tyrianthina* (z-score = 1,877), *Eriocnemis luciani* (z-score = 1,103) and *Eriocnemis nigrivestis* (z = score = 0,48) in Forest Interior.

b) Black-breasted Puffleg preferred food plants.- Since August 2014, we placed cameras in front of 19 plant species found in five study sites. We obtained almost

1000 hours of video that were analysed with Motion Meerkat software (Weinstein 2015). After image processing we recorded 115 visits of the Black-breasted Puffleg, distributed among five plant species, namely *Macleania rupestris* (Ericaceae), *Thibaudia floribunda* (Ericaceae), *Palicourea fuchsioides* (Rubiaceae), *Disterigma alalternoides* (Ericaceae), *Guzmania* sp. (Bromeliaceae) and an unknown Bromeliad that we momentarily named Bromeliad2_purple. Daily visitation rates as well as visits duration where uneven among the five plant species, being *Macleania rupestris* the most visited plant (Figure 4). Accordingly, the duration of each visit (quantified in seconds) was higher in this species in comparison to other plant species (Figure 3)

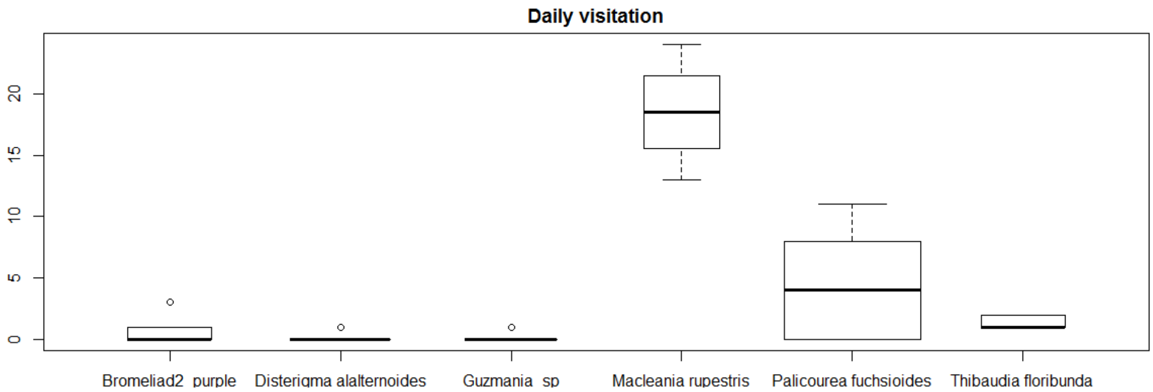

Figure 4. Daily visitation rates of the Black-breasted Puffleg to available flowering plants at Yanacocha, Verdecocha, La Esperanza Hill during period September 2014 – April 2016

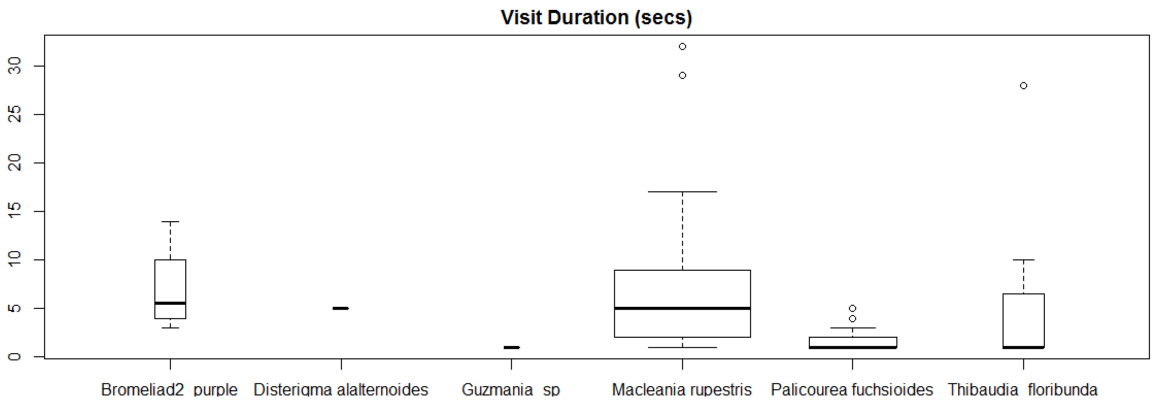

Figure 5. Visit duration (in seconds) of the Black-breasted Puffleg to available flowering plants at Yanacocha, Verdecocha, La Esperanza Hill during period September 2014 – April 2016.

