Darwin Initiative Main Project Annual Report

Darwin Project Information

Project Reference	22-002
Project Title	**Complete Altitudinal Rainforest Transect for research and conservation in PNG**
Host Country/ies	Papua New Guinea
Contract Holder Institution	University of Sussex
Partner institutions	Binatang Research Center, Papua New Guinea
Darwin Grant Value	£292,171
Funder (DFID/Defra)	Defra
Start/end dates of project	1 April 2015 – 31 March 2018
Reporting period and number	1 April 2016 – 31 March 2017 Annual report 2
Project Leader name	Dr Alan J A Stewart
Project website/blog/Twitter	www.entu.cas.cz/png/mtwilhelm/research
Report author(s) and date	AJA Stewart, V Novotny, MR Peck; 28th April 2017

1. Project Rationale

New Guinea includes the world's third largest rainforest, supporting 5% of global biodiversity. However, 24% of Papua New Guinea's forests have been destroyed in the past 30 years. Only 4.5% of land is protected and this protection is ineffectual. PNG's biodiversity is also among the least known in the world. For instance, only 0.2 papers per bird species in PNG, compared with 2.9 papers in Australia, were published in the last 50 years. Furthermore, only 24% of the 396 research papers on PNG biology from the last 10 years had a PNG author. Ecological research is hampered by the lack of permanent study sites, especially along key altitudinal and disturbance gradients with background information on their biota to enable environmental change monitoring. Training the next generation of PNG biologists is a top priority as they are better placed to implement conservation measures than overseas experts. In summary, PNG needs (i) new conservation strategies and conservation areas, (ii) more biodiversity research, including new molecular approaches, (iii) better research training of Papua New Guineans, and (iv) better field research facilities. This project was designed to address all these needs in an integrated program of conservation, research and training for Mt. Wilhelm, a globally important biodiversity hotspot.

Fig. 1. Mt. Wilhelm massif, Papua New Guinea

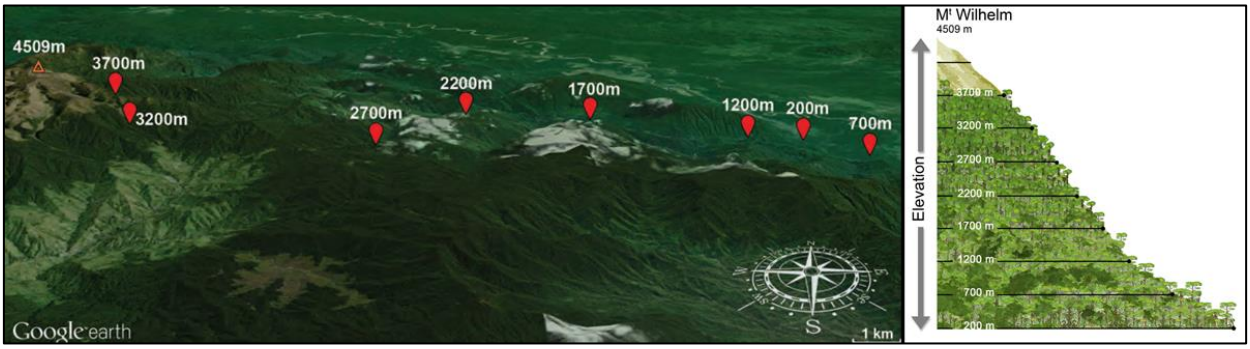


Fig. 2: Map of Complete Altitudinal Rainforest Transect (CART) from 200m to 3700m on Mt Wilhelm comprising eight research sites with elevation increments of 500 m.

2. Project Partnerships

The close partnership between the University of Sussex (UoS) as Lead institution and the Binatang Research Center (BRC), the principal partner in PNG, is substantially based upon the long history of association between the two partners (Alan Stewart and Vojtech Novotny) including on five previous Darwin Initiative projects.

Alan Stewart is responsible for day to day management of the project, including co-ordination of visits to the UK by the para-ecologists as well as visits by UK personnel to PNG. The New Guinea Binatang Research Center (BRC), under the directorship of Prof Vojtech Novotny, is our principal partner in project management, training and research. It is the leading biological research institution in PNG with a staff of 24 researchers, students and highly-skilled research technicians (para-ecologists). Mika Peck (Lecturer in Biology at the University of Sussex) has contributed his expertise on REDD+, forest carbon stock assessment and remote sensing for biodiversity assessment. Dr Peck brings a wealth of experience of South American rainforest ecosystems, including from a previous Darwin Initiative project (14/040) on primate conservation in Ecuador.

We continue to benefit from collaborations with long-standing partners in the UK. Dr Mike Wilson (National Museum of Wales, Cardiff) has been generous with his own time and that of his staff in the Entomology Department in hosting the BRC para-ecologist visitors. We are also continuing collaboration with the Zoology Department at Oxford University (Prof. Owen Lewis and Dr Sofia Gripenberg) who hosted our para-ecologist visitors in 2016 for the second time. This year, we have renewed a long-standing and productive collaboration with the Herbarium staff at the Royal Botanic Garden at Kew (Dr William Baker). Although the training of our para-ecologist visitors was not possible in 2016, it will be renewed in in 2017. Our training programme also benefits from collaboration with the South East Asia Rainforest Research Partnership (Dr Tom Fayle) and the Universiti Malaysia Sabah (Dr Yusah Kalsum), allowing the training of para-ecologists at the Maliau Basin Research Station, the Mt Kinabalu National Park and the Stability of Altered Forest Ecosystems (SAFE) project sites in Malaysian Borneo, and with the Biology Center of the Czech Academy of Sciences (Ceske Budejovice, Czech Republic). These two partnerships allowed us to expand our UK-based training of para-ecologists to additional locations, at no additional cost to the project.

In PNG, BRC has been developing an effective network of partner organization that includes all key local universities, research institutes and NGOs engaged in biodiversity conservation and research. Their senior representatives met in October 2016 at the official opening of the PNG Center for Postgraduate Biology at BRC. This network includes the Science and Technology Secretariat of PNG Government, other government agencies, the five largest PNG universities, two research institutes and three NGOs engaged in PNG conservation (Table 1).

Name	Institution	Position
Dr. Kulala Mulung	Science and Technology Secretariat	Deputy Director
Prof. Peter Petsul	University of PNG	Dean, School of Natural and Physical Sciences
Ms. Savitha DeBritto	University of Goroka	Dean, School of Science and Technology
Dr Darren Bito	Pacific Adventist University	Dean, School of Science and Environment
Prof. Larry Orsak	PNG University of Technology	Head, Forestry Department
Dr John Burton	Divine Word University	Deputy Vice-President, Research
Mr. Wilfred Kasi	Office of Higher Education	Second Secretary
Mr Nathan Jahnorme	Office of Hon. Mr Kipefa, MP	Secretary
Dr Mosses Laman	PNG Medical Research Institute	Senior Research Fellow
Dr Peter Epaina	Cocoa and Coconut Reseach Institute	Director
Mr. John Kuange	Wildlife Conservation Society	Deputy Director
Mr Kafuri Yaro	World Wildlife Fund	Director
Dr Sanjay Bavikatte	The Christensen Fund	Executive Director

Table 1. Guests at the opening of the PNG Center for Postgraduate Biology at BRC in October 2016

3. Project Progress

3.1 Progress in carrying out project activities

Overall, the project continues on track, with good progress towards completing the project's activities; in some cases, projected outputs for the entire project have already been exceeded by the end of the second year. We have made good progress with developing discussions with local landowners regarding delineating conservation areas. Training activities have continued as planned, as have the various biodiversity surveys and ecological studies conducted by para-ecologists, honours and masters students that were started in Year 1. These will all contribute to the CART becoming widely known and accepted as an internationally significant location for future research, survey and ecotourism.

3.2 Progress towards project outputs

The second year of the project continued in successful implementation of the project, with significant progress on all key activities. In general, activities have been carried out as planned and on schedule. We are confident that the planned outputs will be achieved by the end of the project. The output indicators remain appropriate. The following account reports against the project implementation timetable. Activity descriptors below are taken from the logframe and presented in italics.

Output 1:

Activity 1.1 Establish 8 study sites spaced at 500m elevation intervals from 200 to 3700 m asl; design replicated study plots at each site.

The study sites were established in the 1st year of the project. We have continued with developing local logistics as well as the knowledge base on the biodiversity of each site. We have delineated and mapped 10 transects 300 x 10 m at each site, as a replicated framework for various biodiversity surveys. There are presently 11 active research projects focusing on elevation trends in (i) diversity of plants, insects and vertebrates, (ii) the structure of interaction webs between plants, herbivores, mutualists, parasitoids and predators, (iii) genetic structure and dispersal of populations, and (iv) plant anti-herbivore defense, predator pressure and parasitoid pressure, as well as manipulative experiments including translocation of plant and insect species to assess vulnerability of forest communities to climate change. The research projects are briefly characterized and illustrated on the new website at www.entu.cas.cz/png/mtwilhelm/research.

The network of sites is now fully functional and is producing the first published research results, thus demonstrating its efficiency. In particular, the combination of local logistics with BRC para-ecologists and locally trained assistants allows the time- and labour-intensive studies of interaction networks. We have published a high resolution analysis of interaction networks for plant – insect frugivore data from lowland forests (Sam et al. 2016), as well as plant– ant mutualist data sets along the elevation gradient (Plowman et al. 2017; Fig. 3), while a manuscript on the plant - insect herbivore data set is in review. Further, we have used the established sites also for the study of speciation dynamics of fig wasps and their Ficus hosts (Sear et al. 2016), demonstrating the importance of the gradient in examining both evolutionary and ecological processes in maintaining tropical biodiversity.

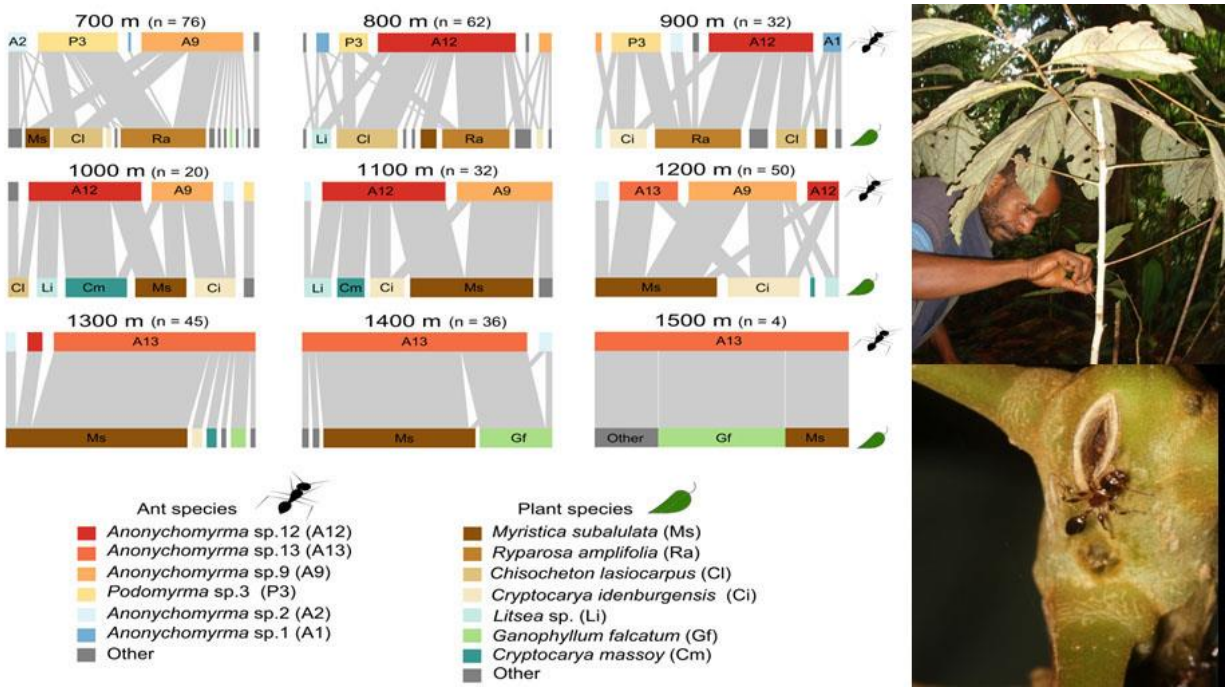


Fig. 3. Trends in the structure of plant – ant mutualist interaction webs documented along the Mt Wilhelm elevation gradient (Plowman et al. 2017, Proc. R. Soc. Biol. Sci. B 284: 20162564)

Activity 1.2 Design and test sampling protocols for the six focal taxa (plants, ants, moths, butterflies, amphibians and birds); execute the sampling

We have now progressed with the quantitative surveys of alpha diversity for focal taxa along the gradient so that there are data sets for nine taxa (Fig. 4), illustrating a variety of elevation trends, from unidirectional decline of diversity from lowlands to higher elevations (either slow, e.g. in birds, or rapid, e.g. in ants or butterflies) to mid-elevation maximum of diversity, seen in geometrid moths, frogs and ferns. Mt Wilhelm is thus becoming one of the best explored long rainforest elevation gradients in the tropics. The biodiversity data sets will be the subject of individual detailed publications, and have already made an important contribution to our analysis of altitudinal trends (Colwell et al. 2016).

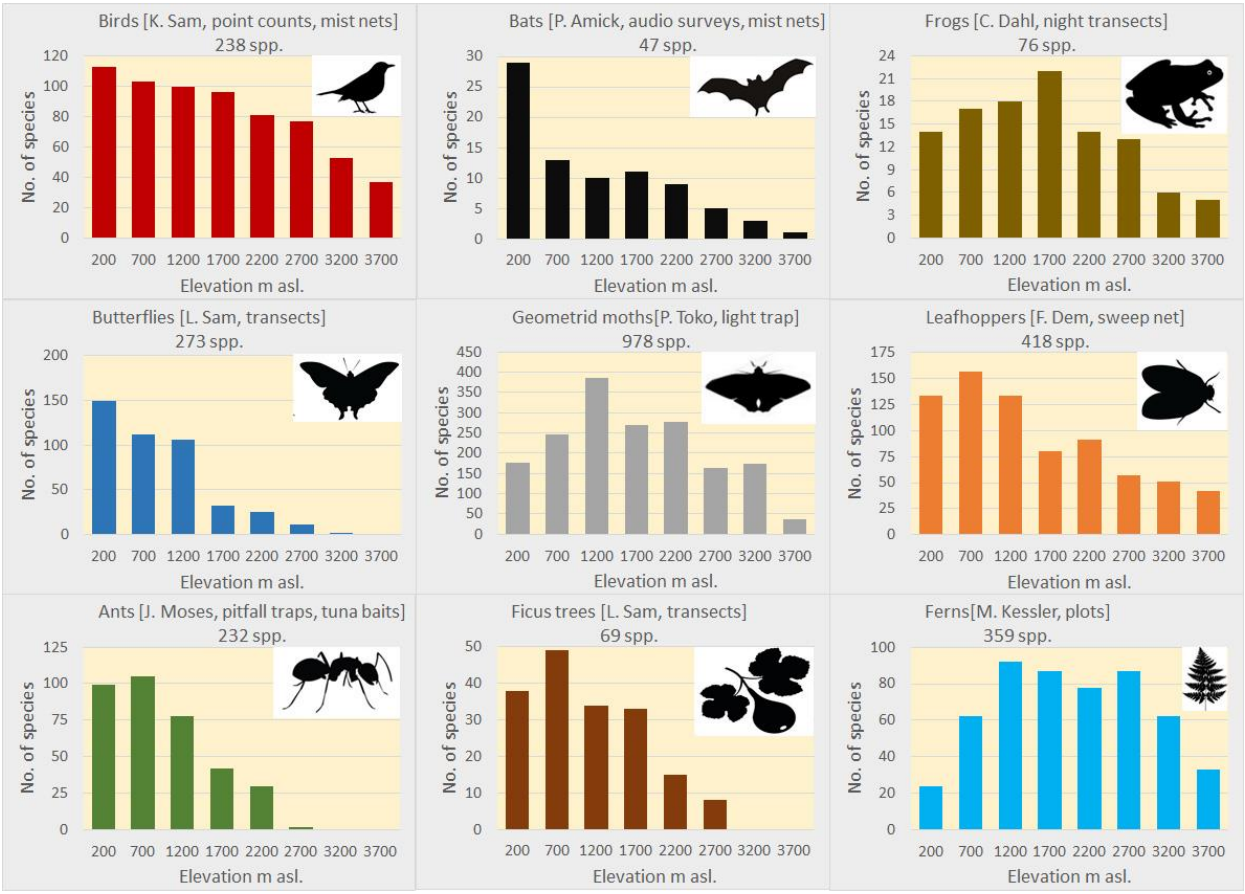


Fig. 4. Species diversity trends for birds, bats, frogs, butterflies, geometrid moths, leafhoppers, ants, fig trees and ferns along the Mt Wilhelm elevation transect (Colwell et al. 2016 and unpubl. data)

a) **Birds (R. Hazell, B. Koane et al.):** A baseline survey of bird communities was completed as described in the previous DI report. In the 2nd year, we have initiated a new project to study the relationship between functional diversity of fruit resources and frugivorous birds, particularly interactions between bird communities and *Ficus* trees. The project included three months of field work in 2016, led by R. Hazell, a PhD student based at UoS and supervised by Mika Peck and Alan Stewart. R. Hazell trained para-ecologists B. Koanne (birds) and G. Kaina (plants) from BRC, as well as ~18 local field assistants, in doing timed bird point-counts, observations of feeding by individual birds, transect surveys for fruiting plants, fruit collection and measurement of fruit and seed traits.

