Darwin Initiative: Final 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
Start/end dates of project	1 April 2015 – 31 March 2018
Project Leader name	Dr Alan J A Stewart
Project website/blog/Twitter	www.entu.cas.cz/png/mtwilhelm/
Report author(s) and date	AJA Stewart, V Novotny, MR Peck; 28th June 2018

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 (Fig 1), a globally important biodiversity hotspot.

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

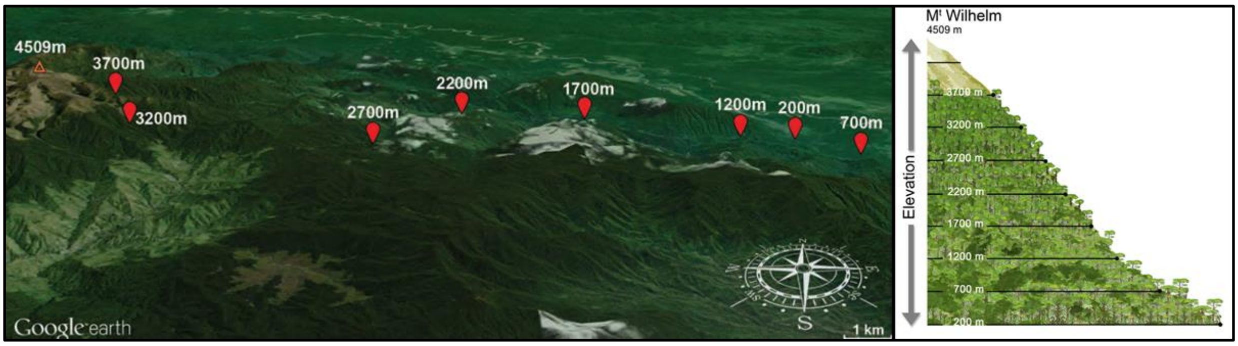


Fig. 2: Map of Complete Altitudinal Rainforest Transect (CART) from 200m to 3700m on Mt Wilhelm comprising eight research sites with elevation increments of 500 m.

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 was 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, was our principal partner in project management, training and research. It is the leading biological research institution in PNG with a staff of 35 researchers, students and highly-skilled research technicians (para-ecologists). Mika Peck (Senior 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. We are continuing collaboration with the Zoology Department at Oxford University (Prof. Owen Lewis and Dr Sofia Gripenberg) who hosted our para-ecologist visitors three times. We have also renewed a long-standing and productive collaboration with the Herbarium staff at the Royal Botanic Garden at Kew (Dr William Baker) during the project. We have also initiated collaboration with the University of Southampton (Dr. Rebecca Morris), leading a study of El Nino impact on livelihoods in our project area in PNG. 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 Danum Valley and the Maliau Basin Research Stations, 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, Malaysia and the Czech Republic, at no additional cost to the project.

In PNG, BRC has been developing an effective network of partner organizations that includes all key local universities, research institutes and NGOs engaged in biodiversity conservation and research. This network includes the Science and Technology Secretariat of PNG Government, which is overseeing research policy in PNG as well as CEPA in charge of conservation areas and policies in PNG. The partners include all six universities with postgraduate research programmes in PNG including three (UPNG, Unitech, UoG) with postgraduate students resident at BRC and trained during this project. The research programme by BRC engaged the three leading institutes in organismic biological research in PNG (FRI, NARI and MRI). Finally, BRC also developed partnership with two conservation-oriented NGOs (TKCP and WCS) (Table 1).

Institution	Collaborative activities	Abbrev.	Org. type
Science and Technology Secretariat of the PNG Government	Input in science policy	STS	PNG government
Conservation and Environment Protection Agency	Conservation areas	CEPA	PNG government
Biology Department, University of PNG	Training under- & postgraduate students	UPNG	University
Forestry Department, PNG University of Technology	Training under- & postgraduate students	Unitech	University
Biology Department, University of Goroka	Training under- & postgraduate students	UoG	University
PNG University of Natural Resources and Environment	Training undergraduate students	UNRE	University
School of Science, Pacific Adventist University	Training undergraduate students	PAU	University
Divine Word University	Public promotion of science	DWU	University
PNG Forestry Research Institute	National herbarium, botanical research	FRI	Research inst.
PNG National Agriculture Research Institute	National insect collection, research	NARI	Research inst.
PNG Medical Research Institute	Health care and medical research	MRI	Research inst.
Wildlife Conservation Society	Conservation activities	WCS	NGO conservation
Tree Kangaroo Conservation Project	Conservation and community outreach	TKCP	NGO conservation

Table 1. PNG partners of the New Guinea Binatang Research Center involved in the DI project

3. Project Achievements

3.1 Outputs

The project has been concluded successfully, with the planned project's activities reached or exceeded, some of them substantially. These include establishing an indigenous conservation area at Mt Wilhelm with exceptional biodiversity value with local landowner communities, and enhancing in-country training for the study and conservation of local biodiversity on all levels, from grassroots community members through para-ecologists and research technicians to under- and postgraduate students and young researchers. Here we report on our Outputs 1-4 set for the project in the logframe.

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*

There are very few complete rainforest altitudinal transects in the tropics, encompassing the entire rainforest variability from the lowlands to the timberline, surveyed for multiple plant and animal taxa. The Complete Altitudinal Research Transect (CART) and Mt. Wilhelm is now one of them, as a result of the present project.

We have, after consultations with the local indigenous communities of rainforest owners, established eight research sites, regularly spaced at 200, 700, 1200, 1700, 2200, 2700, 3200 and 3700 m asl. (Fig. 2). These include basic facilities for field work and in addition to becoming focal points for research also serve to support rainforest conservation and improve the local economy, as they become local foci for employment and training, in support of incoming research. We have delineated and mapped 10 transects 300 x 10 m at each site, as a replicated framework for various biodiversity surveys.

The DI project included 11 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 defence, 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.

Our project developed protocols for surveys of biodiversity (species composition in communities) of several focal taxa, but also focused on ecological interactions between species, including plant-herbivore and predator-prey interactions. These data are essential for the understanding of the mechanisms maintaining the extraordinary species diversity along tropical rainforest gradients (e.g., Mt. Wilhelm is one of the top six most diverse areas for vascular plants in the world), as well as much needed baseline data for monitoring the impact of climate change. This impact may be as important for inter-specific interactions as for the distribution of species.