Interestingly, the second main food resource for the Black-breasted Puffleg is *Palicourea fuchsioides* (RUB) a shrub endemic to Ecuador and considered globally Endangered (Jaramillo et al., 2004). This species was only recorded in Verdecocha in the Forest Interior and in Yanacocha at forest borders. According to our observations the plant species is able to produce flowers during almost the entire year, except by a couple of months during dry season (July, August). This plant might represent an important food resource within critical habitat for the species like Forest Interior at ridge-crest elfin forest where the species is suspected to breed (Juiña comm. pers). Also *Macleania rupestris* is one of the most important food resources, although its flowering period is not constant throughout the year, being the period between January and April when it reaches its flowering peaks.

Accordingly, *Macleania rupestris* and *Palicourea fuchsioides* are the plant species where the Black-breasted Puffleg invested more foraging effort (accounted as visit duration in seconds), the other four species were ocassionally used by the Puffleg. Figure 6 illustrates these patterns.

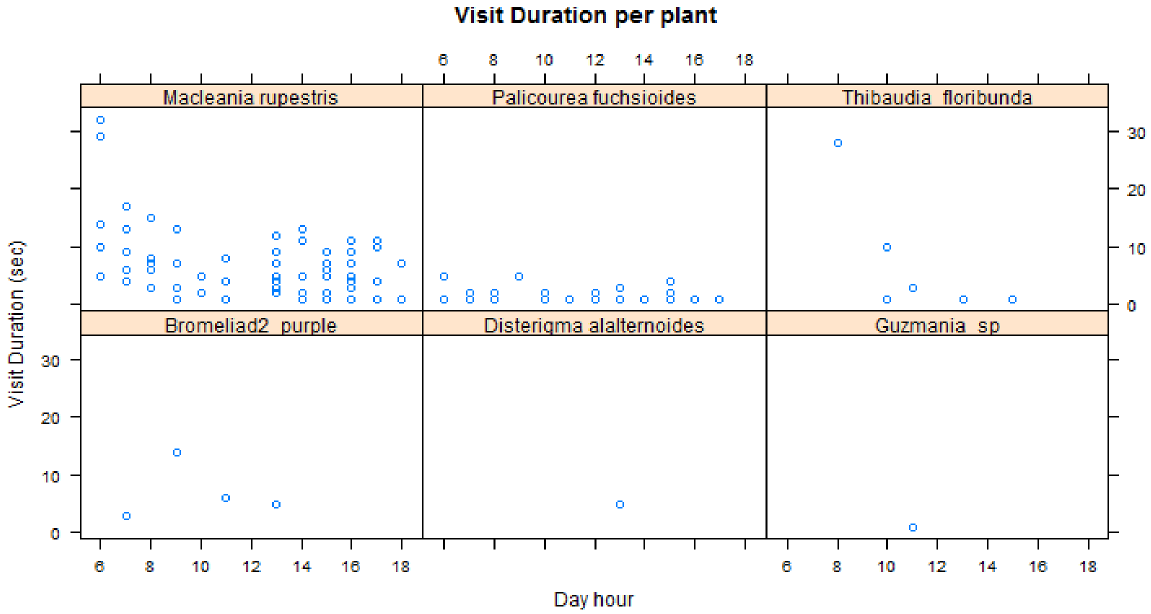

Figure 6. Foraging effort of the Black-breasted Puffleg at each flowering plant where the species was recorded. We considered visit duration in seconds as a proxy to appraise the time invested by the species in each flowering plant.

Also the species seems to occasionally feed on Bromeliads as it has been recorded feeding in two species, *Guzmania* sp. is a common Bromeliad within forest interior. Important feeding resources for the species belong to two plant families Ericaceae and Bromeliaceae.

Consequently, if at the moment we would have to suggest plant species to propagate in restoration initiatives, we would suggest concentrate efforts in these two species that are clearly an important feeding source for the species. Although we recognize the need of further sampling effort, to account for seasonality that may affect flower abundances, we would suggest that important feeding resources for the Puffleg might be *Macleania rupestris* and *Palicoures fuchsioides*.

c) Engagement of third parties.- The implementation of the present Rufford project allowed us to contact researchers involved in similar projects and key stakeholders to maintain camera monitoring in the future. Currently we keep close collaboration with researchers at Stony Brook University, Universidad del Azuay, and Pontificia Universidad Católica del Ecuador. Also we made contacts with managers of further reserves at lower elevations such as Maquipucuna and Santa Lucía Reserves whom have been using camera monitoring at their sites. Keeping close communication and collaboration with these colleagues will allow us to standardize protocols, share data and integrate broader research questions in the future.