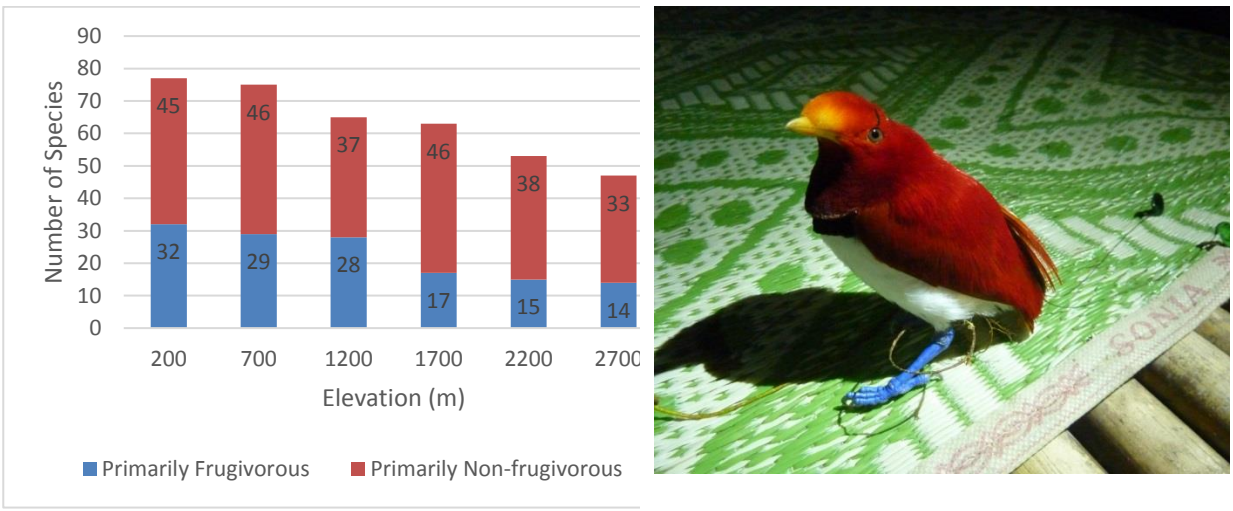


Fig. 5. Species richness of frugivorous and non-frugivorous birds along the Mt Wilhelm transect (left); King Bird of Paradise, recorded at 200, 700 and 1,200 m asl. (right).

b) **Bats (P. Amick et al.):** Peter Amick has completed the analysis of bat communities and successfully defended his work as a BSc Hons thesis at the University of PNG in 2016 (P. Amick, Composition, alpha and beta diversity of bat (Chiroptera) communities along an elevational forest gradient in Papua New Guinea, University of PNG, Port Moresby, 83 pp., See Annex 4, Fig 1).

c) **Fig trees (*Ficus* spp.) and fig wasps (S. Segar, B. Bau, G. Aubona et al.):** Our previous figs and fig wasps collections led to a research paper (Segar et al. 2016) that demonstrated clear genetic differentiation of fig populations along the gradient, with the main discontinuity at approx. 1700 m asl (Fig. 6). Leaf tissue samples have also been analysed for plant defensive compounds, showing trends in chemical content and diversity that match percentage herbivory in some species (Fig. 7). The study will be published next year.

Species boundaries between malvantheran *Ficus* species and their pollinating wasps collected between 700-1,700m have been examined in an MSc project by Billy Bau at the University of PNG. The MSc thesis should be defended next year.

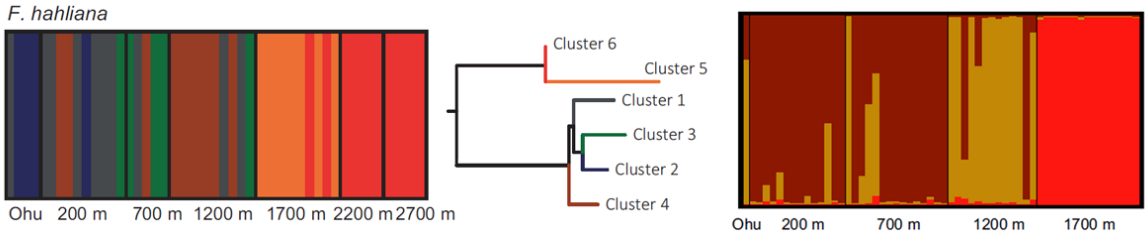


Fig. 6. Clusters resulting from the distribution of alleles in *Ficus hahliana* (left), neighbour-joining trees estimated using Nei's distances coloured according to cluster (centre) and the proportion of the sampled genome originating from each population for k = 3 populations (right) (Segar et al. 2016).

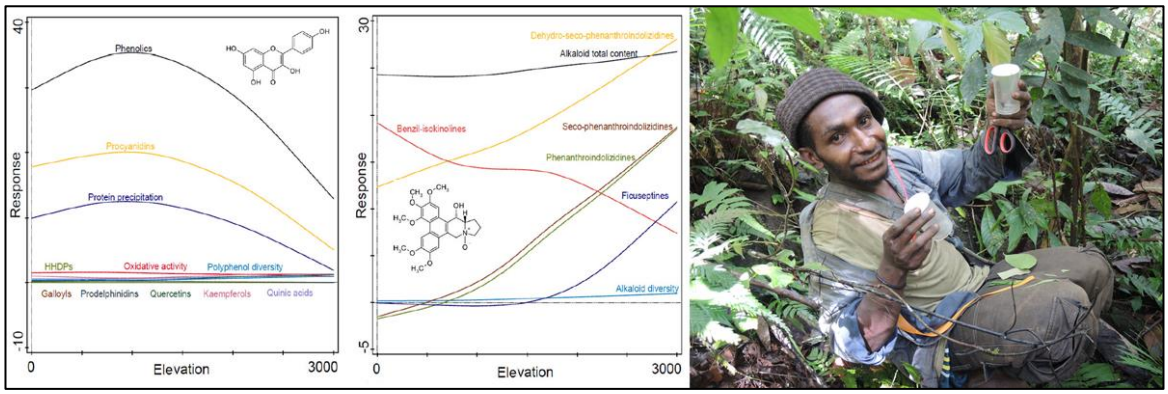


Fig. 7. Elevational trends in secondary metabolites in Ficus trees (left, centre) and sampling insect herbivores from these trees (right).

d) **Insect herbivores on fig trees (*Ficus* spp.) (L. Sam, G. Luke, J. Yalang, S. Tulai et al.):** Herbivorous insects from *Ficus* trees have been sampled along the CART transect in year 1; now we are continuing with sampling herbivores from translocated *Ficus* saplings, some of them to the same elevation, others to 500 altitudinal m above or below their native altitudinal range (1,000 saplings translocated in total). Further, we have analyzed the plant-herbivore food webs for insect herbivores and the trends in their structure with elevation. We are preparing publication of these results in 2017 (Fig. 8). This research includes projects by two PNG students: BSc Hons project by G. Luke (University of PNG) and PhD project by L. Sam (Griffith University, Brisbane). We have initiated molecular analysis of these food webs, including COI barcoding for 1200 insect herbivores and also molecular analysis of 350 plant samples.

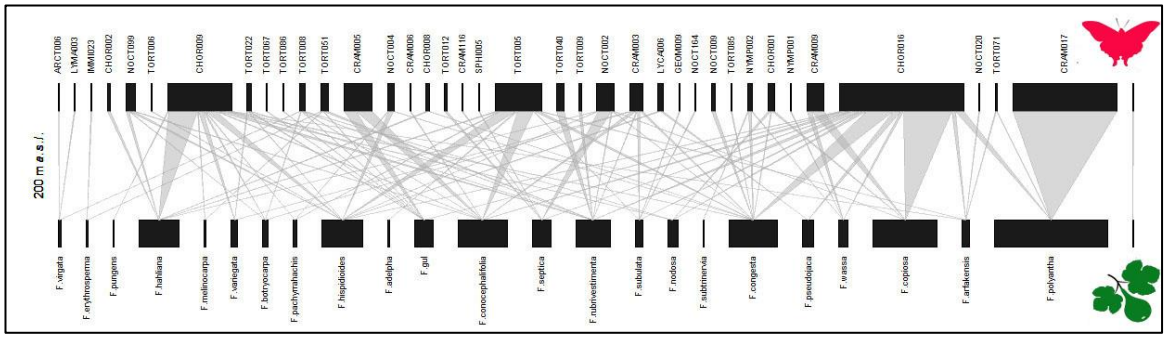
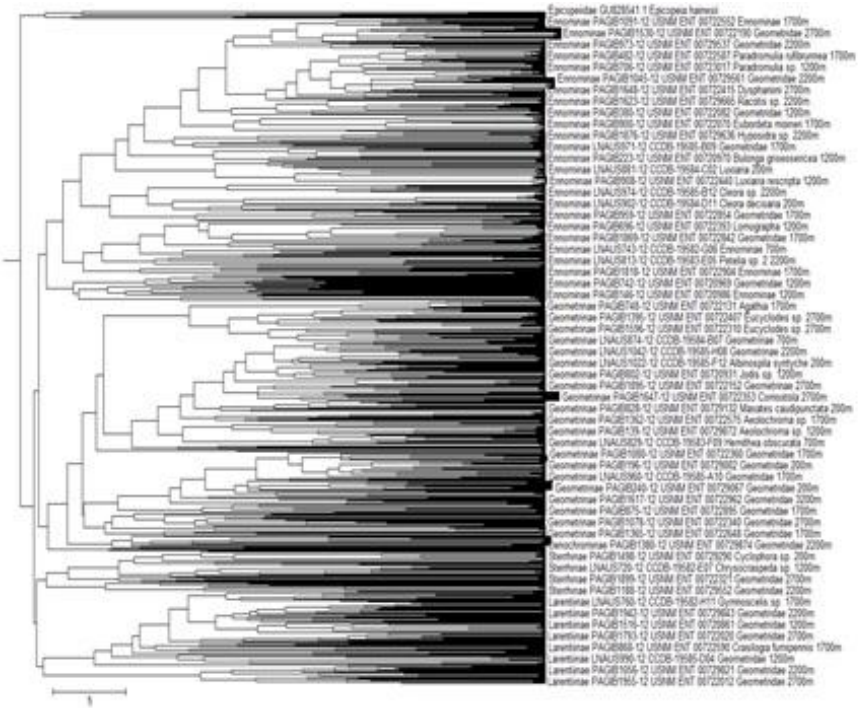


Fig. 8. Quantitative *Ficus* – caterpillar food web at Kausi, the 200 m asl. study site at Mt. Wilhelm.

e) **Ants (J. Moses et al.):** Further analysis of ant community samples previously collected along the CART included molecular analysis (barcoding, COI) of 450 samples. The results are being prepared for publication. This is part of a PhD project by J. Moses at the University of South Bohemia.

f) **Moths (S. Ibalim, P. Toko et al.):** S. Ibalim is implementing a phylogenetic analysis of geometrid moth communities along the CART, obtained during previous research (Fig. 9). This approach will allow us to expand the notion of species to phylogenetic diversity along elevation gradient. This is a MSc research project at the University of PNG.



g)

Fig. 9. Phylogenetic tree for the geometrid moths of Mt Wilhelm elevation gradient.

Output 2:

Activity 2.1 Select suitable candidates for training from local communities and BRC.
Based on our experience from the 1st year of the project, in particular numerous requests from Mt Wilhelm communities, we have changed our training strategy for community members, separating our training into (i) a broadly applied basic training in support of research, and (ii) more intense and focused training on selected biodiversity survey techniques, taxonomy of focal taxa and processing of specimens for selected, particularly gifted applicants.

Our basic training was provided through a series of 3-day field courses for all interested applicants from the target communities at the eight study sites (elevations 200 – 3700 m asl.). We provided this training for 234 trainees (Table 3). Many of them have access and landowners' rights to more than one location so that we have reached 30 – 72 trainees per elevation, ensuring a sufficient pool of skilled assistants for ongoing work.

The intense biology training focused on the six most talented assistants, 10 - 20 days per person (Table 2). One of the trainees, J. Yombai, is a recent BSc graduate from the PNG University for Natural Resources and Environment. After one year of training, he enrolled as MPhil postgraduate student at the PNG University of Technology, thus joining our student group.

Fig. 10. Field training of para-ecologists and field assistants in insect specimen sorting and preparation, and in insect community sampling methods using beating trays and Malaise, intercept, and Steiner traps.

Taxon surveyed	Graham Kaina	Hayden Wagia	Kenneth Molem	Mavis Jimbudo	Mentap Sisol	Nancy Labun	Samuel Jepi	Bonny Koane	Luda Paul	Malakai Parom	Mark Mulau	Michael Kigl	Alfred Mani	Austin Sau	Bradley Gewa	Buya Morgen	Byron Siki	Dominic Rinan	Fidelis Kimbeng	George Dahl	Gibson Mayiah	Joachim Yalang	John Auga	Jonah Filip	Martin Mogia	Raymond Laufa	Roll Lilip	Ruma Umari	Salape Tulai	Shen Sui	Ambros Gena	Gendio Druma	Jacob Yombai	Lui Napa	Samson Yama	Thomas Kiava
Insects													X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X
Birds							X	X	X	X	X	X																				X			X	
Plants	X	X	X	X	X	X																									X					X

Table 2. Training of BRC paraecologists (green) and village assistants (yellow) in survey techniques for insects, birds and plants (10 days per person and taxon).