The DI project contributed to 15 research papers, some of them published in highly prestigious journals:

Chmel, K., Riegert J, Paul, L., Mulau, M. & Novotny, V. 2018. Predation on artificial and natural nests in the lowland forest of Papua New Guinea. *Bird Study* DOI 10.1080/00063657.2017.1420751

Chmel, K., Riegert, J., Paul, L. & Novotny, V. 2016. Vertical stratification of an avian community in New Guinean tropical rainforest. *Population Ecology* **58**, 535-547

Clark, N. J., Clegg, S. M., Sam, K., Goulding, W., Koane, B. & Wells, K. 2018. Climate, host phylogeny and the connectivity of host communities govern regional parasite assembly. *Diversity and Distribution* 24, 13-23.

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. Midpoint attractors and species richness: Modeling the interaction between environmental drivers and geometric constraints. *Ecology Letters* **19**, 1009-1022

Ctvrtecka, R., Sam, K., Miller, S. E., Weiblen, G. D., & Novotny, V. 2016. Fruit sizes and the structure of frugivorous communities in a New Guinea lowland rain forest. *Austral Ecology* **41**, 228-237.

Fibich, P., Leps, J., Novotny, V., Klimes, P., Tesitel, J., Molem, K., Damas, K. & Weiblen, G.D. 2016. Spatial patterns of tree species distribution in the primary and secondary plots of a lowland rain forest. *J. Vegetation Science*, **27**, 328-339

Plowman, N. S., Hood, A.S.C., Moses, J., Redmond, C., Novotny, V., Klimes, P., Fayle, T. M. 2017. Network re-organisation and breakdown of an ant-plant protection mutualism with elevation *Proc. R. Soc. Biol. Sci. B* 284: 20162564.

Sam K, Ctvrtecka R., Miller, S. E., Rosati, M. E., Molem, K., Damas, K., Gewa, B. & Novotny, V. 2017. Low host specificity and abundance of frugivorous Lepidoptera in the lowland rain forests of Papua New Guinea. *PLoS ONE* 12: e0171843

Sam, K., Koane, B., Jeppy, S., Bardos, D. C. & Novotny, V. 2018. Explaining the species richness of birds along a complete rain forest elevational gradient in the tropics: Habitat complexity and food resources matter. *Journal of Biogeography* in press

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

Schmiedel, U., Araya, Y., Bortolotto, I. M., Boeckenhoff, L., Hallwachs, W., Janzen, D., Kolipaka, S. S., Novotny, V., Palm, M., Parfondry, & M., Smanis, A. & Toko, P. 2016. The role of paraecologists and parataxonomists in leading citizen science into the biodiversity-rich world. *Conservation Biology* **30**, 506-519,

Segar, S. T., Volf, M., Zima, J., Isua, B., Sisol, M., Sam, L., Sam, K., Souto-Vilaros, D. & Novotny, V. 2017. Speciation in a keystone plant genus is driven by elevation: a case study in New Guinean *Ficus*. *Journal of Evolutionary Biology* **30,** 512-523

Souto-Vilaros, D., Proffit, M., Buatois, B., Rindos, M., Sisol, M., Kuyaiva, T., Michalek, J., Darwell, C. T., Hossaert-McKey, M., Weiblen, G. D., Novotny, V., Segar, S. T. 2017. Reproductive isolation along an elevational gradient mediated by floral scent and pollinator compatibility in the fig and fig-wasp mutualism. *Journal of Ecology* DOI: 10.1111/1365-2745.12995

Volf M., Segar S.T., Miller, S. E., Isua B., Sisol M., Aubona G., Simek P., Moos M., Salminen, J.-P., Zima J., Rota, J., Weiblen, G. D., Wossa, S. & Novotny V. 2017. Community structure of insect herbivores is driven by defensive traits with contrasting evolutionary dynamics: the role of trait escalation and divergence in Ficus. *Ecology Letters* 21, 83-92.

Vincent, J. B., Turner, B. L., Alok, C., Novotny, V., Weiblen, G. D. & Whitfeld, T. J. S. 2018. Tropical forest dynamics in unstable terrain: a case study from New Guinea. *Journal of Tropical Ecology,* doi: 10.1017/S0266467418000123

Some of the results are illustrated below, but more details on the research projects can be found also on the project site at www.entu.cas.cz/png/mtwilhelm/research.

A) Altitudinal biodiversity trends. Our new and previous biodiversity data sets produced altitudinal biodiversity trends for nine focal taxa: 3 vertebrate, 4 insect and 2 plant (Fig. 3), showing either monotonic decline in species diversity with altitude, or a mid-elevational diversity peak.