4. Briefly describe the involvement of local communities and how they have benefitted from the project (if relevant).

A member of the community of Alambi (Rolando Hipo) participated actively during project field season. Rolando´s help was critical to identify flowering patches as well as to learn about flowering periods of certain species. Rolando is part of the Nono parish, where the project was implemented. In the upcoming weeks we will ask for a meeting with local authorities and inhabitants to disseminate our findings and get feedback from them on future alternatives of continuing this work (e.g. exploring new sites or plant-species).

5. Are there any plans to continue this work?

During the implementation of this work, we kept close communication with researchers performing similar investigations. Dr Catherine Graham and her student Ben Weinstein are engaged in studying bird-plant networks along an elevation gradient in the western Andes of Ecuador. We will cooperate with this project performing flower census and interactions observations in the upper limit of the altitudinal gradient where we have settled our study sites. Therefore, monitoring at our study transects in Yanacocha and Verdecocha will continue for two years more. Also we plan to extend research questions to address the influence of flower availability on bipartite networks.

6. How do you plan to share the results of your work with others?

Rolando, from Alambi community already presented project activities during a Nono Parish meeting on February 28, 2016 where local authorities, land owners and people from several communities were present. Two undergraduate students are involved in the project. One of them will present results concerning Black-breasted Puffleg ecology on the upcoming Ecuadorian Ornithology Meeting (August 2016). Also we are preparing two papers, one concerning the feeding ecology of the Black-breasted Puffleg and a second paper on how habitat degradation may influence visitation patterns of hummingbirds, and thereby pollination. Furthermore, diffusion events like Global Big Day or World Bird Festival will generate spaces where we could share our finding with broader audiences.

7. Timescale: Over what period was the RSG used? How does this compare to the anticipated or actual length of the project?

RSG was effectively used over one year period as proposed in our study. However result presentation will be until august this year and the project will continue as mentioned before in point 5.

8. Budget: Please provide a breakdown of budgeted versus actual expenditure and the reasons for any differences. All figures should be in £ sterling, indicating the local exchange rate used.

Item	Budgeted Amount	Actual Amount	Difference	Comments
Gas & Food (project socialization-one event)	157	181.47	-24.47	Costs were covered with other funds
Gas & Food (3 training workshops x 12people)	279	260	19	
Fungible material (3 training workshops)	63	82.61	-19.61	Costs were covered with other funds
Plotwatcher cameras + memory cards + rechargable batteries (10 cameras)	996	1218.72	-222.72	We covered the cost of 6 cameras with Rufford and we had other funding to buy another 4 cameras
Perdiem (monitoring 18 occasions x 4 people)	1379	1244.68	134.32	We are using this money for one more field trip
Transportation (gas, horses, car rent x 18 occasions)	651	653.66	-2.66	
Intern allowance (for video filtering)	287	287	0	
Environmental good practices guide print (300 units)	638	998.21	-360.21	Difference covered with other grant
Gas & Food (results diffusion-two meetings)	165	13.77	151.23	We will use to present results at the V Ecuadorian Ornithology Meeting
Communications	160	160	0	
TOTAL	4775	5100.12	-325.12	

Exchange rate at May 31, 2016 (1 sterling pound = 0, 68842 US Dollars)

9. Looking ahead, what do you feel are the important next steps?

As flowering plants phenology largely determines the resources available in a community and by that, the structure of mutualistic networks, I would suggest a long-term monitoring of plant-bird interactions, in order to understand how seasonality affects the dynamic of pollination networks. Also, it is important to complement camera monitoring with both flower and bird censuses. In our experience, despite this methods dramatically increase our ability to collect data in the field, it is limited by the number of available cameras.

10. Did you use the RSGF logo in any materials produced in relation to this project? Did the RSGF receive any publicity during the course of your work?

During past World Bird Festival in October 2015, I made a presentation of this project. During this presentation I used RSGF logo. Also one of our students will present at the V Ecuadorian Ornithological Congress and he will use the RSGF logo.

11. Any other comments?

We would like to thank the RSGF for financial support to our project. Catherine Graham and Ben Weinstein provided advice concerning the design, field methods and data analyses during the whole implementation of the project. Landowners at Yanacocha and La Sierra communities as well as reserves managers of Jocotoco and Verdecocha foundations generously provided access to study sites. Mr Rolando Hipo from Alambi community eagerly acted as field assistant and also advised the timing of camera setting according to his knowledge on flowering periods of local plant species. Antonio and Adela Espinosa generously provided access and facilities within their property to implement our project. We acknowledge Bryan Rojas, Cristian Poveda, Ibeth Alarcón and Juan Diego Molina for their collaboration during field work.