Name	200	700	1200	1700	2200	2700	3200	3700	Sum	Sex
Abraham Sai	X								1	M
Aguwa Boundo		X	X						2	M
Albert Mondu		X	X						2	M
Albert Ongoma		X							1	M
Albert Yama						X			1	M
Alex Napa	X								1	M
Alex Tapasia	X								1	M
Alois Sakipa		X	X						2	M
Alphonse Gene				X					1	M
Alphonse Yama						X			1	M
Ambane Sai	X								1	M
Ambros Gena		X							1	M
Andreas Yama				X					1	M
Andrew Sawai				X					1	M
Anna Kruwo					X				1	F
Anna Lapun			X						1	F
Anna Nezengu		X	X						2	F
Anthon Azuwe		X	X						2	M
Anthon Basu				X					1	M
Anthon Bizie		X							1	M
Anthon Koane				X					1	M
Anthon Konda		X	X						2	M
Anthon Manunga				X					1	M
Anthonia Koane				X					1	F
Athon Mungua		X	X						2	M
Auemba Sakipa		X	X						2	M
Awe Munga		X	X						2	M
Barbara Mondu		X	X						2	F
Bats Basu				X					1	M
Basu Kingau				X					1	M
Basu Mathew				X					1	M
Bex Yama						X			1	M
Bill Kosi				X					1	M
Bizei Barua				X					1	M
Bonny Kunda		X							1	M
Bonny Kungunongua							X	X	2	M
Bonny Laki							X	X	2	M
Bonny Mondu		X	X						2	M
Brian Michael	X								1	M
Bruno Koga					X				1	M
Bun Yako					X				1	M
Bundle Kosi		X	X						2	M
Chris Kunda						X			1	M
Chris Yomba		X	X						2	M
Christopha Pagau						X			1	M
Christopha Yama						X			1	M
Cyril Sai	X								1	M
David Umba							X	X	2	M
Demas Ava		X	X						2	M
Demoro Kunda						X			1	M
Dero Waha		X	X						2	M
Divina Krukru		X	X						2	F
Divina Peter		X							1	F
Divina Tonny						X			1	F
Dominic Napa	X								1	M
Dominic Pietus		X							1	M
Doro Gemba							X	X	2	M
Dua William							X	X	2	M
Dua Winman							X		1	M
Dugunu Yako		X	X						2	M
Eddie Tiemura					X				1	M
Elise Mondu		X	X						2	F
Elise Sepik						X			1	F
Engel Guane				X					1	F
Esther Henry		X	X						2	F
Eugene Alma	X								1	M
Francis Loki		X	X						2	M
Francis Markus				X					1	M
Francis Taramba						X			1	M
Francis Yama						X			1	M
Frank Sai	X								1	M
Gabby Borie				X					1	M
Gabriel Goro				X					1	M
Gabriel Mori				X					1	M
Gena Lukas		X	X						2	M
Gene Ambane		X							1	M
Gene Jacob				X					1	M
Gethrude Kaura					X				1	F
Gideon Drumo		X							1	M
Gideon Peter		X							1	M
Gumia Nambados						X			1	M
Henry Gomarai				X					1	M
Henry Kinimbi		X	X						2	M
Henry Kuno							X	X	2	M
Indiana Koane				X					1	M
Isaac Blom	X								1	M
Jacinta Unau	X								1	F
Jacklyn Yama						X			1	F
James Yama						X			1	M

Name	200	700	1200	1700	2200	2700	3200	3700	Sum	Sex
Jeffrey Anthon		X							1	M
Jeffrey Yama						X			1	M
Jerry Kusti	X								1	M
Job Gene				X					1	M
Joe Dua							X	X	2	M
Joe Kuma							X	X	2	M
Joe Kunda							X	X	2	M
Joe Wagai		X	X						2	M
Joel Gendio		X	X						2	M
Joel Borie					X				1	M
John Ava		X							1	M
John Azuwe		X	X						2	M
John Borie					X				1	M
John Drekore					X				1	M
John Drumo		X							1	M
John Gorigi					X				1	M
John Guandi					X				1	M
John Kamex		X							1	M
John Mondu		X	X						2	M
John Nezengu		X	X						2	M
John Toure			X						1	M
John Yuara		X							1	M
John Bizei				X					1	M
John Kuma							X	X	2	M
John Kunda				X					1	M
John Kuvia				X					1	M
John Lapun						X			1	M
John Simon							X	X	2	M
John Turie				X					1	M
Johnathon Bun		X							1	M
Jonn Snr Nezengu			X						1	M
Jonny Bonny							X	X	2	M
Jonny Jnr Nezengu		X							1	M
Joseph Andembo					X				1	M
Joseph Mondia		X							1	M
Joseph Sepik						X			1	M
Joshua Nuri	X								1	M
Julie Francis		X	X						2	F
Junior More							X	X	2	M
Junior Peter		X	X						2	M
Kaluwin Tuma				X					1	M
Kaluwin Yako					X				1	M
Kenunga Anthon					X				1	M
Kenunga Benedict					X				1	M
Kenunga Gabriel					X				1	M
Kenunga Kunda					X				1	M
Koane Gideon					X				1	M
Koane Joseph				X					1	M
Koga Kips						X			1	M
Kogge Kips				X					1	M
Kogi Joseph					X				1	M
Kombo Yapoi					X				1	M
Kua Gestop		X							1	M
Kunda Huva					X				1	M
Kunda James				X					1	M
Kunda Yama						X			1	M
Kuya Garima					X				1	M
Kuyawa Markus		X	X						2	M
Lapun Dugunu		X							1	M
Leo Bare							X	X	2	M
Leo Tuma						X			1	M
Lui Napa	X								1	M
Lukas Ambros		X	X						2	M
Lukas Gapma							X	X	2	M
Lukas Gena		X							1	M
Lukas Mondu		X	X						2	M
Malachai Kunda					X				1	M
Margarette Yama						X			1	F
Maria Gem		X	X						2	F
Maria Simon					X				1	F
Markus Bundikana				X					1	M
Markus Gendio		X	X						2	M
Markus Kuyawa		X							1	M
Martin Kuyawa		X	X						2	M
Martin Numba							X	X	2	M
Max Sai	X								1	M
Michael Kingau		X							1	M
Michael Bre							X		1	M
Michael Pai	X								1	M
Michael Pius							X	X	2	M
Michanna Tobby					X				1	F
Miriam Christopha					X				1	F
Monica Pai	X								1	F
Monica Sai	X								1	F
Moses Napa	X								1	M
Nambados Thomas					X				1	M
Nick Gene						X			1	M
Nick Kuyawa				X					1	M
Nicky Mondu		X	X						2	M

Name	200	700	1200	1700	2200	2700	3200	3700	Sum	Sex
Nigel Kus						X			1	M
Nimambo Yapoi					X				1	M
Ovo Dam		X	X						2	M
Paul Kuma						X			1	M
Paul Ava						X			1	M
Paul Nandex		X							1	M
Paulus Gumisi						X			1	M
Pepa Henry						X			1	M
Perry Topi		X	X						2	M
Peter Andrew							X	X	2	M
Peter Bax					X				1	M
Peter Dilangk							X	X	2	M
Peter Gandio						X			1	M
Peter Gandumu					X				1	M
Peter Gendio		X	X						2	M
Peter Gendwena				X					1	M
Peter Gumb							X	X	2	M
Peter Jias							X	X	2	M
Peter Kunuma					X				1	M
Peter Kuyawa		X	X						2	M
Peter Sai	X								1	M
Peter Veneza				X					1	M
Peter Yako				X					1	M
Petra Olapu	X								1	M
Philip Kagi		X	X						2	M
Philip Kumuna				X					1	M
Poinde Mavi			X						1	M
Regina Wom					X				1	F
Roy Joseph							X	X	2	M
Rudy Kinimbi		X	X						2	M
Salvador Ase	X								1	M
Sammy Kosi				X					1	M
Samson Yama						X			1	M
Samuel Napa	X								1	M
Silas Sakipa		X	X						2	M
Simon Kunai						X			1	M
Simon Napa	X								1	M
Simon Yama					X				1	M
Stanley Kosi				X					1	M
Stanley Sai	X								1	M
Steven Gaima						X			1	M
Steven Gand						X			1	M
Steven Kuno							X	2	3	M
Susan Moku	X								1	F
Susan Yawari	X								1	F
Tagai Sinopi							X		1	M
Tarsy Kinimbi		X	X						2	M
Theo Vitus		X							1	M
Thomas Benedict						X			1	M
Thomas Borie						X			1	M
Thomas Boundo		X	X						2	M
Thomas Dame						X			1	M
Thomas Kalape							X	X	2	M
Thomas Kuyawa				X					1	M
Thomas Maine						X			1	M
Thomas Noah							X	X	2	M
Thomas Tuma						X			1	M
Thomas Wagai		X	X						2	M
Thomson Leo				X					1	M
Thopha Dekene						X			1	M
Thresia Sai	X								1	F
Tobby Dingua					X				1	M
Tobby Gamba							X	X	2	M
Tobby Kela							X	X	2	M
Tobby Koane				X					1	M
Tobias Napa	X								1	M
Tolai Borie					X				1	M
Tora Maina							X	X	2	M
Tora Otto							X	X	2	M
Tudak Pandum							X	X	2	M
Uwa Gale					X				1	M
Uwa Garima				X					1	M
Uwe Tobby					X				1	M
Valentine Kunda				X					1	F
Vero Miri		X	X						2	M
Vincent Wapia							X	X	2	M
Waim Waine				X					1	M
Wamuru John						X			1	M
William Mai		X							1	M
Yama Gendwena				X					1	M
Yama Kondu					X				1	M
Yama Teke						X			1	M
Yama Tuma						X			1	M
Yomba Chris				X					1	M
Zachery Sai	X								1	M
Zachery Yako				X					1	M
Total	30	72	53	46	38	40	34	32	345	

Table 3. The list of personnel (including gender and CART station positions) consulted about conservation activities and receiving basic training as field or camp assistants, guides, and carriers.

Activity 2.2 Design training programme, then implement training with regular feedback from the trainees in PNG

The para-ecologist training included (i) ant identification training lead by O. Mottl, a PhD student (Univ. of South Bohemia) resident at BRC, (ii) bird identification courses by R. Hazell (a DI-sponsored Univ. Sussex PhD student resident at BRC), (iii) sap-sucking insect identification led by F. Dem, a BRC researcher, and (iv) herbivore and parasitoid rearing by M. Libra, a PhD student (Univ. of South Bohemia) resident at BRC. Further, we have had a series of training workshops by E. Beauchamp (Oxford University) on participatory social research and community surveys (Fig. 11), and by Y. Basset (Smithsonian Tropical Research Institute) on insect sampling methods. Furthermore, the training has continued for BRC researchers, resident Hons, MPhil and MSc students and para-ecologists included (i) training in the analysis of molecular data by S. Segar (via email and skype interaction), (ii) regular statistical seminars led by resident students at BRC and visiting PhD students (P. Szefer, O. Mottl. J. Moses, M.

Libra), and (iii) weekly journal club discussing interesting research papers led by resident students. The training in insect community sampling (ants, fruit flies, moths), birds surveys (point counts) and plant surveys (vegetation structure and composition in plots) produced three training manuals (plants, insects, birds) ready for sustained future use at BRC (see Annex 4, Figs. 2, 3).

As is usual in research, training combines on-the-job daily training under supervision by senior paraecologists with formal training sessions, lectures and seminars (Fig. 11). Para-ecologists at BRC received training for their own jobs, while also being exposed to lectures and seminars for students (detailed below).

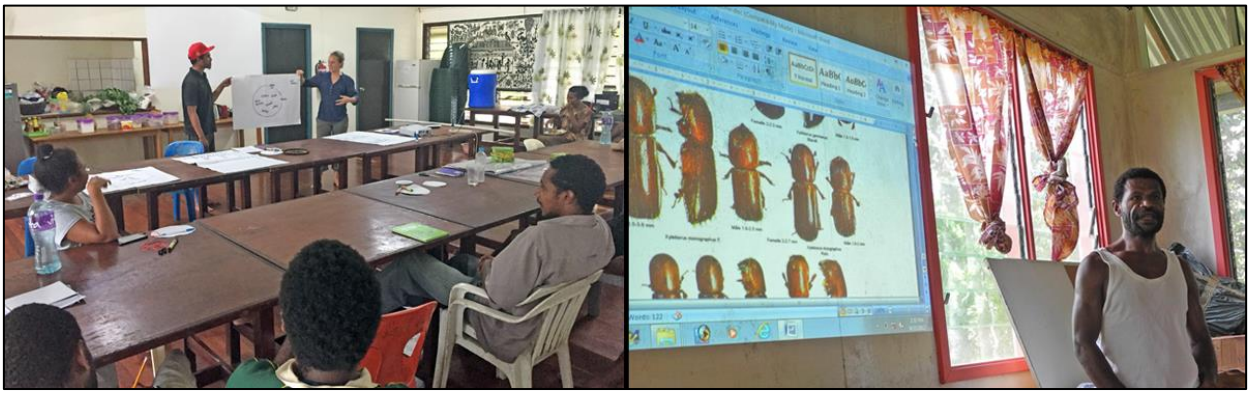


Fig. 11. Training at BRC on participatory social research by E. Beauchamp at BRC (L), and BRC paraecologist M. Mogia giving lecture at BRC on insect morphology and taxonomy

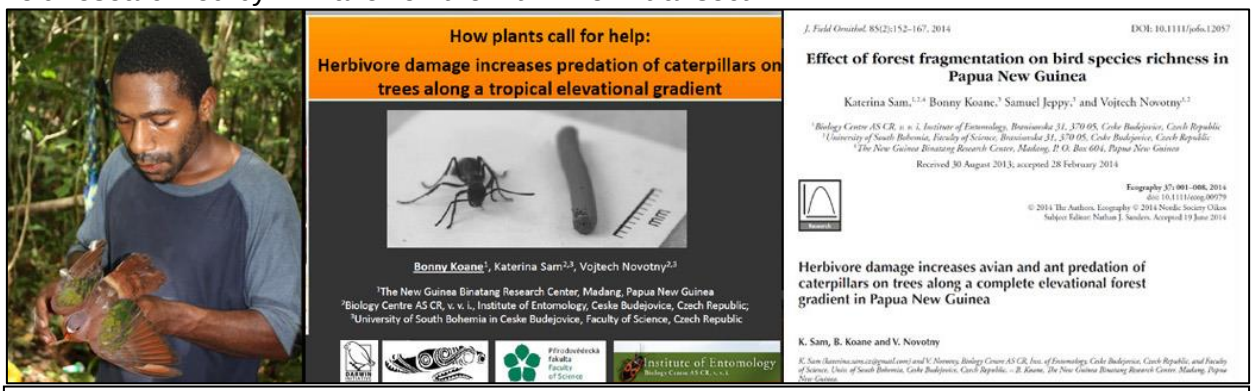
Activity 2.3 Design training programme, then implement training with regular feedback from the trainees in UK

Para-ecologists Graham Kaina (botany) and Bonny Koane (ornithology) had a 1-month training visit to the UK. This was combined with an additional 6 weeks of training with our Darwin Initiative project collaborators in Malaysia and the Czech Republic at no additional cost to DI. Their itinerary included:

- a one-month stay in the UK, receiving training from: A. Stewart & M. Peck (Univ. Sussex) on forest carbon estimation, data analysis techniques and visiting local temperate habitats; M. Wilson (National Museum of Wales) on entomology and museum curatorial techniques; Stourhead National Trust estate (Basic Canopy Access course); R. Morris & O. Lewis (Zoology Department, Oxford) an introduction to various sampling and experimental techniques with researchers who are currently working in collaboration with BRC, as well as visits to local field sites.
- one month visit to the Biology Centre of the Czech Academy of Sciences and the Zoology Department at the University of South Bohemia in the Czech Republic, as long-term partners of BRC, running several research projects at CART (K. Sam – birds, S. Segar – *Ficus* trees and their pollinators, L. Sam – *Ficus* trees and their herbivores, J. Hrcek – *Drosophila* communities and their parasitoids, M. Libra – caterpillars and their parasitoids). They visited local study sites, saw manipulative botanical and eco-physiological vegetation experiments in grasslands, and were trained in insect taxonomy. This visit was facilitated by C. Dahl, J. Moses, and P. Toko, all former DI-sponsored MSc students that are presently PhD students at the University of South Bohemia.
- one week visit to Malaysia where T. Fayle (Imperial College London and Czech Academy of Sciences), with Y. Kalsum, hosted them on his field research project at the SAFE rainforest fragmentation experiment (https://www.safeproject.net/), and they also visited the Mt. Kinabalu altitudinal rainforest transect – the closest parallel to the Mt. Wilhelm CART in the Australian-Pacific region.
- 3-day visit to the National University of Singapore, hosted by D. Bickford to see conservation research projects at the Department of Biological Sciences.
- they gave talks/seminars on their work at the Biology Centre of the Czech Academy of Sciences, University of Sussex (twice), University of Oxford, and National Museum of Wales.

B. Koane is a secondary school graduate who was recruited from a village community on the Mt Wilhelm altitudinal gradient and proved to be a talented and enthusiastic ornithologist. He is presently one of the two best ornithologists in PNG and with seven co-authored publications, including one in *Science*, belonging to the promising young generation of biologists in PNG

(Fig. 12). G. Kaina is a biology graduate from the University of PNG trained at BRC in botany. His focal project is the study of lowland plant communities and carbon stocks in lowland forests, initiated during our previous DI project. In the present project, both Koane and Kaina joined field research led by R. Hazell on the Mt Wilhelm transect.



Leponce M. et al. (with B. Koane and 37 co-authors) 2016. Land module of Our Planet Reviewed - Papua New Guinea: aims, methods and first taxonomical results. In Robillard T., Legendre F., Villemant C. & Leponce M. (eds), Insects of Mount Wilhelm, PNG. Muséum national d'Histoire naturelle, 209). ISBN: 978-2-85653-784-8.

Marki, P. Z., Sam, K., Koane, B., Kristensen, J. B., Kennedy, J. D. & Jønsson, K. A. 2016. New and noteworthy bird records from the Mt. Wilhelm elevational gradient, Papua New Guinea. The *Bulletin of the British Ornithologists' Club* **136**, 263-271.