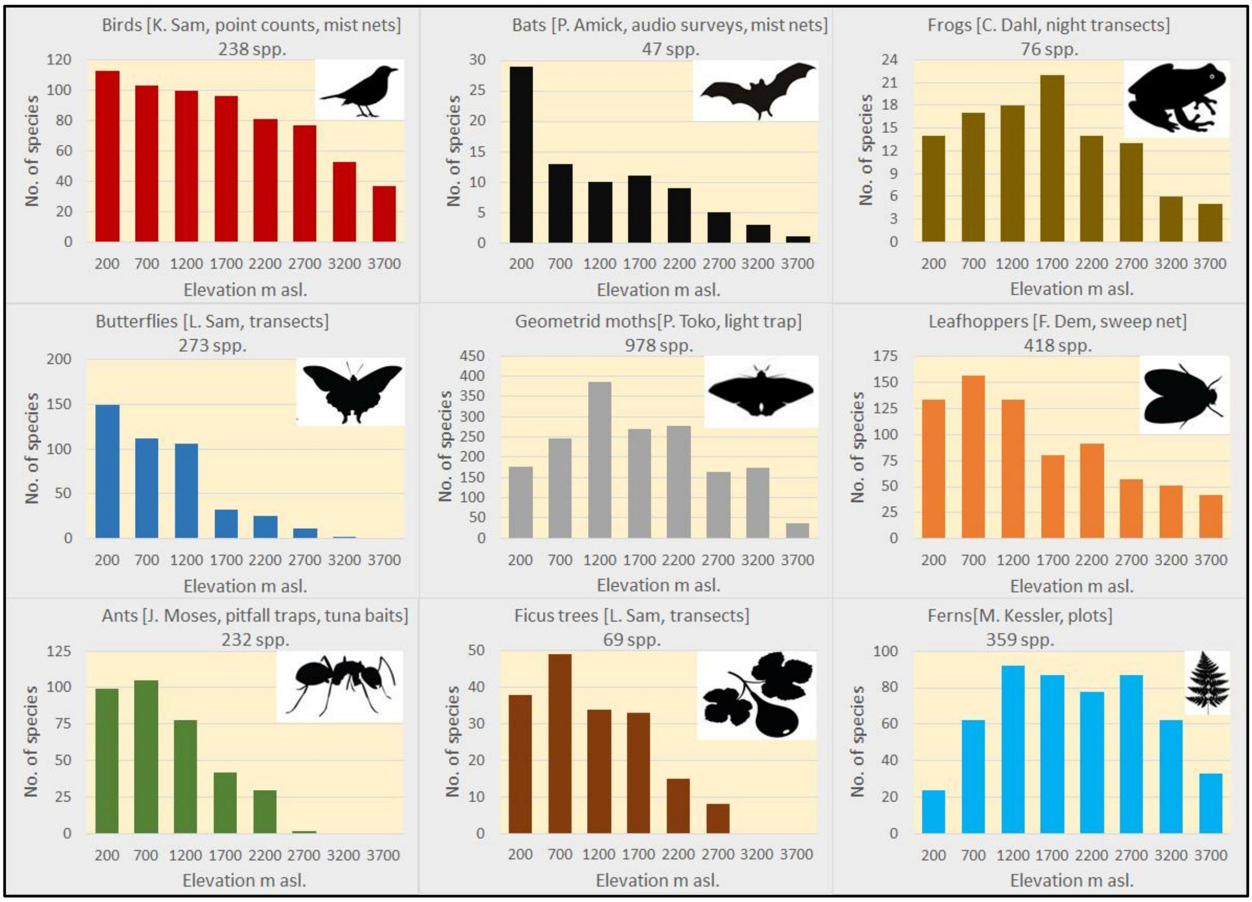


Fig. 3. Species diversity trends for birds, bats, frogs, butterflies, geometrid moths, leafhoppers, ants, fig trees and ferns along the Mt Wilhelm elevation transect (Colwell et al. 2016, Sam et al. 2018, Amick 2016, and unpubl. data)

B) Bird communities and food webs (K. Sam, R. Hazell, B. Koane et al.): Bird communities were surveyed along the Mt Wilhelm transect (200-2,700m.asl) by R. Hazel (a PhD student at UoS, supervised by M. Peck and A. Stewart) in 2015 and 2017, using the same methods as earlier surveys by K. Sam (Fig. 4). This work aims to document and understand the bird communities and their changes that have taken place due to severe droughts related to the El Nino effect in 2015, as well as to document their food specialization on various fruits and insects. Specialist ornithological training was provided during the survey to five new para-ecologists.

Fig. 4. Field survey of bird communities and their food resources along the Mt. Wilhelm elevation gradient, with R. Hazell (left), BRC paraecologists and local assistants.

The Sam et al. (2017) paper analysed stomach content of almost 1,000 birds along CART, and mapped elevational trends in the use of plant and insect food, including a positive correlation between body weight of birds and their prey (Fig. 5). Sam et al (2018) analysed altitudinal trends in bird diversity at CART (Fig. 3) in response to environmental variables.

Fig. 5. The analysis of bird diet was based on the morphology of insect and plant remnants in the stomach content (centre, ants) and revealed several interesting patterns, including a correlation between bird and prey body size (right).

C) Bat communities (P. Amick, K. Sam et al.): Peter Amick surveyed bat diversity along CART as the topic of his DI-supported BSc Honours Thesis at the University of PNG (Fig. 3, Appendix 2). He documented the key importance of lowland rainforests for maintaining overall diversity of bats.

D) Fig trees (*Ficus* spp.) and fig wasps (S. Segar, B. Bau, G. Aubona, D. Souto-Villaros et al.): Collections of figs and fig wasps have been made along the CART (200-2,700m) for population genomic analysis (Fig. 6). This work aims to understand the evolutionary processes that have generated sister species of lowland and highland *Ficus*. Genetic differentiation and speciation along elevational gradients may be an important process generating PNG's incredible diversity of *Ficus* species (it has more species than any other country in the world). 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 analysis of proteases was the focus of BSc Hons dissertation by Gibson Aubona, who successfully graduated at the University of PNG (Appendix 3). 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 (Appendix 3).

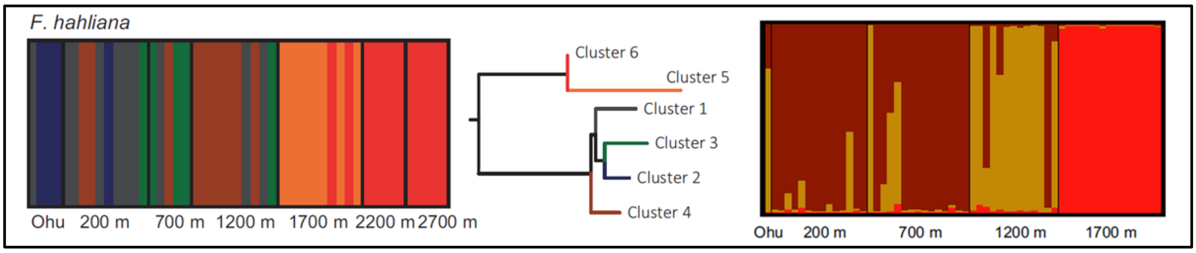


Fig. 6. Clusters resulting from the distribution of alleles in *Ficus hahliana* (L), neighbour-joining trees estimated using Nei's distances coloured according to cluster (C) and the proportion of the sampled genome originating from each population for k = 3 populations (Segar et al. 2017, Souto-Villaros et al. 2017)