13. References

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Appendix 1. - Details of camera sampling effort applied to record plant-bird interactions during the field season our Rufford project (April 2015 – May 2016)

Site	Habitat	Plant	First recording day	Month	Last recording day	Total sampling days	Total Effort (hours)
Yanacocha	Forest Border	Barnadesia_sp	26/05/2015	5	29/05/2015	3,5	40,5
Yanacocha	Forest Border	Berberis pichinchensis	25/10/2015	10	30/10/2015	5,5	60,5
Esperanza	Forest Border	Berberis pichinchensis	07/03/2016	3	11/03/2016	4,5	49,5
Verdecocha	Forest Interior	Bomarea lutea	22/09/2015	9	26/09/2015	4,5	49,5
Yanacocha	Forest Border	Brachyotum ledifolium	26/10/2015	10	30/10/2015	4,5	49,5
Yanacocha	Forest Patch	Bromeliad_(purpleflowers)	30/11/2015	11	04/12/2015	4,5	49,5
Verdecocha	Forest Interior	Bromeliad_(purpleflowers)	05/05/2016	5	09/05/2016	4,5	49,5
Yanacocha	Forest Interior	Disterigma alalternoides	24/03/2016	3	26/03/2016	3	34,5
Esperanza	Forest Border	Disterigma alalternoides	07/03/2016	3	11/03/2016	4	46
Yanacocha	Forest Border	Fucsia_sp	26/10/2015	10	30/10/2015	4,5	49,5
Verdecocha	Forest Interior	Guzmania_sp	25/07/2015	7	28/07/2015	4,5	51,5
Verdecocha	Forest Interior	Guzmania_sp	05/05/2016	5	08/05/2016	3,5	40,25
Esperanza	Forest Border	Guzmania_sp	06/05/2016	5	08/05/2016	3	34,5
Verdecocha	Forest Interior	Heppiella_ulmiflora	22/09/2015	9	26/09/2015	4	46
Verdecocha	Forest Interior	Heppiella_ulmiflora	05/07/2015	7	08/07/2015	3,5	40,25
Yanacocha	Forest Patch	Macleania rupestris	18/04/2015	4	21/04/2015	4,2	48,9
Yanacocha	Forest Border	Macleania rupestris	26/10/2015	10	30/10/2015	4	46
Esperanza	Forest Border	Macleania rupestris	07/03/2016	3	10/03/2015	4	46
Yanacocha	Forest Patch	Macleania rupestris	19/12/2015	12	22/12/2015	4	46
Verdecocha	Forest Interior	Macleania rupestris	05/05/2015	5	08/05/2016	4	44,5
Yanacocha	Forest Interior	Palicourea fuchsioides	20/06/2015	6	21/06/2015	2	23

Verdecocha	Forest Interior	Palicourea fuchsioides	16/09/2014	9	18/09/2014	2,5	35
Yanacocha	Forest Patch	Palicourea fuchsioides	18/04/2015	4	21/04/2015	4,2	48,9
Yanacocha	Forest Patch	Palicourea fuchsioides	11/03/2015	3	14/03/2015	3,6	41,5
Yanacocha	Forest Patch	Palicourea fuchsioides	01/12/2015	12	04/12/2015	3,5	40,25
Yanacocha	Forest Patch	Palicourea fuchsioides	19/12/2015	12	23/12/2016	4	46
Verdecocha	Forest Interior	Palicourea fuchsioides	05/05/2016	5	08/05/2016	3,7	42,5
Yanacocha	Forest Border	Palicourea_amethystina	25/07/2015	7	28/07/2015	3,7	41,83
Yanacocha	Forest Border	Passiflora_cumbalensis	05/07/2015	7	08/07/2015	3,7	41,8
Verdecocha	Forest Interior	Racinea tetrantha	24/07/2015	7	28/07/2015	4,5	39,5
Yanacocha	Forest Interior	Salvia_sp	19/06/2015	6	22/06/2015	3,4	38,5
Verdecocha	Forest Interior	Thibaudia_floribunda	07/08/2014	8	13/08/2014	6,5	75
Esperanza	Forest Border	Thibaudia_floribunda	05/05/2016	5	08/05/2016	3,5	40,25
Verdecocha	Forest Interior	Thibaudia_floribunda	05/05/2016	5	08/05/2016	4	44,5
Yanacocha	Forest Interior	Centropogon pichinchensis	23/03/2016	3	27/03/2016	4,5	39,5
Yanacocha	Forest Interior	Gentianella jamesoni	17/05/2016	5	21/05/2016	4,5	49,5
Yanacocha	Forest Interior	Disterigma alalternoides	24/03/2016	3	26/03/2016	3	34,5
Esperanza	Forest Border	Disterigma alalternoides	07/03/2016	3	11/03/2016	4	46
Total FB							591,88
Total FI							777,5
Total FP							321,5
Total						**150,5**	**1690,8**