Roslin, T., Hardwick, B., Novotny, V., Andrew, N., Asmus, A., Barrio, I. C., Basset, Y., Boesing, A. L., Bonebrake, T. C., Cameron, E. K., Dattilo, W., Donoso, D. A., Drozd, P., Gray, C. L., Hik, D. S., Hill, S., Hopkins, T., Huang, S., Koane, B., Laird-Hopkins, B., Laukkanen, L., Lewis, O. T., Milne, S., Mwesige, I., Nakamura, A., Nell, C. S., Nichols, E., Petry, W. K., Prokurat, A., Sam, K., Schmidt, N. M., Slade, A., Slade, V., Suchankova, A., Teder, T., van Nouhuys, S., Vandvik, V., Weissflog, A., Zhukovich, V. & Slade, E. M. 2017. Higher predation risk for insect prey at low latitudes and elevations *Science* in press

Sam, K. & Koane, B. 2014. New avian records along the elevational gradient of Mt. Wilhelm, Papua New Guinea. *Bulletin of the British Ornithologist's Club* **134**, 116-133.

Sam, K., Koane, B., Jeppy, S. & Novotny, V. 2014. Effect of forest fragmentation on bird species richness in Papua New Guinea. *Journal of Field Ornithology* **85**, 152–167.

Sam, K., Koane, B. & Novotny, V. 2015. Herbivore damage increases avian and ant predation of caterpillars on trees along a complete elevational forest gradient in Papua New Guinea. *Ecography*, **38**, 293–300.

Sam, K., Koane, B., Jeppy, S., Sykorova, J. & Novotny, V. 2017. Diet of land birds along an elevational gradient in Papua New Guinea. *Scientific Reports* **7**, 44018

Fig. 12. Trainee Bonny Koane is one of PNG's leading ornithologists with an increasingly distinguished publication record.

Fig. 13. Training in the Czech Republic (top) and in Malaysia (bottom): training in insect taxonomy, visiting grassland photosynthesis experiments, visiting SAFE fragmentation experiment, and climbing Mt. Kinabalu.

Output 3:

Activity 3.1 Select four candidate students, enrol them at University of PNG and select suitable dissertation topics

We have enrolled one additional MSc student, Mr. Kipiro Damas. Further, Mr. Peter Amick, our BSc Hons. student, completed his studies and is awaiting graduation. He was accepted onto the MSc programme at the University of PNG, thus continuing within the DI programme for a higher degree. These changes increased the number of Hons or MSc degrees pursued within the DI project to seven. In addition to DI students, BRC also hosts seven other resident Hons, MPhil and MSc students from other programmes, and provides also a logistical base for field research to four PNG students pursuing their PhD degrees at overseas universities (Table 4). The resulting group of 13 resident and 4 visiting biology students, formalized this year as the PNG Centre for Postgraduate Biology (Fig. 14), is the largest in PNG. In synergy with para-ecologists and researchers, this is the best learning environment for biodiversity studies in PNG.

Student name	Degree	University	Thesis title	DI
Luke, Grace	BSc Hons	UPNG	Fundamental and realized trophic niches for folivorous herbivores on Ficus hosts along a rainforest altitudinal gradient"	Y
Aubona, Gibson	MSc	UoG	Identifying and quantifying plant chemicals sequestered by Lepidoptera: aposematic study of butterflies in Papua New Guinea	Y
Bau, Billy	MSc	UPNG	A revision of the Ficus section Malvanthera in New Guinea.	Y
Damas, Kipiro	MSc	UPNG	Biogeographical and ecological aspects of Syzygium (Myrtaceae) in Papua New Guinea	Y
Ibalim, Sentiko	MSc	UPNG	Community structure and biogeographic origin of geometrid moths along Mt. Wilhelm altitudinal gradient inferred from mitochondrial DNA	Y
Amick, Peter	MSc	UPNG	Effects of forest fragmentation on bat communities in the lowland forests of the Madang area, Papua New Guinea	Y
Amick, Peter	BSc Hons	UPNG	Composition, alpha and beta diversity of bat (Chiroptera) communities along an elevational forest gradient in Papua New Guinea	Y
Pesco, Markis	BSc Hons	UPNG	Elevational distribution of birds on Mt. Michael in Eastern Highlands Province, Papua New Guinea	N
Iova, Bulisa	MPhil	Unitech	The effect of forest habitats on the bird community composition, beta- and alpha-diversity, and abundance.	N
Opasa, Redley	MPhil	Unitech	Species diversity and community composition of fruit fly communities in the forests of Papua New Guinea	N
Paliau, Jason	MPhil	Unitech	The alpha and beta diversity of gemoetrid moths in Papua New Guinea	N
Sosanika, Gibson	MPhil	Unitech	Species Richness and Functional Diversity of New Guinea Tropical Rainforest Ferns	N
Yombai, Jacob	MPhil	Unitech	Ant diversity and community composition in forests of Papua New Guinea	N
Kik, Alfred	MSc	UPNG	Current trends in language skills and ethno-biological knowledge in the Madang Province, a globally important hotspot of cultural diversity	N
Dahl, Chris	PhD	USB	A cross-continental comparison of assemblages of seed-and fruit-feeding insects in tropical rainforests	N
Legi, Sam	PhD	GU	Trends in plant-herbivore food web structure for herbivores feeding on Ficus along an altitudinal rainforest gradient in Papua New Guinea	N
Moses, Jimmy	PhD	USB	Elevation diversity trends in tropical communities of ants	N
Toko, Pagi	PhD	USB	Elevation patterns of alpha and beta diversity in geometrid moths	N

Table 4. DI students (green), other resident students (grey), and visiting students (pink) at BRC, with their degrees, thesis topics and home universities: UPNG – Univ. of PNG, UoG – Univ. of Goroka, Unitech – PNG Univ. of Technology, USB – Univ. of South Bohemia, GU – Griffith Univ. Australia.

Fig. 14. Biology students resident at BRC (L to R: P. Amick, S. Ibalim, B. Bau, B. Iova, G. Luke, G. Sosanika, R. Opasa, K. Damas, A. Kik.) at the Center for Postgraduate Biology (L), and a student presentation at a student conference at BRC in October 2016

Activity 3.2 Continuous supervision during the field work and laboratory training, including weekly seminars

The students received supervision of their field work and training in field and laboratory techniques by more senior members of the BRC team and visiting scientists. Students attended seminars given on a broad range of topics by scientists from seven countries (Table 5). All students also attended weekly Kokomo seminars (named after a pet hornbill at BRC) where a recent interesting research paper is presented by a student, followed by in-depth discussion led by a senior researcher (Table 6). Finally, V. Novotny gave a full university course of Tropical Ecology in a series of 16 lectures (presentations available here: http://zoo.prf.jcu.cz/index.php/stahovani/category/14-tropical-ecology.html).

The BRC students had an opportunity to show their progress at a Student Conference on Biodiversity, organized by BRC on 3rd October 2016 at the opportunity of opening the PNG Center for Postgraduate biology. Eight BRC students gave 20-min presentations (Table 7). The audience included guests, including those listed in Table 1.

Name	Institution	Country	Title	Date
John Burton	Divine Word Univ.	PNG	Social aspects of tourism and development along the Kokoda Track	20-May-16
Lucie Houdkova	Univ. of South Bohemia	Czech Rep.	Seedling and sapling dynamics in the Wannang 50 ha forest plot	17-Jun-16
George Weiblen	Univ. of Minesota	USA	Building a natural history museum in Minnesota	24-Jun-16
Yves Basset	Smithsonian Tropical Res. Inst.	Panama	Forest Geo Arthropod initiative	1-Jul-16
Richard Hazell	Univ. of Sussex	UK	Bird communities along Mt Wilhelm altitudinal transect	8-Jul-16
Martin Libra	Univ. of South Bohemia	Czech Rep.	Community structure of parasitoids along Mt Wilhelm altitudinal gradient	5-Aug-16
Jan Sobotnik	Univ. of Life Sciences, Prague	Czech Rep.	Defensive strategies of termites	17-Aug-16
Petr Stibik	Univ. of Life Sciences, Prague	Czech Rep.	Ectosymbionts and termite abundance across continents	17-Aug-16
Tomas Vetrovsky	Inst. of Microbiology, Czech Acad. Sci.	Czech Rep.	SEED2: A useful tool for large sequence datasets processing.	17-Aug-16
Martina Konecna	Univ. of South Bohemia	Czech Rep.	Social structure, dominance and hormonal status in a PNG village	26-Aug-16
K. Jonsson & P.Marki	Nat. Hist. Museum Denmark	Denmark	Biogeography and evolution of passerine birds	22-Sep-16
Chris Dahl	Biology Center, Czech Acad. Sci.	Czech Rep.	Cross-continental comparison of rainforest communities of fruit feeding insects	23-Sep-16
Ondrej Mottl	Univ. of South Bohemia	Czech Rep.	Testing ant mosaics in a primary tropical rainforest	27-Sep-16
Emilie Beauchamp	Oxford Univ.	UK	Social aspects of conservation projects in SE Asia	28-Oct-16
Jiri Synek	Univ. of Life Sciences, Prague	Czech Rep.	Impotance of ash tree for saproxylic beetles	24-Feb-17
Franktisek Juna	Univ. of Life Sciences, Prague	Czech Rep.	Cockroaches	24-Feb-17
Petr Stiblik	Univ. of Life Sciences, Prague	Czech Rep.	Ecosymbionts of termites	24-Feb-17
Benjamin Normark	Uni of Massachusetts	USA	Evolutionary biology of Armoured scale insects	17-Mar-17
Michael Kessler	Zurich University	Switzerland	Patterns of biodiversity along elevational transects: potential and challenges	10-Dec-17

Table 5. Seminars at BRC given by visiting researchers.

Name	Title	Date
Jacob Yamboi	Are riparian forest reserves sources of invertebrate biodiversity spillover and associated ecosystem functions in oil palm landscapes? Gray et al, 2016, Biol. Cons. 194, 176-183	6-May-16
Peter Amick	Effect of forest fragmentation on bird species richness in Papua New Guinea Sam et al, 2014, Journal of Field Ornithology 85, 152–167	10-Jun-16
Alfred Kick	Loss of traditional ecological knowledge in the Western James Bay Tsuji 1996, The Canadian Journal of Native Studies	17-Jun-16
Billy Bau	Factors influencing tree diversity and compositional change across logged forests in the Solomon Islands Katovai et al, 2016, Forest Ecology and Management 372, 53-63	24-Jun-16
Sentiko Ibalim	Shifts in species richness, herbivore specialization, and plant resistance along elevation gradients Pellisier et al, 2012, Ecology and Evolution, DOI: 10.1002/ece3.296	15-Jul-16
Grace Luke	Climate-driven change in plant–insect interactions along elevation gradients Rasmann et al, 2014, Functional Ecology 28, 46-54	22-Jul-16
Redley Opasa	Host specialization and species richness of fruit flies (Diptera: Tephritidae) in a New Guinea rain forest Novotny et al. 2005, Journal of Tropical Ecology 21, 67-77	29-Jul-16
Sosanika Gibson	Spatial patterns of tree species distribution in New Guinea primary and secondary lowland rain forest Fibich et al. 2016, J. Vegetation Science, 27, 328-339	5-Aug-16
Mavis Jimbudo	Delayed greening in tropical plants, an antiherbivore defense? Kursar and Coley 1992, Biotropica 24 (2b): 256-262.	12-Aug-16
Vojtech Novotny	Midpoint attractors and species richness: Colwel et al. 2016, Ecology Letters, DOI: 10.1111/ele.12640	26-Aug-16
Bulisa Iova	Rapid upslope shifts in New Guinean birds illustrate strong distributional responses of tropical montane species to global warming Freemana et al, 2013, PNAS 111: 4490–4494.	2-Sep-16
Sentiko Ibalim	Evolution of endemism on a young tropical mountain Merck 2015, Nature 524, 347–350	9-Sep-16
Cassey Uvau	Diversity and ensemble composition of geometrid moths along a successional gradient in Eucadorian Andes Hilt et al. 2006, J.Trop.Ecol. 22: 155-166.	16-Sep-16
Sentiko Ibalim	The towering orogeny of New Guinea as a trigger for arthropod megadiversity Toussaint et al., 2014, Nature Communications 5, Article No. 4001	4-Nov-16
Billy Bau	New and noteworthy bird records from the Mt. Wilhelm elevational gradient, Papua New Guinea. Marki et al. 2016, Bulletin of the British Ornithologists' Club 136, 263-271	13-Jan-16
Sentiko Ibalim	Patterns or mechanisms? Bergmann's and Rapoport's rule in moths along an elevational gradient Beck et al. 2016, Community Ecology 17, DOI: 10.1556/168.2016.17.2.2	10-Mar-17
Bulisa Iova	How Many Kinds of Birds Are There and Why Does It Matter? Barrowclough et al. 2016, PLoS ONE 11(11): e0166307.	17-Mar-17

Table 6. Programme of Kokomo seminars: presenting students and the papers discussed.

Name	Title
Peter Amick	Effects of forest fragmentation on bat communities in the lowland forests of the Madang area, Papua New Guinea
Alfred Kik	Current trends in language skills and ethno-biological knowledge in Madang Province, a globally important hotspot of cultural diversity
Sentiko Ibalim	Community structure and biogeographic origin of geometrid moths along Mt. Wilhelm altitudinal gradient inferred from mitochondrial DNA
Billy Bau	A Revision of the Ficus section Malvanthera in New Guinea
Kipiro Damas	Biogeographical and ecological aspects of Syzygium (Myrtaceae) in Papua New Guinea
Bulisa Iova	The effect of habitats on bird communities in different elevations throughout Papua New Guinea: Exploration of beta-diversity and abundance.
Gibson Sosanika	Patterns of Fern Species Richness and Beta Diversity in Highlands Ecosystems of Papua New Guinea
Grace Luke	The effect of plant latex on leaf chewing herbivores

Table 7. Programme of Student conference on biodiversity at BRC on 3rd October 2016.

Output 4:

Activity 4.1 Conduct detailed consultations with communities interested in conservation; identify land ownership in the field

Discussions on conservation with all the communities along the transect, explaining the benefits and addressing the problems of conservation on their lands, have continued in 2016,

including large community meetings and sustained visits by BRC staff for consultations at all sites. This work culminated in a community-wide meeting on 23-24 July at Numba Village with representatives of communities and landowners from along the entire Mt Wilhelm transect from 200 to 3200 m asl. (i.e. from the lowlands to the upper border of the existing Mt Wilhelm National Park). Since then, we have continued working with individual communities, addressing their concerns. The process was greatly helped by our team of BRC para-ecologists and students led by conservation scientist Dr E. Beauchamp (Oxford Univ.) who conducted household surveys along the entire transect – this information clarified the demographics, impact of agriculture on the forests, economic and social status of communities and land ownership of individual clans (Figs. 15, 16).

The surveys of 187 respondents along the Mt. Wilhelm transect demonstrated low education standards, with a third of respondents lacking any schooling and only 20% of them achieving higher than primary school education (Fig. 16A). Further, only a quarter of households lived in permanent or semi-permanent houses, the rest in bush material houses. High access to electricity was achieved solely by private means – portable generators or solar panels, none of the house was connected to a power grid. Relatively high ownership of mobile phones (70%) is a recent phenomenon, stimulated also by good mobile signal coverage of the area (Fig. 16B).

The local economy is based largely on growing crops for subsistence and local sale at the markets, growing cash crops, and local and long-distance trade in agricultural produce (including exports and imports of locally grown crops between lowlands and highlands, such as lowland betel nuts or highland vegetables). Only 23% of households had any significant livelihood activities unrelated to farming (Fig. 16D). The annual income from farming, despite it being the principal source of income, was generally low (Fig. 16E). It ranged from zero to GBP 1,651 per year, but the median income was only GBP 23.6 per year. The access to banking (<25% of respondents) also remains low. In summary, these are under-privileged communities with largely subsistence economies almost entirely based on agriculture, low monetary income and low standards of housing and education.

Fig. 15. Intense discussion at a conservation community meeting at Mt Wilhelm – Numba (left), and BRC staff engaged in household survey along the transect (using tablets to record information from structured interviews) (right).