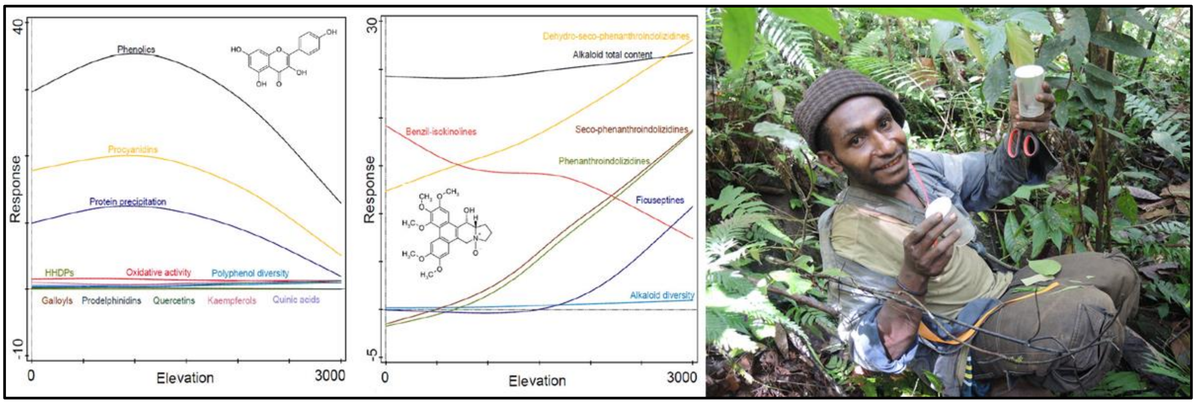


Fig. 7. Elevational trends in secondary metabolites in Ficus trees (L, C) and sampling insect herbivores from these trees (R).

E) 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, including native trees and experimental trees transplanted to elevations 500 m outside the plants' native elevational range. Selected herbivore species have been experimented with on a range of *Ficus* species in order to determine their full host plant ranges. Many of the moth species reared from *Ficus* have been barcoded to help understand species boundaries and study phylogenetic community turnover of *Ficus* feeding moths along the gradient. 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) (Fig. 8).

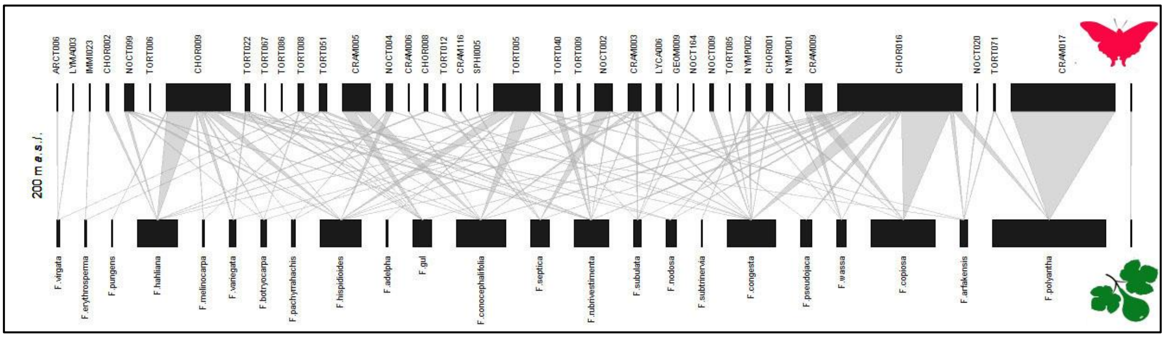


Fig. 8. Quantitative Ficus – caterpillar food web at Kausi, the 200 m asl. study site at Mt. Wilhelm.

F) Ant communities (J. Moses, N. Plowman et al.): The analysis of ant community samples along the CART are the focus of a PhD project by PNG student J. Moses at the University of South Bohemia. Further, N. Plowman led a study of ant interaction networks with ant-plants along CART, documenting simplification of these interaction webs with increasing elevation (Fig. 9, Plowman et al. 2017).

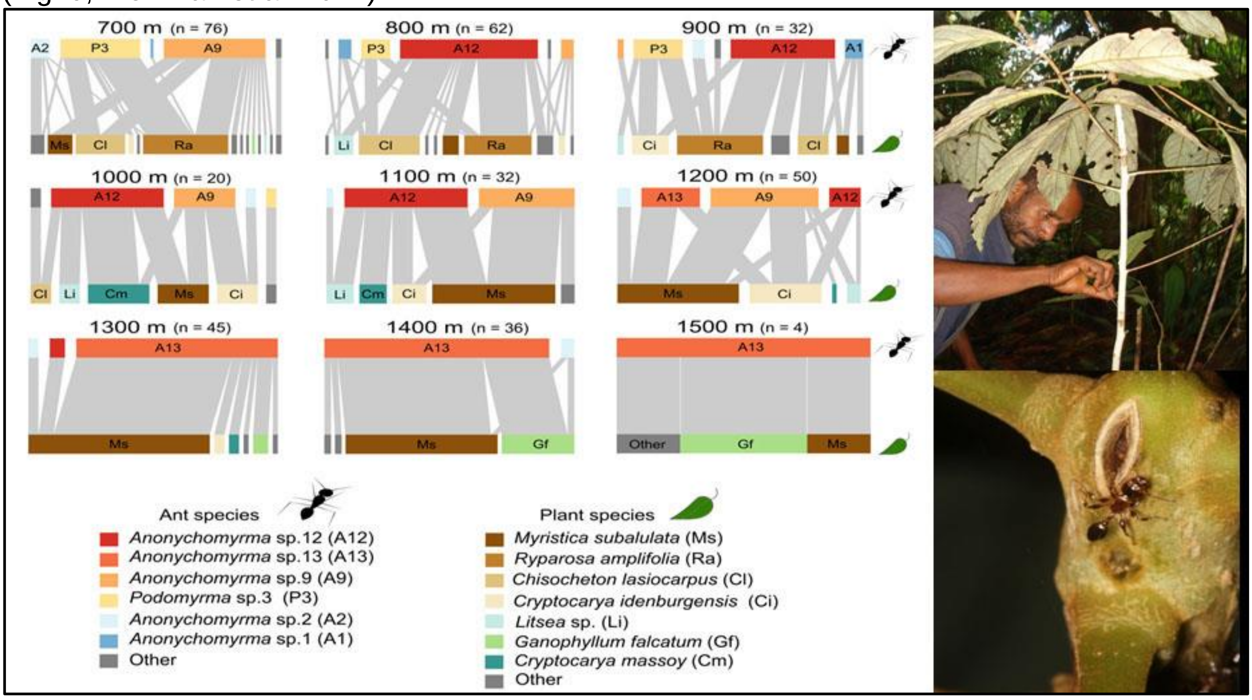


Fig. 9. Trends in the structure of plant – ant mutualist interaction webs documented along the Mt Wilhelm elevation gradient (Plowman et al. 2017).