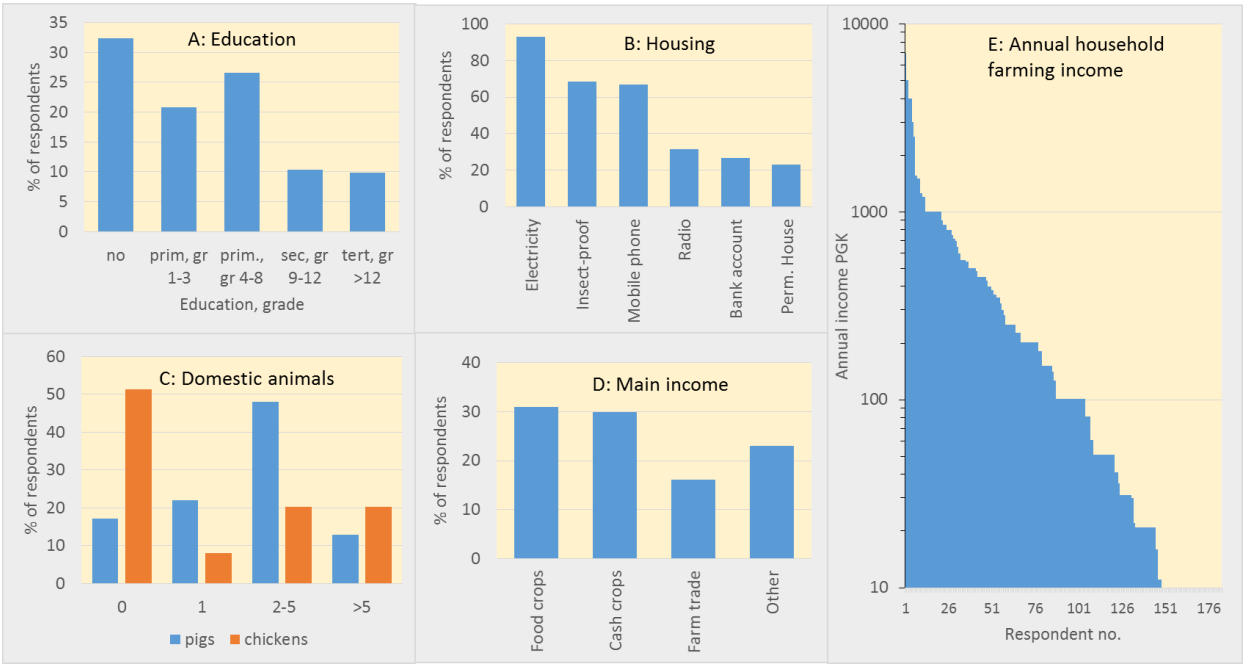


Fig. 16. The results of interviews of 187 households along the Mt. Wilhelm transect, showing the education of the interviewees (A), their housing standards (B), number of pigs and chickens as the main domestic animals kept (C), main source of income (D), and annual household income from farming; current exchange rate: PGK 4.24 = GBP 1.00 (E).

The Mt Wilhelm surveys also clarified the tribe and clan structure of the landowners. This tends to be complicated in PNG and here as well includes four different languages, five tribes and at least 39 clans (Table 8). We are now in the process of clarifying and mapping boundaries of the proposed conservation areas. Ideally, our goal is to merge the areas dedicated by individual clans into a contiguous single area following the CART transect, encompassing the area of 15-20,000 ha and directly adjacent to the Mt Wilhelm National Park encompassing the summit of Mt Wilhelm (Fig. 17). The next steps will be: (i) finalizing the areas proposed for conservation, (ii) signing community deeds with the landowners, (iii) writing a proposal for the Conservation and Environment Protection Agency (CEPA) of the PNG Government), (iv) getting approval from the Provincial Government, (v) getting approval from CEPA and having the PNG Government declare the Conservation Area. BRC hosted the local Member of Parliament for Usino-Bundi, Anton Yagama, in July at BRC premises to discuss the Conservation Area. BRC representative Pagi Toko was invited by CEPA to take part in a seminar on reviewing the new law on conservation areas and national parks that is being drafted for the PNG Parliament. We were approached by Rainforest Trust (https://www.rainforesttrust.org/) who have an interest to facilitating the process of implementing the CART conservation. They provided seed funds (USD 5,000) to clarify the conservation boundaries, after which they would like to consider a more substantial funding (up to USD 200K) in support of the Conservation Areas.

Tribe	Clan	Tribe	Clan	Tribe	Clan	Tribe	Clan	Tribe	Clan
Mendi 1	Erinugua	Mendi 2	Bindogu	Mendi 3	Geruranama	Nombri	Bundizomo	Wandike	Gochane
	Geremi		Bindu		Gonmagimo		Izomo		Goglkana
	Gonmagem		Jamiaklari		Inolawa		Kovoki		Wopana
	Gonomagemo		Jomo		Irenugua		Kuiawa		
	Inaonarawa		Kambagu		Irindua		Nakawa		
	Kondmage		Kambaug		Kanarowa		Piyawa		
	Konomangimo		Yambiyakra		Kegerunara		Renivuga		
	Moinakiniga		Yameakarari		Kombonarawa		Renua		
					Kombonro		Rinuguwa		
					Kumponarawa		Rinuwa		

Table 8. The tribe and clan structure along the Mt Wilhelm transect, including the clans with landownership within the proposed conservation area(s).

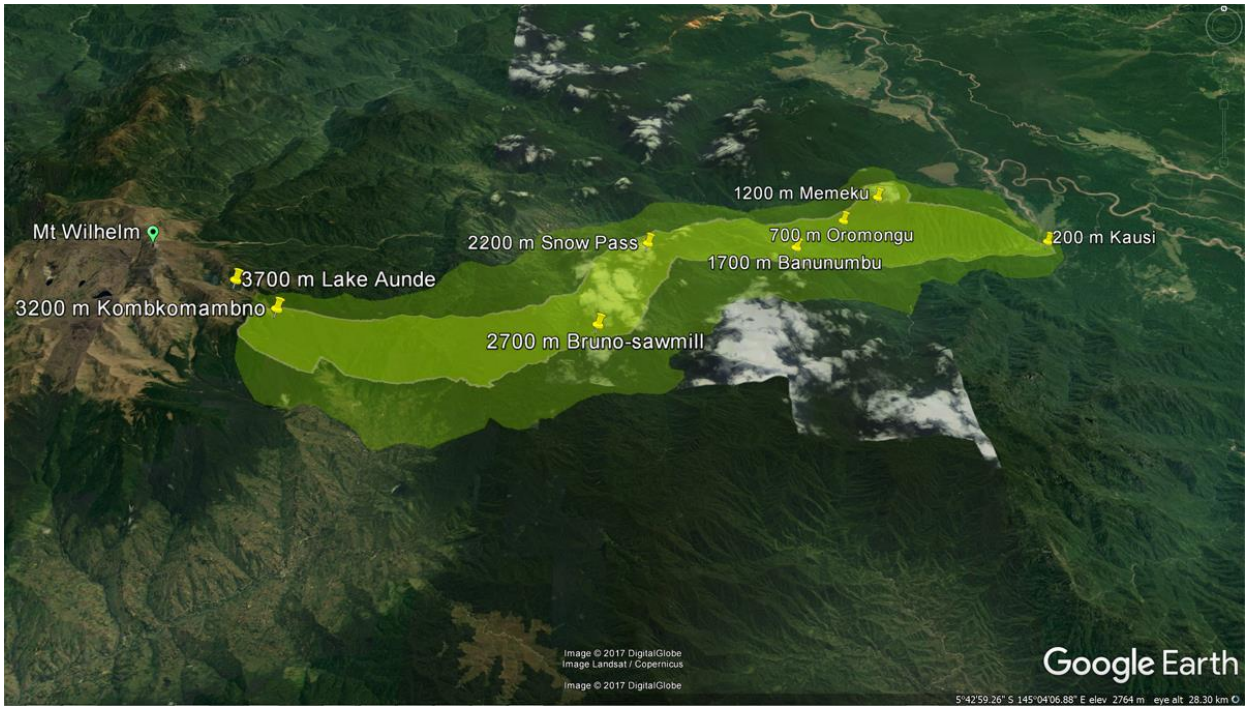


Fig. 17. The proposed conservation area including the core area along the CART transect (light green) and peripheral areas (dark green) to enlarge the size and thus the sustainability of the protected rainforests.

Output 5:

Activity 5.1 Prepare research and tourist infrastructure (trails, accommodation, research camps).

All eight sites have the basic infrastructure, including local camp managers, camp sites, and local teams that provide basic field accommodation and catering (cooks, porters) to visitors (Fig. 18). As a major development, we have established 10 research transects (500 m each) in primary forest at each study site, and also additional transects in secondary vegetation at six sites where such vegetation is available. The local communities are now able to receive research teams, as has been demonstrated by hosting five research projects in 2016 (household survey of El Nino impacts, bird-fruit interactions project, herbivores on *Ficus* trees, *Ficus*-fig wasp interactions, and the study of caterpillar-parasitoid food webs).

Fig. 18. Field camps in Kausi (top left) and Numba (remaining photos), with village style catering.

Activity 5.2 Develop community management for research and tourist activities, structure of fees, financial management, and visitor rules.

We have designed the Mt Wilhelm web site (www.entu.cas.cz/png/mtwilhelm) providing information on the logistics of research and tourist visits (Fig. 19), as well as the rules and procedures that visitors should observe. We have developed pricing policies for porters, accommodation and field assistants along the transect.

The Mt Wilhelm transect continued to attract external research projects. In particular, it supported six research projects funded from UK, USA and the Czech Republic (Table 9). These projects brought GBP 34,600 income to the Mt Wilhelm communities, in addition to GBP 99,300 to BRC, as payment for the field work, accommodation and transport.

PI	Funding Agency	Receiving Institution	Theme	BRC	Mt Wilhelm	2018 prospect
Simon Segar	Czech Science Foundation, CZ	Czech Academy of Sciences	Ficus - fig wasp phylogeny	11,500	5,500	none
Yves Basset	Czech Science Foundation, CZ	Czech Academy of Sciences	Plant - herbivore food webs	52,000	12,000	steady
Rebecca Morris	NERC, UK	Oxford University	El Nino impact on agriculture	19,500	9,000	none
Alan Stewart	Sussex Sustainability Res. Progr., UK	Sussex University	Health in rainforest communities	2,500	1,500	increasing
Francesca Dem	Rainforest Alliance, USA	BRC	Rainforest conservation	1,800	2,100	increasing
Vojtech Novotny	Christensen Foundation, USA	BRC	PNG student biodiversity research	12,000	4,500	steady
Total				99,300	34,600	

Table 9. External projects active at the Mt Wilhelm transect, with the funds paid for logistical support to BRC and to Mt Wilhelm communities, with an assessment of the prospective financial income for 2018.

Fig. 19. Village life on the Mt Wilhelm transect: a local market, a group of porters ready to assist a research team, a night discussion with researchers in a village house, a family with a pet cassowary, and traditional adornments including bird of paradise feathers.

The table below summarises the outputs in the second year. With two exceptions (2.4 & 4.2), progress against all indicators has been good, in some cases with overall project targets having been exceeded by the end of Year 2. We are confident that the remaining targets can be achieved by the end of the project. The output indicators remain appropriate for assessing progress. Please note that the 'baseline' column in the template table has been removed because it is not appropriate in this project; this is the first time anyone has conducted any activities on the newly-established transect, and no protected areas pre-existed except the Mt Wilhelm National Park, so the baseline is zero in all cases.

	Progress in Year 2	Source of evidence	Comments
Output 1:	**Focal plant and animal taxa (plants, ants, moths, butterflies, amphibians and birds) surveyed along CART as base-line information for climate change impact monitoring, and results published**		
Indicator 1.1: Specimen distribution records along CART collected and databased: on average 1,000 records per focal taxon; 6,000 records in total.	Taxonomic and ecological analysis of 4,200 insect specimens and 15,000 ecological interactions from years 1-2 progressed to the stage when it could be used to produce research papers.	Database records, research papers (e.g. Plowman et al., 2017; Colwell et al., 2017).	Target number of specimens met; taxonomic work continues.
Indicator 1.2: Molecular information (COI sequences) obtained for 2,000 insect specimens, building molecular identification database for CART biota	We have barcoded 1,650 insect specimens; the analysis and publication of data is pending.	Published research papers (e.g. Segar et al., 2016), COI databases.	The target of 2,000 specimens will be met by Sept 2017.

Indicator 1.3: 3 papers on CART biodiversity published in international research journals	5 papers published (see Annex 3, Table 2).	On-line access to the papers as pdfs's via Mt Wilhelm website.	Current total of 7 papers significantly exceeds the target.
Output 2:	**Locally recruited field assistants, BRC para-ecologists and researchers trained in biodiversity surveys and biodiversity data interpretation to assist research along CART**		
Indicator 2.1: 16 local assistants recruited from CART communities each receive 10 days training per year (480 person-days of training by end of project)	234 personnel received basic training of 3 days each (702 person-days total), 6 field assistants recruited from CART communities trained for 90 person-days	Employment and training records	The project target in person-days substantially exceeded (220 person-days of training in Year 1).
Indicator 2.2: 18 BRC para-ecologists each receive 10 days training per year in biodiversity survey field methods, and the analysis of ecological and molecular data, (540 person-days of training by end of project)	30 BRC para-ecologists each received 10 days training in field survey methods of plants, insects or birds, 300 person-days in total.	Employment and training records	Training target in person-days for Year 2 exceeded.
Indicator 2.3: 6 BRC para-ecologists each receive 15 days training in UK in biodiversity survey and molecular barcoding methods, (90 person-days of training across 3 years of project)	2 BRC para-ecologists visit UK, each receiving 25 days training, plus additional 30 days of training per person whilst visiting collaborators in the Czech Republic and Malaysia.	Training programme.	Training target in person-days for Year 2 exceeded.
Indicator 2.4: 2 PNG researchers each receive 45 days training in biodiversity survey field methods, and the analysis of ecological and molecular data (90 person-days of training by end of project)	No activity this year.		
Output 3:	**PNG Honours and M.Sc. students trained in biodiversity research**		
Indicator 3.1: 2 BSc Honours students trained and graduated by end of project	1 BSc Honours student completed the study, 1 student continues	Degree awarded, student progress reports	We are on schedule to reach the project goal.
Indicator 3.2: 2 MSc students trained and graduated by end of project	5 MSc students being trained	Student progress reports	We are on track to exceed the project goal by 100%
Output 4:	**New forest conservation areas established by local landowners along CART**		
Indicator 4.1: Two conservation areas within the CART established by local forest landowners, 10,000 ha total, spanning 200-2700 m asl	Landowners engaged in continuing discussions on conservation, at the stage of confirmed interest and clarifying the boundaries of the conservation areas	Photo documentation, records of attendance at meetings; files of GPS coordinates of draft boundaries.	We are slightly delayed in the negotiations, but still confident that the the project goal will be achieved
Indicator 4.2: Two Conservation Boards established for the Conservation Areas management	The Boards can be formed only once the negotiations are finalized; no progress here.		Now scheduled for Year 3.
Output 5:	**Financial situation of indigenous forest owners improved along CART**		

Indicator 5.1: 80 personnel from CART communities each employed part-time for 20 day-equivalents during lifetime of project, assisting research and tourism (1,600 person-days of employment in total)	234 persons from CART communities (Table 3) employed for average of 5 days each (1,168 person-days in total).	Employment records.	We have exceeded the project goal (1,280 person-days of employment in Year 1).
Indicator 5.2: GBP 12,000 of sustainable annual income (GBP 36,000 total during the project) received by CART communities from research and tourism	GBP 34,600 of income received for 6 CART communities from 6 external grants (Table 9)	Payment records	At the end of Year 2, we have already exceeded the overall project goal (GBP 8,400 received in Year 1).

3.3 Progress towards the project Outcome

The indicators remain appropriate and adequate for measuring the outcome of the project. We are confident that the planned outcome will be achieved by the end of the project, but we will continue to monitor progress to ensure this remains the case.

Outcome:	Biodiversity survey of Complete Altitudinal Rainforest Transect (CART) to: prioritise and establish protected forest; improve sustainability for indigenous landowners; enable climate change monitoring; build national capacity in biodiversity data interpretation.		Comments
	Progress in Year 2	Source of evidence	
Indicator 1: Quantitative biodiversity data on focal taxa from CART – number of samples and specimens	Data collected and analysed, published in 7 papers; 4,200 insect specimens, 450 plant specimens, 15,000 ecological records obtained.	Research publications, specimens in biological collections and specimen database records	On track for achieving outcome by end of project.
Indicator 2: Number of field assistants, para-ecologists and researchers trained; number of person-days of training	234 field assistants, and guides trained for 702 person-days, 30 para-ecologists trained for 300 person-days	Records of training, tests and personal projects completed to monitor the results of training	
Indicator 3: Hons. and MSc degrees completed by PNG nationals	1 Hons completed, 1 Hons and 5 MSc in progress	Hons. and MSc dissertations (e.g. Annex 4) and resulting publications	On track for target number of Hons students and double the number of MSc students to complete.

Indicator 4: Community conservation areas established – number and size	6 communities engaged in ongoing discussion and clarification of conservation area boundaries.	Signed Community Conservation Deeds	Significant progress in negotiations with communities, including boundaries of potential conservation areas GPS mapped.
Indicator 5: Income generated for indigenous forest owners – amount per year	GBP 34,600 raised for assistance by the local communities to 6 external research projects	Financial reports by Conservation Boards established by local communities	Target income for project (£36,000) already exceeded by end of Year 2.

3.4 Monitoring of assumptions

With one exception, all the original outcome and output level assumptions still hold true. The single exception is the accessibility of the sites along the CART by road. Landslips have made parts of the road impassable. Fortunately, the sites affected (between 900 and 2700 m asl.) can nevertheless be accessed on foot easily from neighbouring sites, so we do not propose to change any of them.

Outcomes:	Still holds true?	Comments	Source of evidence
Assumption 1: Focal area remains accessible by road (for researchers and tourists)	No	Part of access road blocked by landslides, preventing vehicle access to the sites between 900 and 2700 m asl. It is unlikely that the road will be reinstated within the lifetime of the project. However, access to all stations along CART is still possible, but in some cases only on foot, making logistics more time consuming and expensive.	
Assumption 2: Sufficient local expertise and interest can be developed for biodiversity surveys	Yes	The level of interest by local communities has exceeded our expectations. Our trainees recruited from local communities continue to make excellent progress and to support external research projects.	Progress reports of trainees, feedback by hosted research teams
Assumption 3: Sufficient supply of students interested in honours and postgraduate training	Yes	There is exceptionally high demand among undergraduate students to join our Hons and MSc training programme.	Applications for studentships
Assumption 4: Indigenous communities in the focal project area are interested in declaring forest conservation areas on their land	Yes	Communities have been keen to discuss options for declaring their land as conservation areas. Discussions continue with all target communities on the specifics and boundaries of the proposed conservation areas.	Meetings with rainforest owners.
Assumption 5: Researchers and biologically oriented tourists can be attracted to project areas, providing income from paid services	Yes	Six external projects provided higher than expected income. The potential for ecotourism is now being tested as the new web site has been launched. We will also advertise through the PNG Tourist promotion Board and local guesthouses catering for tourists climbing the Mt Wilhelm summit.	No. of visiting researchers
Outputs:			
Output 1 assumption: Biodiversity sampling yields sufficient numbers of specimens and records (if not, change protocols); DNA extraction and sequencing successful (if not, change specimen preservation methods); data analysis sufficiently interesting for research papers (if not, refocus the field research)	Yes	Survey protocols tested and agreed to be appropriate. Field surveys already yielding valuable data on plants, birds, and insects. DNA techniques have been successfully employed. Seven high-quality research papers published.	Research papers published on biodiversity
Output 2 assumption: Training adjusted to different levels (field assistants, para-ecologists, researchers) so	Yes	Training of CART village assistants was adjusted to allow for different levels of ability and motivation by differentiating between 234 assistants who received basic training in	Feedback questionnaires; results of

that it is attractive, accessible to the target audience, and sufficiently advanced to be useful (if not, based on the trainees' feedback, modify the content)		logistical support and six who received intensive training in support specifically for research. Training has proved effective to get the required jobs, viz. research projects, done. This is the case on all levels, from field assistants to para-ecologists and researchers.	annual appraisals.
Output 3 assumption: Student projects designed so that they are both scientifically novel and feasible, students systematically supervised and problems rapidly rectified based on their feedback.	Yes	All 6 students are on track to produce theses of a high standard, obtain their degree and publish the results in research papers.	Degrees awarded, research papers published.
Output 4 assumption: Landowners interested in declaring conservation areas as a way of securing research and tourist benefits (if not, either work more with the focal communities, or search for more interested communities in the CART area)	Yes	Landowners already engaged in robust discussions on specific conservation arrangements and Conservation Area boundaries. In one case where a community did not want to be involved, we have found alternative communities to work with.	Conservation Areas declared
Output 5 assumption: Communities are sufficiently well organized to provide quality research and tourist assistance (if not, based on customers' feedback, work with Conservation Board to rectify), researchers and tourists are aware of opportunities at CART (if not, advertise more).	Yes	The visiting research teams (six projects in 2016) report that support in the field from the local communities was efficient. Opportunities for research and eco-tourism are described on the new project website.	Feedback from research teams

3.5 Impact: achievement of positive impact on biodiversity and poverty alleviation

The project includes a prominent biodiversity conservation component, working with the village-based landowners to establish two protected areas. These will be designed to connect with the existing Mt. Wilhelm National Park to include biologically important, yet currently unprotected, areas at altitudes below 3000 m asl. The project is also designed to bring sustained conservation-based income from research and ecologically-oriented tourism to indigenous communities of about 400 members, currently living largely in extreme poverty (<$1.25 per day), directly benefiting about 80 people employed specifically by the project. Additionally, the professional careers of 30 para-ecologists and 2 junior researchers will be enhanced by training and employment on the project, while 5 postgraduate students will obtain their degrees, opening up new career prospects for them. These parameters exceed the targets in the project proposal.

4. Contribution to SDGs

By the time of its completion, our project will contribute to the following UN Sustainable Development Goals:

1.1 (eradicate extreme poverty): contributed to through employment of indigenous village people as field research assistants and ecotourism guides.

15.2 (sustainable management of forests, halt deforestation, restore degraded forest): contributed to through establishment of two forest protected areas.
15.4 (conservation of mountain ecosystems including their biodiversity): the new conservation areas will extend the existing high altitude Mt. Wilhelm National Park to biologically important lower elevations between 200 and 2700 masl.
15.5 (reduce degradation of natural habitats, half biodiversity loss, prevent extinction of threatened species): contributed to through better understanding of species distributions and changes therein predicted by climate change models, management of habitats and their recovery after disturbance.

After two years these targets appear feasible, as we are able to attract important and probably sustainable sources of funding to improve the livelihood of local landowners, which in turn will contribute to already existing interest in rainforest conservation.

5. Project support to the Conventions, Treaties or Agreements

Our project is highly relevant to the CBD Aichi Biodiversity targets for 2011-2020, particularly Target 5 (halving the rate of loss of forests by 2020), Target 11 (protecting minimum areas of important habitats) and Target 19 (building research capacity and knowledge base). The project is also relevant to the *Nagoya Protocol on Access to Genetic Resources and Benefit Sharing Arising from their Utilization*, which strives for fair and equitable access to genetic resources and transfer of relevant technologies. Our project will develop extensive libraries of DNA barcodes for insect species, and make them available on-line free of charge to PNG professionals, thus facilitating identifications and biodiversity conservation decisions. It will also develop local expertise for the application of this DNA information to conservation decisions, thereby laying the foundation for future implementation of the Nagoya protocol (still to be signed and ratified by PNG).

Our project has already contributed to better documentation of PNG biodiversity through research publications and other resources (DNA library, collections, databases). These publications are already made available free of charge on our web site (http://baloun.entu.cas.cz/png/ptcpubl.htm).

6. Project support to poverty alleviation

An important goal for the project is to directly improve the economic status of about 80 members of the indigenous communities living along the CART. The income will come from assisting research and ecologically-oriented tourists, including entry and accommodation fees, research assistants, field guides, carriers, camp managers and cooks. The project area is exceptionally suitable for these activities. The benefits are expected to be felt by the wider communities along the CART (totalling about 400 people). People in these communities live in extreme poverty, defined as daily income <$1.25, and rely on subsistence slash-and-burn agriculture. At the same time, they own lands harbouring uniquely valuable biodiversity. The fundamental premise of our project is that additional income will be a strong incentive for these communities to consider forest conservation as an attractive alternative to other more destructive land uses.

The project has already improved income during Year 2 as there were six research projects operating in the study area, bringing employment opportunities and income of more than GBP 30,000 in total. This is particularly significant compared to the low incomes and living standards, as documented by our survey in year 2.

7. Project support to Gender equity issues

BRC has a policy of promoting equal opportunities irrespective of gender. Women are encouraged and included in all BRC activities and a small but increasing number of students showing an interest in biodiversity research are female: one of the five students that we have

recruited for MSc studies is female; so is the Deputy Director of BRC, appointed this year (one of our former PhD students).

We do encourage women from the village communities to apply for work and provide appropriate opportunities in the project, but typically they do not even apply for these positions, due to the customs and traditions of their communities. Consequently, the great majority of people in village communities applying to become field assistants are likely to be male (206 male: 28 female receiving basic training amongst the CART villages; see Table 2). Women in PNG, especially those in remote communities with poor educational opportunities, have very low social status and are subject to strong discrimination in a highly male-dominated society. Gender issues therefore need to be treated with great caution and sensitivity. Our primary goal is to focus on achieving conservation objectives, which means working with indigenous communities and respecting their traditions.

8. Monitoring and evaluation

Performance monitoring in our small teams is constant and intense, as it happens on an everyday basis by team leaders and student supervisors. However, we have developed also more formal evaluation procedures that differ for paraecologists and students (Table 10). The students are evaluated by their peers, the Student Team leader, their Supervisor and also the Postgraduate Committee at the university. The paraecologists are evaluated by their peers, their Team leader, and the BRC management. Performance in training and research is constantly monitored and training is formally assessed by knowledge tests (Annex 4, Figs. 2, 3). Progress by students is also monitored based on their essays, presentations in regular seminars, and annual progress reports. At the same time, the trainees, workers and students are encourage to give feedback, both at weekly meetings and also in anonymous questionnaires. The ultimate test of performance is goals achieved – university degrees awarded, research papers published, conservation areas declared and incomes earned. We also care about the general work satisfaction of students and staff and monitor it annually by anonymous feedback. The results of our monitoring (Fig. 20) indicate progress in technical knowledge during the current project (note that the knowledge tests are intentionally made difficult so achieving full scores is not expected; this is a way to separate excellent performers from the rest). Further, our evaluation shows high levels of job satisfaction.

Student evaluation				
Activity	Evaluated parameters	Periodicity	Evaluator(s)	Evaluation
Kokomo seminar	Attendance & activity	Weekly	Student Team Leader	oral
Interim evaluation	Research progress	Quarterly	Thesis Supervisor	oral
Progress report	Research progress	Annually	Postgraduate Committee	written
Essay	Grasp of research topic, writing skills	Annually	Thesis Supervisor	written
Kokomo seminar	Paper presentation & discussion	Annually	Student group	written
Thesis	Research results, publication potential	End of study	Postgraduate Committee	written

Paraecologist & trainees evaluation				
Activity	Evaluated parameters	Periodicity	Evaluator(s)	Evaluation
Research	Performance, work attendance	Weekly	Team Leader	oral
Annual evaluation	Performance, training progress	Annually	BRC management	written
Annual evaluation	Performance, team work	Annually	BRC staff	written
Knowledge & skills test	Progress in training, skills, knowledge	Annually	BRc Director	written
Patrol debriefing	Field work performance	End of field work	Team Leader	oral
Thesis	Research results, publication potential	End of study	Postgraduate Committee	written

Table 10. The monitoring system for BRC-based students, paraecologists and trainees recruited from the local communities.

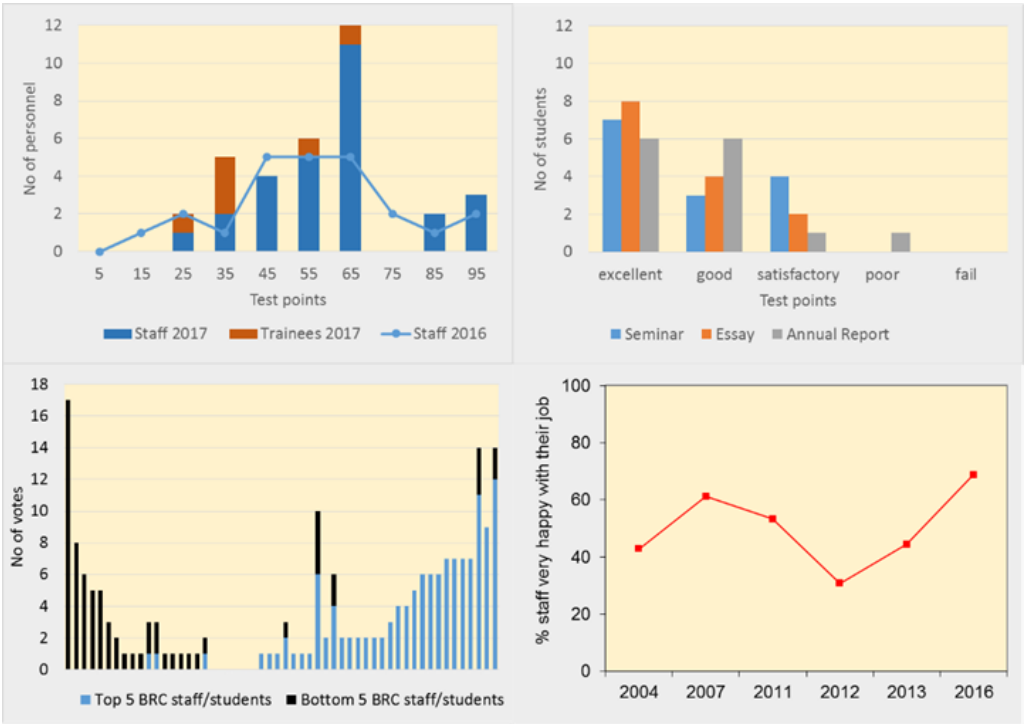


Fig 20. Performance monitoring and evaluation. Test points (maximum 100) achieved by 30 BRC staff and 6 village trainees in 2017, in comparison with the results of 24 staff achieved in 2016 (top left); the evaluation of the postgraduate students resident at BRC by their supervisors in 2017, grading their seminar presentations, essays and progress reports (top right); the results for individual BRC staff and students in anonymous voting indicating the best (blue) and the lowest performing (black) peers; the number of votes received shown for each staff and student (with their names omitted), ranging (L to R) from the worst to the best performing personnel (bottom left); the proportion of BRC staff "very happy" with their job based on anonymous surveys, from 2004 to 2016 (bottom right).

9. Lessons learnt

The project is already exceeding some of the training and research targets and is on track to achieve the conservation goals. Not entirely surprisingly, the technical research challenges in documenting and monitoring biodiversity and publishing the results, as well as training PNG students and staff in the controlled environment at BRC, are proving easier to manage and achieve than the field social work required for the negotiation and setting-up of the conservation areas, where the work is on track but slightly behind schedule.

10. Actions taken in response to previous reviews (if applicable)

The Review of our Annual Report for Year 1 highlighted a number of issues that needed to be addressed. With the exception of on-line presence of the project, these issues related more to our report than the project itself so that no changes to the actual project plan were deemed to be necessary.

(i) *Clear exit plan for the project to ensure continued sustainable tourism/job generating activities*: We were asked to address this in the half-annual report. Our response is reproduced here:

> Sustainability was addressed in the project proposal and we are carrying out this plan. We are developing an alternative livelihood based around income from research. CART needs to become sufficiently prominent in the research community and attractive to researchers so that it attracts the critical volume of research projects to support the community. This is being accomplished by (i) research publications from CART, (ii) training local para-ecologists and assistants, (iii) putting in place local management systems for visitors (an

entry fee structure etc.), and (iv) declaring a Conservation Area which will attract research and conservation funding and raise the profile of the site. The project proposal makes the plan for sustainable employment very clear, by setting up CART as an open access field research facility attractive to researchers who will bring employment and funds to pay for the services. Ultimately, management of PNG forests is decided by the local landowners, not through enforcement, no matter what the formal status of the forest is. Work with local communities is therefore crucial for the success of the project.

Ideally, in addition to this "soft" infrastructure it would be beneficial to upgrade the accommodation facilities at the study sites, but this is beyond the scope of the Darwin project and will be addressed by other fundraising activities. This is a model that we have already tested in the previous DI project in the Wanang Conservation Area, which is thriving since the completion of that project in March 2015. The activities that have recently been attracted to CART (a NERC project by Oxford University and a proposal by the Rainforest Trust) indicate that the strategy is starting to work in this area as well.

The reviewer raises the concern that 'potential negative consequences in increasing human activities in the area' need to be managed and planned for. We believe that this concern is unnecessary. There is no appreciable risk of negative effects of increased accessibility to the CART. Even the most optimistic prospects for research and tourism envisage activities well below levels causing significant disturbance, balanced against many positive benefits for forest conservation. We are starting from zero tourism in this location, in a country where the most frequented tourist destinations are visited by only a few thousand people per year.