G) Moths (S. Ibalim, P. Toko et al.): S. Ibalim analysed, as a DI-supported MSc student at the University of PNG, phylogenetic structure of geometrid moth communities sampled previously along the CART by P. Toko (Fig. 3). This included also large-scale DNA sequencing of the specimens. This study expanded the notion of species diversity to phylogenetic diversity of communities along CART and resulted in a MSc Thesis (Fig, 10, Appendix 3).

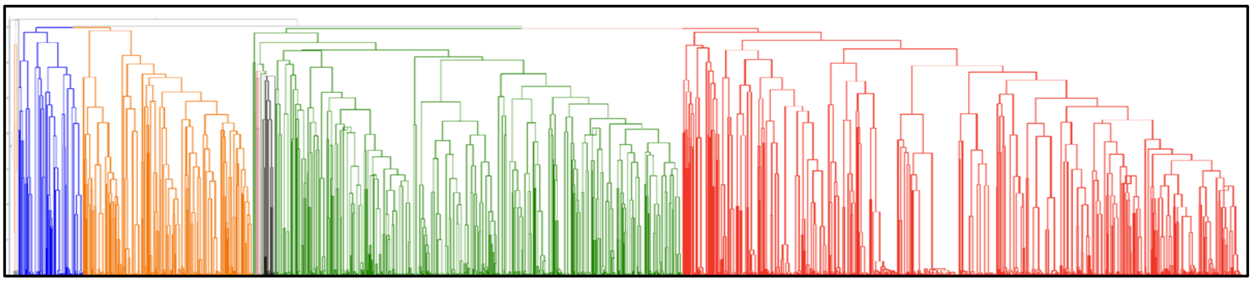


Fig. 10. Reconstruction of phylogenetic relationships between geometrid species (subfamilies shown in different colours) along the altitudinal gradient at Mt. Wilhelm (Ibalim 2018).

In summary, we have established CART at Mt. Wilhelm as one of the best studied rainforest altitudinal gradients in the tropics, documented its exceptional diversity and how it changes with altitude, established base-line data on the distribution of species and ecological interactions to monitor future climate changes, and conducted experiments testing ecological interactions and potential effects of climate change. We have established a strong locally driven research programme that has the potential to attract international research. This is essential for achieving our other objectives: research training and financial sustainability of the Mt Wilhelm conservation areas. The volume of biodiversity species and DNA data collected and the 15 papers resulting from the project greatly exceed our original targets (including three published papers).

Output 2: *Locally recruited field assistants, BRC para-ecologists and researchers trained in biodiversity surveys and biodiversity data interpretation to assist research along CART*
Output 3: *PNG Honours and M.Sc. students trained in biodiversity research*

We describe both outputs together as our training in conservation and biodiversity research has been integrated across a range of levels: (i) grassroots members of indigenous communities at Mt. Wilhelm, preparing them for the role of research assistants and potentially BRC research staff, (ii) BRC para-ecologists and junior biologists in advanced sampling and analytical methods, (iii) undergraduate university students receiving practical research experience, and (iv) postgraduate student training for their Hons, MPhil and MSc degrees. The interaction between these groups of trainees, and their trainers, is reciprocal, as each group can train others in some aspect of biological research. In particular, the knowledge of theoretical concepts of biology and skills at data analysis increase from field assistants to researchers, the knowledge of natural history exhibits a trend in the opposite direction, as local assistants have often a life-long intimate knowledge of the rainforest ecosystem, including hunting and farming activities there. Taxonomic knowledge is often highest in paraecologists who can specialize on particular taxa and build a long-term skills and knowledge base. It is lower in field assistants, without formal taxonomy training, but also in students of all levels as their study is too short for acquiring detailed taxonomic knowledge (Fig. 11).

In Mt Wilhelm communities, our training strategy comprised (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 (Fig. 12). Our basic training was received by 234 trainees in the course of a series of 3-day field courses for all interested applicants from the target communities at the eight study sites (Table 2). 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.

The intense biology training focused on 24 assistants involved in local research projects (incl. 19 assistants on ecological succession project, Fig. 33), receiving 30 days of training per person, except for Thomas Kiava, Samson Yama, Gendio Druma, Lui Napa, and Ambros Gena who received 65 person-days of training each (Table 3). 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. The training for CART field assistants included a one week course in insect identification led by BRC staff B. Gewa (Fig. 13), 20 days of practical training in bird identification by BRC staff B. Koanne, and five 3-day courses of botany work in plant plots. As is usual in research, training combines on-the-job daily training under supervision by senior paraecologists with formal training sessions, lectures and seminars.

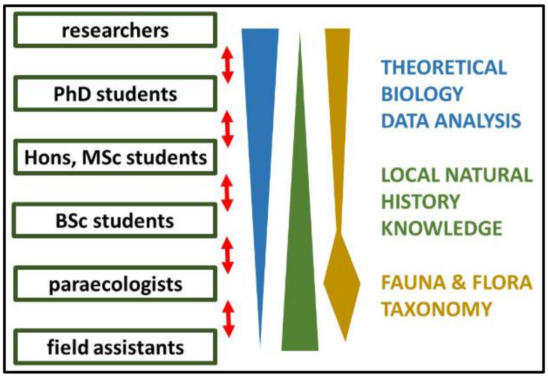


Fig. 11. Trends in skills in theoretical biology, local natural history and taxonomy among staff and students engaged in biological research. Different levels of knowledge means training interactions (red) go both ways, and the most efficient research teams comprise local assistants, paraecologists, students and researchers.

Fig. 12. Field training of para-ecologists and field assistants in insect specimen sorting and preparation, and in insect community sampling methods by beating trays and Malaise, intercept, and Steiner traps.

Fig. 13. In-house training at BRC: biostatistics in R course for BRC staff and students (L), the teacher Jimmy Moses (C), and moth identification course for BRC staff and CART field assistants (R).