Since then, we have been upgrading the camp in Numba, at the centre of CART, to provide suitable accommodation for tourist visits. We have also started developing an entry fee structure and a process to appoint community personnel to be trained for financial management and logistics. The training process and the creation of relevant management and visitor rules will only be possible once the borders for the conservation area have been agreed, a process that is now nearing completion. We will be emulating our previous, successful DI project in achieving conservation in the Wanang Conservation Area, where we have tested our approach (www.entu.cas.cz/png/wanang)

(ii) *Creating an online presence and providing project information & data online*: We have now established a detailed bespoke project web site (www.entu.cas.cz/png/mtwilhelm) containing information about the CART, logistics arrangements for research and tourist visitors, the research projects being conducted, the proposed conservation areas, partner organisations and publications arising out of the work. Further references to other online BRC material (especially relating to our previous Darwin project at Wanang, 19-008) were given in our half-annual report.

Data resulting from the project will be made available online and open-access as individual research projects mature. Some of the results have been published in open-access journals (see list in Annex 3, Table 2), and we pursue this wherever appropriate, but we take the view that the work will reach its intended audience most effectively and have the greatest impact by being published in the best quality journals irrespective of whether they are open access or not.

(iii) Evidence of the training programme and clear outcomes of training activities: We were asked to address this in the half-annual report. Our response is reproduced here:

> The reviewer seeks evidence of training events and their outcomes. BRC para-ecologists and other staff are trained individually, "on the job" and by visiting and resident researchers and students. This is complemented by a programme of discussion sessions, lectures, seminars, workshops and other training events (e.g. see postgraduate website). These activities are on-going rather than formalised within a specific timetable and therefore often do not readily generate a specific record of their occurrence. Individual progress by all staff, however, is regularly appraised to ensure that performance levels are maintained and that training needs are assessed and met. Nevertheless, we will renew our efforts to record the implementation of our training programme.

We have provided more information on the training under Activity 2.2.

(iv) Information provided on the plan/approach to establish two protected areas: We started to address this in the half-annual report and our response is reproduced here:

> BRC developed the Wanang Conservation Area that was awarded for its "innovative approaches to conservation" by the UNDP Equator Prize in 2015. BRC is also being consulted on the draft new legislation for Conservation Areas by CEPA, the PNG

Government nature protection agency, and has 20 years of experience in PNG conservation. We believe this demonstrates that we are aware of the precise sequence of steps that need to be implemented for identifying potential protected areas and getting them officially designated as such. The first and most important step is negotiating a conservation deed with local communities, as detailed in our 1st year report. The other steps will follow but were not relevant for reporting in the 1st year report.

We have now explained our approach to establishing the two protected areas in more detail under Activity 4.1 above and in Section 12 below.

(v) *Need for a clear and robust approach for monitoring and evaluating the project work and progress*: We were asked to address this in the half-annual report. Our response is reproduced here:

> The reviewer suggests that the project is 'lacking a robust and clear approach to monitor and evaluate its own work and progress in a measurable way'. We disagree with this conclusion. BRC is a small organization very focused on what it does and has been doing it successfully for the past 20 years. It hosted four previous DI projects and reached excellent results in each of them, including the most recent, and similar, project on the Wanang Conservation Area. We will report more extensively on our monitoring and evaluation activities in the next annual report.

11. Other comments on progress not covered elsewhere

As we reported in our half-annual report, the two para-ecologists (Graham Kaina and Bonny Koane) were prevented from boarding their flight from Colombo airport, Sri Lanka to London last summer, even though all their travel documentation was in order. They were held in transit for two days but despite numerous enquiries, we were unable to establish the reason for this, either before or since. We attempted to recover the £2,244 that we had to spend to enable them to continue their journey to Europe from Sri Lankan Airlines, the Colombo airport authorities and our university's travel agent, Key Travel. Unfortunately, none of these parties would accept responsibility, the matter remains unresolved and we have had to accept that the funds cannot be recovered. Once the visitors had safely reached their destination, Eilidh Young (DI Secretariat) was informed on 17th August.

12. Sustainability and legacy

There are multiple components to the project's planned legacy including: (i) the physical infrastructure of CART (field labs, permanent plots, transects etc.) available for future biodiversity research; (ii) rainforest conservation areas organized and led by indigenous landowners, extending the existing Mt. Wilhelm National Park to biologically important lower elevations; (iii) detailed information on plant, insect and vertebrate communities, especially in relation to altitude; (iv) a 20% increase in annual income for indigenous communities generated by sustainable conservation-based initiatives; (v) 5 postgraduate students qualified to Honours or Masters level and 30 para-ecologists trained to a high standard, all with enhanced career prospects.

Establishment and sustainability of Conservation Areas in PNG:

The Review of our first Annual Report queried our procedure for establishment of the Conservation Areas and our strategy for their future sustainability.

In PNG, indigenous landowners have a legal right to decide on the use of their lands, including forest conservation, logging or conversion to agriculture. At the same time, the land is typically not formally registered and the ownership is documented by oral histories rather than cadastral maps. A Conservation Area therefore has to be negotiated and agreed with all landowning clans, and its borders and rules for the land use have to be clarified. This in turn requires reaching consensus within the clans, as well as explaining concepts to the landowners which are often novel to them, such as the notion of rainforest conservation. The ultimate decision often depends on the balance between benefits and missed opportunities that conservation offers. This makes the sustainability of income essential for successful conservation. This situation is described in Novotny (2010, *Biotropica*, **42**, 546-549). The goal of the present

project is to conduct negotiations with landowners, clarify the Conservation Area boundaries, and sign conservation deeds. Only after the Conservation Area has been firmly established with the local landowners can it also be declared officially by the Government. However, this latter stage in the procedure, of utmost importance in other countries, is of secondary importance in PNG since even legally declared conservation areas cannot be effectively protected against the wishes of indigenous landowners. The Mt Wilhelm Conservation Area will indeed be subjected to this formal process, guided by BRC, but the main focus of our project is to get it firmly established with the indigenous landowners.

The conservation goals of the present project are thus focused on the ability of BRC, the local partner in PNG, and the Mt Wilhelm communities to sustain income related to rainforest conservation. We contend that these benefits will be brought by hosting, logistically supporting and assisting research projects studying biodiversity within the Conservation Area. This strategy is informed by our previous successful experience from the Wanang Conservation Area, also the focus of a former Darwin Project (19-008), where we have been sustaining such conservation by research for more than 15 years (www.entu.cas.cz/png/wanang). The validity of our approach was recognised by the Wanang community being awarded the prestigious United Nations Equator Prize in 2015.

This “conservation by research” approach is feasible only for sites that are able to attract international research projects. The Mt Wilhelm area does have such potential since it is one of the few “complete altitudinal rainforest gradients” in the tropics where an uninterrupted gradient of rainforest vegetation can be studied from the lowlands to the alpine zone. The aim of our project is to create the physical and administrative conditions for such a possibility, with BRC able to attract and support research teams administratively and with lab facilities, while the local communities will support them in the field. Our strategy relies upon a positive feedback between them which we are confident will develop here. With an increasing number of research projects conducted in the area, the volume of biological information available, and the number of research papers published, will grow, thus attracting an ever broader range of research projects. Our assumption is that, after three successful years supported by this Darwin Project, conservation could be supported by sustained research traffic in the area, managed by BRC and funded by visiting researchers. We consider this to be entirely feasible and the results so far, including the annual funds raised from external projects (see above), suggest that this represents a realistic exit strategy for this project.

13. Darwin Identity

The contribution of the Darwin Initiative is always acknowledged on publications (listed in Annex 3, Table 2), on line, at research conference presentations, and in all publicity material. All presentations and talks by students and staff at conferences and seminars use the Darwin logo on their slide presentations, as do all training workshops conducted by UK trainers and PNG staff. The Darwin Initiative contribution is acknowledged prominently on the websites for the Center for Postgraduate Biology (http://binatangstudents.weebly.com/partners.html), the Binatang Research Center (http://baloun.entu.cas.cz/png/parataxoweb.htm) and the Mt Wilhelm Research & Conservation Area (http://baloun.entu.cas.cz/png/mtwilhelm/partners).

14. Project Expenditure

Please note that the final expenditure figures for 2016-17 are not ready yet as these are normally submitted by the deadline of 31st May. The completed table will be sent as soon as the figures are available.

Table 11 Project expenditure during the reporting period (1 April 2016 – 31 March 2017)

Project spend (indicative) since last annual report	2016/17 Grant (£)	2016/17 Total Darwin Costs (£)	Variance %	Comments (please explain significant variances)
Staff costs (see below)				
Consultancy costs				
Overhead Costs				
Travel and subsistence				
Operating Costs				
Capital items (see below)				
Others (see below)				
TOTAL				

Annex 1: Report of progress and achievements against Logical Framework for Financial Year 2016-2017

Project summary	Measurable Indicators	Progress and Achievements April 2016 - March 2017	Actions required/planned for next period
Impact Effective contribution in support of the implementation of the objectives of the Convention on Biological Diversity (CBD), the Convention on Trade in Endangered Species (CITES), and the Convention on the Conservation of Migratory Species (CMS), as well as related targets set by countries rich in biodiversity but constrained in resources.		First steps in developing sustainable livelihood for forest-based local communities through employment in collecting biodiversity data to inform decisions on selection of protected areas.	[redacted]
Outcome: Biodiversity survey of Complete Altitudinal Rainforest Transect (CART) to: prioritise and establish protected forest; improve sustainability for indigenous landowners; enable climate change monitoring; build national capacity in biodiversity data interpretation.	1. Quantitative biodiversity data on focal taxa from CART – number of samples and specimens 2. Number of field assistants, para-ecologists and researchers trained; number of person-days of training 3. Hons. and MSc completed degrees by PNG nationals 4. Community conservation areas established – number and size 5. Income generated for indigenous forest owners – amount per year	Biodiversity survey of CART well advanced including 7 research publications; employment of local field assistants helping to develop sustainable livelihoods for village communities; student training contributing to building capacity for collecting, handling and interpreting biodiversity information.	Continued training of students and local assistants in biodiversity survey, biodiversity publications; finalizing protection areas with landowners, students obtaining postgraduate degrees .
Output 1. Focal plant and animal taxa (plants, ants, moths, butterflies, amphibians and birds) surveyed along CART as base-line information for climate change impact monitoring, and results published	1. Specimen distribution records along CART collected and databased: on average 1,000 records per focal taxon; 6,000 records in total. 2. Molecular information (COI sequences) obtained for 2,000 insect specimens, building molecular identification database for CART biota 3. 3 papers on CART biodiversity published in international research journals	1. Specimen distribution records along CART analysed including 4,200 insect specimens, 15,000 ecological interactions, published. 2. Molecular information (COI sequences) obtained for 1,650 insect specimens, building molecular identification database for CART biota 3. 5 papers on CART biodiversity published in international research journals	
Activity 1.1 Establish 8 study sites spaced at 500m elevation intervals from 200 to 3700 m asl; design replicated study plots at each site.		8 study sites established along CART; study plots and transects designed and established.	

Activity 1.2 Design and test sampling protocols for the six focal taxa (plants, ants, moths, butterflies, amphibians and birds); execute the sampling		Protocols designed and tested for plants, ants, bats, birds and butterflies; sampling 80% completed, analysis 80% completed.
Activity 1.3 Process the specimens, sort into species, using morphological and DNA evidence, and database the results		Specimens processed with preliminary sorting to species using morphological evidence, databasing the results; DNA analyses of 1,650 insect specimens
Activity 1.4 Analyse the data, write and publish in research journals		5 research papers published
Output 2. Locally recruited field assistants, BRC para-ecologists and researchers trained in biodiversity surveys and biodiversity data interpretation to assist research along CART	1. 16 local assistants recruited from CART communities each receive 10 days training per year (480 person-days of training by end of project) 2. 18 BRC para-ecologists each receive 10 days training per year in biodiversity survey field methods, and the analysis of ecological and molecular data, (540 person-days of training by end of project) 3. 6 BRC para-ecologists each receive 15 days training in UK in biodiversity survey and molecular barcoding methods, (90 person-days of training across 3 years of project) 4. 2 PNG researchers each receive 45 days training in biodiversity survey field methods, and the analysis of ecological and molecular data (90 person-days of training by end of project)	1. 234 community members received training 3 days each (792 person-days), 6 local assistants recruited for extended training in biodiversity methods, 90 person-days total 2. 30 BRC para-ecologists each receive 10 days training per year in biodiversity survey field methods, and the analysis of ecological and molecular data, (300 person-days of training by end of project) 3. 2 BRC para-ecologists each receive 25 days training each in UK in biodiversity survey methods, plus 25 days each in the Czech Republic and Malaysia 4. No activity this year
Activity 2.1 Select suitable candidates for training from local communities and BRC		Local assistants and BRC para-ecologists trained for CART and field work started.
Activity 2.2 Design training programme, then implement training with regular feedback from the trainees in PNG		Training programme implemented, training materials produced.
Activity 2.3 Design training programme, then implement training with regular feedback from the trainees in UK		2 para-ecologists visited UK for intensive training over 4 weeks; also visited collaborators research projects in Czech Republic and Malaysia for 6 weeks total
Activity 2.4 Review results of training using practical tests and questionnaires		Training tests to be implemented in Year 3.
Output 3. PNG Honours and M.Sc. students trained in biodiversity research	1. 2 BSc Honours students trained and graduated by end of project 2. 2 MSc students trained and graduated by end of project	1. 1 BSc Honours student completed study, 1 Hons continues 2. 5 MSc students being trained

Activity 3.1 Select four candidate students, enrol them at University of PNG and select suitable dissertation topics		One BSc Hons student successfully completed studies, one BSc Hons continues to study, 5 MSc students enrolled and continue study.
Activity 3.2 Continuous supervision during the field work and laboratory training, including weekly seminars		Supervision on-going. Mandatory attendance at weekly seminars.
Activity 3.3 Data analysis, dissertation writing, submission and defence		Research continues, students on track to complete their studies..
Activity 3.4 Publication of results in research journals		Planned for Year 3.
Output 4. New forest conservation areas established by local landowners along CART	1. Two conservation areas within the CART established by local forest landowners, 10,000 ha total, spanning 200-2700 m asl 2. Two Conservation Boards established for the Conservation Areas management	1. Two conservation areas within the CART under negotiation with landowners, 2. No Conservation Boards established yet
Activity 4.1 Conduct detailed consultations with communities interested in conservation; identify land ownership in the field		Indigenous landowners interested in conservation, boundaries of conservation areas are being clarified.
Activity 4.2 Form Conservation Boards; set rules for Conservation Areas,		Planned for Year 3
Activity 4.3 Sign Conservation Deeds and declare Conservation Areas		Planned for Year 3
Output 5. Financial situation of indigenous forest owners improved along CART	1. 80 personnel from CART communities each employed part-time for 20 day-equivalents during lifetime of project, assisting research and tourism (1,600 person-days of employment in total) 2. GBP 12,000 of sustainable annual income (GBP 36,000 total during the project) received by CART communities from research and tourism	1. 234 personnel from CART communities each employed part-time, assisting research (1,168 person-days of employment in total) 2. GBP 34,600 of sustainable annual income received by CART communities from research
Activity 5.1 Prepare research and tourist infrastructure (trails, accommodation, research camps)		Research camps equipped by basic accommodation at 8 sites along CART; trails established
Activity 5.2 Develop community management for research and tourist activities, structure of fees, financial management, and visitor rules		Local personnel trained, successfully supported six research projects

Activity 5.3 Advertise new research and tourist opportunities	New web site on-line: www.entu.cas.cz/png/mtwilhelm
Activity 5.4 Host research and tourist visits and assist in their activities	Six external research projects successfully hosted at the CART.