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 Bau				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
Awa Munga		X	X						2	M
Barbara Mondu		X	X						2	F
Bats Bau				X					1	M
Bau Kingau				X					1	M
Bau 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
Bundie 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 Piatus		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 Aima	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 Nambadoa						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 Biom	X								1	M
Jacinta Unau	X								1	F
Jacklyn Yama						X			1	F
James Yama						X			1	M
Jeffrey Anthon		X							1	M
Jeffrey Yama						X			1	M
Jerry Kuati	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 Andambo					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
Kogga 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
Nambadoa Thomas					X				1	M
Nick Gene						X			1	M
Nick Kuyawa				X					1	M
Nicky Mondu		X	X						2	M
Nigel Kua						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 Gumiai						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 Diangk							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 Snopi						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 Maina						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
Uwa 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	F
Zachery Sai	X								1	M
Zachery Yako				X					1	M
Total	30	72	53	46	38	40	34	32	345	

Table 2. List of personnel that received basic training as field or camp assistants, guides, and carriers at CART Mt. Wilhelm

Name	Note	Bats	Frogs	Plants	Birds	Insects
Alfred Mani	C	X				X
Austin Sau	C					X
Bradley Gewa	S					X
Buya Morgen	S					X
Cassey Uvalu	C					X
Fidelis Kimbeng	C					X
Gibson Mayiah	C					X
Joachim Yalang	C					X
John Auga	C					X
Joseph Kua	C					X
Martin Mogia	C					X
Raymond Laufa	P					X
Roll Lilip	C					X
Ruma Umari	C					X
Salape Tulai	C					X
Shen Sui	C					X
Steven Sau	C					X
Luda Paul	C				X	
Mark Mulau	C				X	
Michael Kigl	C				X	
Brus Isua	C			X		
Byron Siki	C			X		
Dominic Rinan	P			X		
Graham Kaina	P			X		
Hayden Wagia	C			X		
Jonah Filip	C			X		
Kenneth Molem	C			X		
Kenneth Pomoh	C			X		
Mavis Jimbudo	C			X		
Mentap Sisol	C			X		
Nancy Labun	C			X		
George Dahl	C		X			
Ambros Gena	C			X		X
Bonny Koane	C				X	
Gendio Druma	C			X		X
Loui Napa	C					X
Samson Yama	C				X	
Thomas Kiava	C					X

Table 3. Training of BRC paraecologists (green) and CART field assistants (yellow) in survey techniques for insects, birds, frogs, bats and plants (10 days per person and taxon). Staff in red participated in overseas training.

BRC is one of the leading organizations for para-ecologist training in the tropics, and has been developing the concept since its first DI grant (162/10/030) in 2001-4 that was primarily focused on paraecologist training. The present project contributed to training 32 para-ecologists (Table 3), on average 45 days per person, and resulted also in a collaborative paper describing the para-ecologist approach to a research audience (Schmiedel et al. 2016). In addition to day-to-day training on the job, working on research projects with postgraduate students and researchers (see above), we have conducted several specialized training courses focused on field sampling methods, taxonomy and analytical methods:

(i) ant identification training lead by O. Mottl, a PhD student (Univ. of South Bohemia) resident at BRC,
(ii) bird identification courses by K. Sam, K. Chmel (visiting researchers at BRC) and R. Hazell (a DI-sponsored PhD student resident at BRC),
(iii) sap-sucking insect identification led by F. Dem, a BRC researcher,
(iv) butterfly identification training by BRC staff,
(vi) herbivore and parasitoid rearing by M. Libra, a PhD student (Univ. of South Bohemia) resident at BRC,
(vii) field methods of insect sampling by Y. Basset (visiting researcher at BCR), (Fig. 12)
(viii) plant surveys in botanical plots by T. Whitfeld (visiting researcher at BRC)
(ix) socio- and anthropological research and community surveys by E. Beauchamp (Oxford University) (Fig. 14).

Para-ecologists at BRC received training for their own jobs, while also being exposed to lectures and seminars for students (detailed below), including (i) regular seminars led by resident students at BRC and visiting PhD students, and (ii) weekly journal club discussing interesting research papers led by resident students. Furthermore, the training for BRC researchers, resident Hons 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. M. Libra), (iii) one-week long course in biostatistics in R software, led by J. Moses (formerly a DI-sponsored MSc student at BRC, presently a PhD student at the University of South Bohemia) (Fig. 13). Paraecologists, with their detailed knowledge of certain taxa, also give lectures and training to others (Fig. 14).

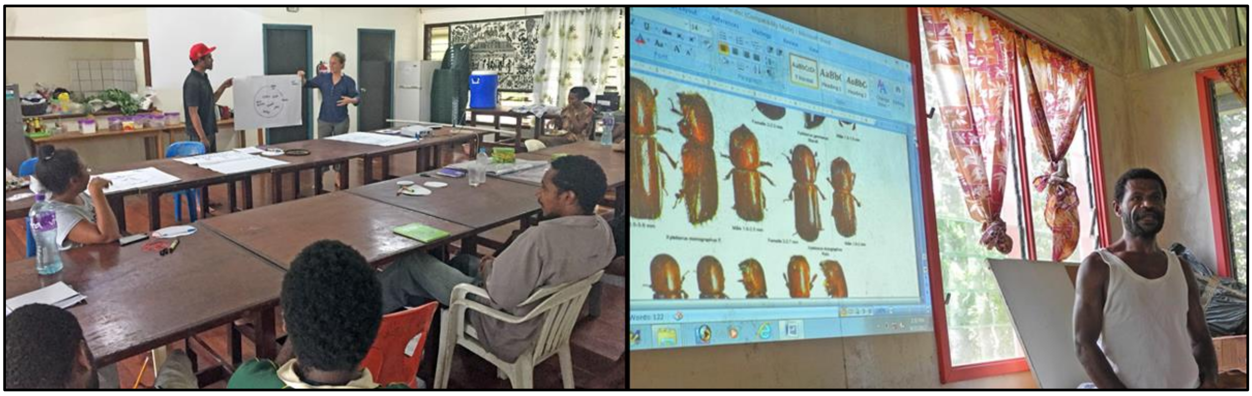


Fig. 14. E. Beauchamp (Oxford U.) leading training for socio-anthropological community research at BRC (L), and paraecologist M. Mogia giving lecture on insect morphology (R).

BRC has also been training biologists from other PNG organizations, and is active in outreach to the general public on environmental issues. Every year, BRC staff took part in an Open Day at the Divine Word University with its own displays visited by >350 visitors, students and general public (Fig. 6). Further, BRC also organized 2 days of training and field demonstration in ecological methods for 38 undergraduate students from the Forestry Department of the PNG University of Technology every year of the project (Fig. 15).

Fig. 15. BRC staff at the Open Day with a science fair for the public (L & C), and demonstration of the Malaise trap insect sampling for the University of Technology students (R).

The local paraecologist training at BRC was combined with overseas training experience for six paraecologists (two every year of the project, Table 3). Their stay in the UK was extended by training in the Czech Republic and Malaysia, at no additional cost to DI. Their training typically included:

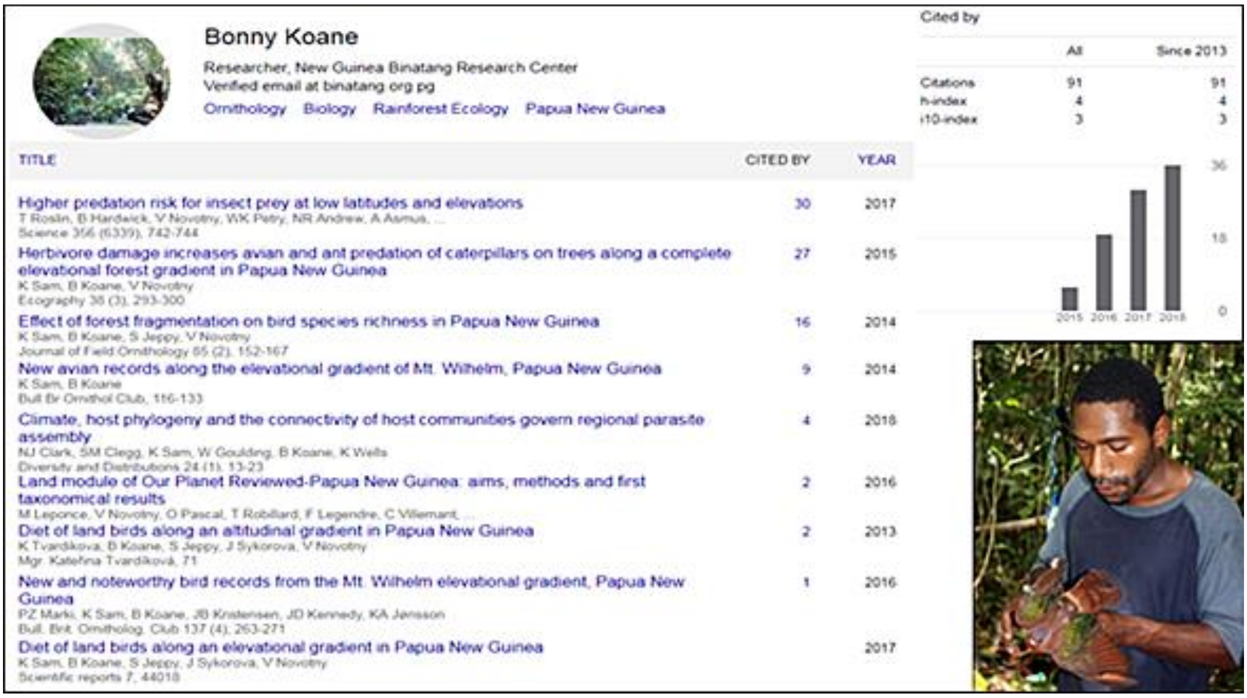
- A one-month stay in the UK, receiving training from: A. Stewart & M. Peck (Univ. Sussex) on forest carbon estimation, data analysis techniques and visiting local temperate habitats; R. Morris & O. Lewis (Zoology Department, Oxford) an introduction to various sampling and experimental techniques; B. Baker (Kew Gardens) visit to the herbarium and the greenhouses; M. Wilson (National Museum of Wales, Cardiff), museum curatorial and insect specimen examination techniques; Stourhead National Trust estate (Basic Canopy Access course; years 1 and 2 only) (Fig. 16).
- Three weeks 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, P. Butterill – galling herbivores, M. Libra – caterpillars and their parasitoids). They visited local study sites, including 25ha CTFS forest dynamics plot in Zofin, saw manipulative botanical and eco-physiological vegetation experiments in grasslands, visited elevation gradients in the Austrian Alps, and were trained in insect taxonomy and botany. 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.
- Two weeks visit to Malaysia (years 2 and 3 only) where T. Fayle (Imperial College London and Czech Academy of Sciences), with Y. Kalsum (Universiti Malaysia Sabah), hosted them for visits to the 50-ha CTFS forest dynamics plot at the Danum Valley field station, primary, logged and secondary dipterocarp forests, and oil palm plantations, as well as altitudinal gradient at Mt. Kinabalu, providing comparison with Mt. Wilhelm (Figs. 17, 18).
- Talks/seminars given on the project research and conservation activities at the Biology Centre of the Czech Academy of Sciences, University of Sussex, and Oxford University.

Fig 16. Training in the UK. S. Tulai and J. Yalang taking tree diameter measurements to assess age structure of Sussex deciduous forest, 2015 (L); G. Kaina and B. Koane visiting Kew Gardens, 2016 (C); N. Lebun and G. Mayia visiting Wytham Woods near Oxford, 2017 (R).

Fig. 17. Training in the Czech Republic (L, C) and in Malaysia (R) in Year 2: training in insect taxonomy, visiting grassland photosynthesis experiments, and climbing Mt. Kinabalu.

Fig. 18. International training in year 3. Danum Valley (Malaysia) botany team working on 50 ha CTFS plot with G. Mayiah N. Labun (L), N. Labun at the Kew Gardens herbarium (C), N. Labun and G. Mayiah with two former DI-sponsered MSc studetns, P. Toko and J. Moses, now both PhD students at the University of S. Bohemia (C), and G. Mayiah exploring a temperate zone CTFS forest dynamics plot Zofin in the Czech Republic (R).

The para-ecologists selected for overseas training are long-term BRC staff who already became experts in a particular field of biodiversity research. For example, Bonny Koane is a secondary school graduate that was recruited from a village community om 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 nine co-authored publications, including one in *Science*, and belongs to a promising young generation of biologists in PNG (Fig. 19).