Annex 2 Project's full current logframe as presented in the application form

Project summary	Measurable Indicators	Means of verification	Important Assumptions
Impact: Effective contribution in support of the implementation of the objectives of the Convention on Biological Diversity (CBD), the Convention on Trade in Endangered Species (CITES), and the Convention on the Conservation of Migratory Species (CMS), as well as related targets set by countries rich in biodiversity but constrained in resources.			
Outcome: Biodiversity survey of Complete Altitudinal Rainforest Transect (CART) to: prioritise and establish protected forest; improve sustainability for indigenous landowners; enable climate change monitoring; build national capacity in biodiversity data interpretation.	1. Quantitative biodiversity data on focal taxa from CART – number of samples and specimens 2. Number of field assistants, para-ecologists and researchers trained; number of person-days of training 3. Hons. and MSc completed degrees by PNG nationals 4. Community conservation areas established – number and size 5. Income generated for indigenous forest owners – amount per year	1. Research publications, specimens in biological collections and specimen database records 2. Records of training, tests and personal projects completed to monitor the results of training 3. Hons. and MSc dissertations and resulting publications 4. Signed Community Conservation Deeds 5. Financial reports by Conservation Boards established by local communities	1. Focal area remains accessible by road (for researchers and tourists) 2. Sufficient local expertise and interest can be developed for biodiversity surveys 3. Sufficient supply of students interested in honours and postgraduate training 4. Indigenous communities in the focal project area are interested in declaring forest conservation areas on their land 5. Researchers and biologically oriented tourists can be attracted to project areas, providing income from paid services
Outputs: 1. Focal plant and animal taxa (plants, ants, moths, butterflies, amphibians and birds) surveyed along CART as base-line information for climate change impact monitoring, and results published	1. Specimen distribution records along CART collected and databased: on average 1,000 records per focal taxon; 6,000 records in total. 2. Molecular information (COI sequences) obtained for 2,000 insect specimens, building molecular identification database for CART biota	Specimen database records (at www.entu.cas.cz/png/caterpillars/index_n.php?s=xbrc), specimen DNA sequence records (at http://www.boldsystems.org/), publications.	Biodiversity sampling yields sufficient numbers of specimens and records (if not, change protocols); DNA extraction and sequencing successful (if not, change specimen preservation methods); data analysis sufficiently interesting for research papers (if not, refocus the field research)

	3. 3 papers on CART biodiversity published in international research journals		
2. Locally recruited field assistants, BRC para-ecologists and researchers trained in biodiversity surveys and biodiversity data interpretation to assist research along CART	1. 16 local assistants recruited from CART communities each receive 10 days training per year (480 person-days of training by end of project) 2. 18 BRC para-ecologists each receive 10 days training per year in biodiversity survey field methods, and the analysis of ecological and molecular data, (540 person-days of training by end of project) 3. 6 BRC para-ecologists each receive 15 days training in UK in biodiversity survey and molecular barcoding methods, (90 person-days of training across 3 years of project) 4. 2 PNG researchers each receive 45 days training in biodiversity survey field methods, and the analysis of ecological and molecular data (90 person-days of training by end of project)	Staff records at BRC, staff CVs	Training adjusted to different levels (field assistants, para-ecologists, researchers) so that it is attractive, accessible to the target audience, and sufficiently advanced to be useful (if not, based on the trainees' feedback, modify the content)
3. PNG Honours and M.Sc. students trained in biodiversity research	1. 2 BSc Honours students trained and graduated by end of project 2. 2 MSc students trained and graduated by end of project	Dissertations and graduation records at the University of PNG	Student projects designed so that they are both scientifically novel and feasible, students systematically supervised and problems rapidly rectified based on their feedback.
4. New forest conservation areas established by local landowners along CART	1. Two conservation areas within the CART established by local forest landowners,	Records at the PNG Department of Environment and Conservation	Landowners interested in declaring conservation areas as a way of securing research and tourist benefits (if not, either

	10,000 ha total, spanning 200-2700 m asl 2. Two Conservation Boards established for the Conservation Areas management		work more with the focal communities, or search for more interested communities in the CART area)
5. Financial situation of indigenous forest owners improved along CART	1. 80 personnel from CART communities each employed part-time for 20 day-equivalents during lifetime of project, assisting research and tourism (1,600 person-days of employment in total) 2. GBP 12,000 of sustainable annual income (GBP 36,000 total during the project) received by CART communities from research and tourism	Financial reports of the Conservation Boards	Communities are sufficiently well organized to provide quality research and tourist assistance (if not, based on customers' feedback, work with Conservation Board to rectify), researchers and tourists are aware of opportunities at CART (if not, advertise more).

Activities (each activity is numbered according to the output that it will contribute towards, for example 1.1, 1.2 and 1.3 are contributing to Output 1)

Activity 1.1	Establish 8 study sites spaced at 500m elevation intervals from 200 to 3700 m asl; design replicated study plots at each site.
Activity 1.2	Design and test sampling protocols for the six focal taxa (plants, ants, moths, butterflies, amphibians and birds); execute the sampling
Activity 1.3	Process the specimens, sort into species, using morphological and DNA evidence, and database the results
Activity 1.4	Analyse the data, write and publish in research journals
Activity 2.1	Select suitable candidates for training from local communities and BRC
Activity 2.2	Design training programme, then implement training with regular feedback from the trainees in PNG
Activity 2.3	Design training programme, then implement training with regular feedback from the trainees in UK
Activity 2.4	Review results of training using practical tests and questionnaires
Activity 3.1	Select four candidate students, enrol them at University of PNG and select suitable dissertation topics
Activity 3.2	Continuous supervision during the field work and laboratory training, including weekly seminars
Activity 3.3	Data analysis, dissertation writing, submission and defence
Activity 3.4	Publication of results in research journals
Activity 4.1	Conduct detailed consultations with communities interested in conservation; identify land ownership in the field
Activity 4.2	Form Conservation Boards; set rules for Conservation Areas,
Activity 4.3	Sign Conservation Deeds and declare Conservation Areas
Activity 5.1	Prepare research and tourist infrastructure (trails, accommodation, research camps)
Activity 5.2	Develop community management for research and tourist activities, structure of fees, financial management, and visitor rules

Activity 5.3	Advertise new research and tourist opportunities
Activity 5.4	Host research and tourist visits and assist in their activities

Annex 3 Standard Measures

Table 1 Project Standard Output Measures

* Undergraduates and postgraduates receive continuous training; figures in table allow for study time at university and holidays.

Code No.	Description	Gender of people (if relevant)	Nationality of people (if relevant)	Year 1 Total	Year 2 Total	Year 3 Total	Total to date	Total planned during the project
1A	Number of people to submit thesis for PhD	Male	UK	0	0		0	1
2	Number of people to attain Masters qualification (MSc, MPhil etc.)	Male	PNG	0	0		0	3
3	Number of people to attain other qualifications (BSc Hons)	1 male	PNG	0	1		1	2
4A	No. undergrads receiving training	1 male, 1 female	PNG	2	1		2	2
4B	No. of training weeks received			40*	50		40*	120*
4C	No. postgrads receiving training	5 males	PNG	3	5		5	3
4D	No. of training weeks received			40*	250		40*	120*
5	Other training (field assistants)	28 female, 206 male	PNG	234			234	18
9	No. of habitat / protected area management plans			0			2	2
10	No. of field guides			0	3		3	3
11A	No. of papers published			2	5		7	5
11B	No. of papers submitted			2	2		4	5
12B	No. of computer databases enhanced			0	2		2	5
13B	No. of species reference collections enhanced			1	1		2	3
14A	No. of conferences,			0	1		1	2

	workshops organised							
14B	No. of conferences, workshops attended			1	3		4	3
20	Value (££s) of physical assets handed over to host country (vehicle)			29,500	0		29,500	29,500
22	No. of permanent field plots & sites established			8	0		8	8
23	Value (££s) of other resources raised			67,331	133,900		201,231	164,551

Table 2 Publications

Title	**Type** (e.g. journals, manual, CDs)	**Detail** (authors, year)	**Gender of Lead Author**	**Nationality of Lead Author**	**Publishers** (name, city)	**Available from** (e.g.weblink or publisher if not available online)
Contributions of paraecologists and parataxonomists to research, conservation, and social development	Journal	Schmiedel, et al. (2016) Conservation Biology 30, 506-519	Female	German	Wiley	DOI: 10.1111/cobi.12661
Midpoint attractors and species richness: Modeling the interaction between environmental drivers and geometric constraints.	Journal	Colwell, R. K., Gotelli, N. J., Ashton, L., Beck, J., Brehm, G., Fayle, T. M., Fiedler, K., Forister, M. L., Kessler, M., Kitching, R. L., Klimes, P., Kluge, J., Longino, J. T., Maunsell, S. C., McCain, C. M., Moses, J., Noben, S., Sam, K., Sam, L., Shapiro, A. M., Wang, X. & Novotny, V. 2016. Ecology Letters, 19, 1009-1022	Male	USA		DOI: 10.1111/ele.12640

Spatial patterns of tree species distribution in the primary and secondary plots of a lowland rain forest.	Journal	Fibich, P., Leps, J., Novotny, V., Klimes, P., Tesitel, J., Molem, K., Damas, K. & Weiblen, G.D. 2016. Journal of Vegetation Science, 27, 328-339,	Male	Czech		DOI: 10.1111/jvs.12363
Speciation in a keystone plant genus is driven by elevation: a case study in New Guinean *Ficus*.	Journal	Segar, S. T., Volf, M., Zima, J., Isua, B., Sisol, M., Sam, L., Sam, K., Souto-Vilaros, D. & Novotny, V. 2016. Journal of Evolutionary Biology, early view	Male	UK		doi: 10.1111/jeb.13020
Low host specificity and abundance of frugivorous Lepidoptera in the lowland rain forests of Papua New Guinea.	Journal	Sam, K. Ctvrtecka, R., Miller, S. E., Molem, K., Weiblen, G. D., Gewa, B. & Novotny, V. PLoS ONE 12: e0171843	Female	Czech		
Network re-organisation and breakdown of an ant-plant protection mutualism with elevation	Journal	Plowman, N. S., Hood, A.S.C., Moses, J., Redmond, C., Novotny, V., Klimes, P., Fayle, T. M. Proc. R. Soc. Biol. Sci. B 284: 20162564	Female	UK		

Annex 4 Onwards – supplementary material (optional but encouraged as evidence of project achievement)

Figure 1. BSc Hons Thesis defended by Peter Amick at the University of PNG in 2016

Composition, α- and β-diversity of bat (Chiroptera) communities along an elevational forest gradient in Papua New Guinea

PETER KONGA AMICK

Submitted on the 9th of March, 2016, in partial fulfillment of the requirements for Bachelor of Science Honours Degree (BSc. Hons.)

Biology Department, School of Natural and Physical Sciences
University of Papua New Guinea

9th March 2016

ABSTRACT

I investigated patterns of chiropteran diversity in eight study sites along an elevational gradient between 200m and 3700m in the Bismarck Range in north-eastern New Guinea, Papua New Guinea (PNG), within the ranges of latitude 05°43'S and longitude 145°03'E. I used a variety of field techniques including mist netting, use of ultrasonic (bat) voice detectors, roost site visit, and observation.

I mist-netted for four nights per location. I spent five hours (i.e. from 6pm – 7am) per night capturing and recording bats. The point-count methods was used to record bat calls for two to four nights per location. I recorded bat calls for ±15mins per point at four to eight points per night thus standardizing for 16 point-counts per survey. All points were separated by ±200m apart.

I recorded 47 species of which, 42 species belonging to six bat families (viz. Pteropodidae, Vespertilionidae, Hipposideridae, Molossidae, Emballonuridae, and Rhinolophidae), and 5 species were unrecognized microbat (suborder Microchiroptera) calls.

Mist-netting yielded 701 individual bats belonging to 17 species in three families. I analyzed information from 501 individual bats recorded for five hours (i.e. 6pm – 11pm). The dominant species caught in mist nets were the common blossom bat (*Syconycteris australis*), followed by the green tube-nosed bat (*Paranyctimene raptor*), and the common tube-nosed bat (*Nyctimene albiventer*).

I analyzed 284 bat echolocation calls representing 23 different call types (*sensu* morphotypes) of which 18 were attributed names and five were unidentified. An evening bat call, attributed to *Miniopterus oceanites* (*schreibersii sensu lato*), was recorded at 3700m. This record is both a range extension of this species and a new elevation record set for all bats occurring in New Guinea (as *M. macroneme* is (was) the only bat know to occur at the highest altitude, 3200m asl).

Seven species were recorded from non-standardized methods including cave visits, observations, local hunting methods, and collection of hunt trophies.

Altitudinal trend in species richness showed a declining pattern, that is, species richness (as a proxy of α-diversity) decline as altitude increase. Analysis on the number of species shared (β-diversity) between adjacent study sites along the altitudinal gradient, based on the rate of species turnover (β_t-diversity index), showed no clear relationship ($r = -0.22$, $n = 7$, $P = 0.64$).

Temporal analysis of species richness for the two sampling periods (January-April survey and June-July survey) showed no significant difference ($p<0.05$). This indicated that environmental variable (e.g. fruiting seasons, rainfall, atmospheric temperature, etc.) did not account for much of the temporal patterns in bat diversity along the altitudinal gradient.

I investigated atmospheric temperature, humidity, and dew point as possible factors responsible for the observed spatial diversity pattern (declining richness and abundance) along the altitudinal gradient. All climatic variables tested for accounted for 67.5% of explained variability. Dew point and atmospheric temperature explained 24.38% and 23.97%, respectively, whilst humidity explained for 19.15% of the changes in diversity patterns along the gradient. Other unexplained factors that may contribute to patterns of species diversity along the altitudinal gradient include species-area relationship, habitat characteristics, ecological variables, humans' direct and indirect influence on bats, and sampling efforts and gears used.

Future study on chiropteran community with considerations on climatic, biotic (ecological) and physiological variables may indicate the extent of effects possible factors can have on determining bat diversity patterns along the Mt Wilhelm transect.

Key words: bat, α- and β-diversity, altitudinal gradient, Mt Wilhelm transect, Papua New Guinea

Greater Tube-nosed Bat *Nyctimene aello*

Dorsal view showing thick mid-dorsal stripe

Lesser Bare-backed Bat *Dobsonia minor*

Figure 2. First pages of the Botany Training Manual for paraecologists

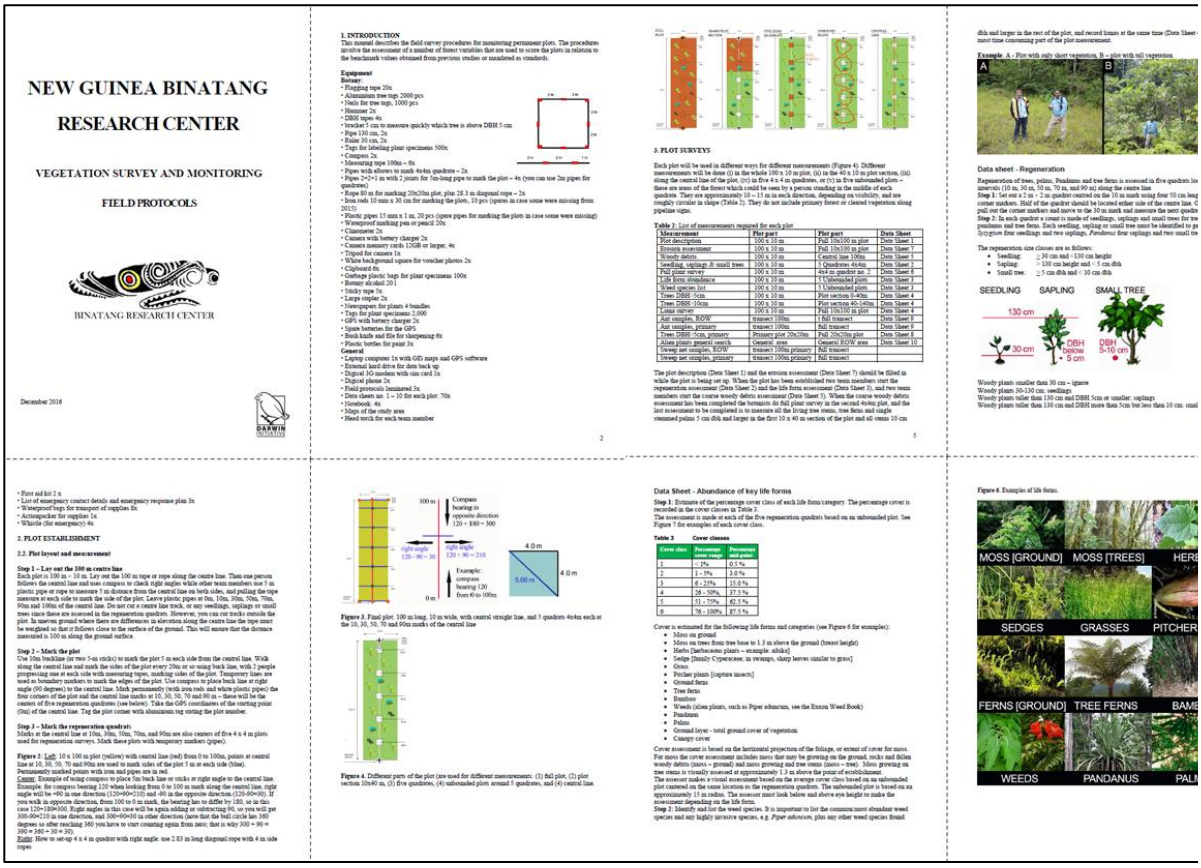


Figure 3. Examples of images from the knowledge tests in entomology (L) and botany (R) for paraecologists and students.