Bonny Koane
Researcher, New Guinea Binatang Research Center
Verified email at binatang org pg
Ornithology Biology Rainforest Ecology Papua New Guinea

Cited by

	All	Since 2013
Citations	91	91
h-index	4	4
i10-index	3	3

TITLE	CITED BY	YEAR
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Diet of land birds along an altitudinal gradient in Papua New Guinea K Tvardikova, B Koane, S Jeppy, J Sykorova, V Novotny Mgr. Kateřina Tvardíková, 71	2	2013
New and noteworthy bird records from the Mt. Wilhelm elevational gradient, Papua New Guinea PZ Marki, K Sam, B Koane, JB Kristensen, JD Kennedy, KA Jønsson Bull. Brit. Ornitholog. Club 137 (4), 263-271	1	2016
Diet of land birds along an elevational gradient in Papua New Guinea K Sam, B Koane, S Jeppy, J Sykorova, V Novotny Scientific reports 7, 44018		2017

Fig. 19. Para-ecologist Bonny Koane from BRC is one of PNG's leading ornithologists with an increasingly distinguished publication record, as illustrated by his Google Scholar profile.

We have also been very active in securing other non-DI overseas training for our para-ecologists and students (Fig 20):

- Our students Grace Luke and Alfred Kik participated in the Tropical Biology Association (http://www.tropical-biology.org/) field course in Danum Valley, 2 - 30 October 2017. The students worked on their own small research projects:

G. Luke: Comparison of butterfly composition between baits among open and close canopy of the tropical rainforest of Danum Valley, Borneo

A. Kik: Investigating environmental factors affecting number of pollinators in *Etlingera megalocheilos* (Zingerbracea) in Danum Valley, Borneo

- Our student Gibson Sosanika attended training by the Center for Tropical Forest Science (http://www.forestgeo.si.edu/) in data management in botanical research, hosted by the Nanyang University of Technology in Singapore
- Our student Jacob Yombai was awarded a competitive scholarship for 3 months research stay at the University of New Caledonia where he studied the ecology of ant communities in forests.

Fig. 20 Grace Luke and Alfred Kik at the TBA course in Malaysia (A-C), Jacob Yombai in the field in New Caledonia (D) and Gibson Sosanika at a workshop in Singapore (E).

Our student training included seven DI-sponsored students (exceeding the target of four students), together with other seven postgraduate students in residence. Further, four PhD students from PNG, presently studying overseas, were involved in PNG and overseas training of the BRC-based students and staff (Table 4). The postgraduate students at BRC, enrolled at three local universities, represent the largest group of postgraduate students in PNG and constitute the Center for Postgraduate Biology as an organizational unit of BRC (Fig. 21).

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

Table 4. List of postgraduate students resident at BRC for their studies (DI-sponsored students in green, others in grey), and PNG students studying overseas but visiting for field work (in pink). Theses were submitted (Subm.) by six DI students (both BSc Hons and MSc in the case of two students), three already graduated (Grad.), and the rest is awaiting graduation. UPNG – Univ. of PNG, UoG – Univ. of Goroka, Unitech – PNG Univ. of Technology, USB – Univ. of South Bohemia, GU – Griffith Univ. Australia.

Fig. 21. Center for Postgraduate Biology students at BRC (L), and A. Kik, giving presentation on his MSc work at a student conference at BRC in October 2016 (R).

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. The number of students present at BRC was sufficient for a cycle of seminars by visiting researchers (Table 5). 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).

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
Jan Frouz	Univ. of South Bohemia	Czech Rep.	Primary and secondary succession: trends in soil ecosystems	12-Jun-17
Knud Jonsson	University of Copenhagen	Denmark	Monitoring bird dispersal using telemetry	17-Aug-17
Michael Kessler	Zurich University	Switzerland	Patterns of biodiversity along elevational transects: potential and challenges	10-Dec-17
Elizah Nagombi	James Cook University, Cairns	Australia	PNG LNG -- PIDU Research Scholarship -- Lessons Learnt from a JCU Masters	18-Jan-18
Mirjam Hazenbosch	Oxford University	UK	Effects of El Nino on food security in PNG	15-Feb-18
Elina Mäntylä	Biology Centre, Czech Acad. Sci.	Czech Rep.	The attraction of insectivorous birds to herbivore-damaged trees	27-Mar-18

Table 5. Lectures given for staff and students by visiting researchers at BRC.

Name	Title	Date
Billy Bau	New and noteworthy bird records from the Mt. Wilhelm elevational gradient, Papua New Guinea	13-Jan-17
Sentiko Ibalim	Patterns or mechanisms? Bergmann's and Rapoport's rule in moths along an elevational gradient	27-Jan-17
Bulisa Iova	How Many Kinds of Birds Are There and Why Does It Matter?	17-Mar-17
Grace Luke	Sabotaging behavior and minimal latex of Asclepias curassavica incur no cost for larvae of the southern monarch butterfly Danaus erippus	28-Apr-17
Jason Paliau	Determinants of diversity in afrotropical herbivorous insects (Lepidoptera: Geometridae): plant diversity, vegetation structure or abiotic factors?	5-May-17
Markis Pesco	Avian diversity and its association with vegetation structure in different elevational zones of Nainital district (Western Himalayan) of Uttarakhand.	26-May-17
Jacob Yombai	Negative Correlation between Ant and Spider Abundances in the Canopy of a Bornean Tropical Rain Forest.	9-Jun-17
Redley Opasa	Effect of Elevation and Host Availability on Distribution of Sterile and Wild Mediterranean Fruit Flies (Diptera: Tephritidae)	16-Jun-17
Sentiko Ibalim	Convergent structure of multitrophic communities over three continents	23-Jun-17
Grace Luke	Host use and crop impacts of Oribius Marshall species (Coleoptera: Curculionidae) in Eastern Highlands Province, Papua New Guinea	7-Jul-17
Markis Pesco	Bird Species Diversity in Forest Understory: Analysis of Mist-Net Samples	15-Sep-17
Redley Opasa	Elevational gradient of Hemiptera (Heteroptera, Auchenorrhyncha) on a tropical mountain in Papua New Guinea	22-Sep-17
Billy Bau	Reconstructing the phylogeny of figs (Ficus, Moraceae) to reveal the history of the fig pollination mutualism	29-Sep-17
Billy Bau	Phylogeny, biogeography, and ecology of Ficus section Malvanthera (Moraceae)	20-Oct-17
Gibson Sosanika	Detection and mapping the spatial distribution of bracken fern	12-Nov-17
Jason Paliau	Diverging diversity patterns of vascular plants and geometrid moths during forest regeneration on Mt Kilimanjaro, Tanzania	24-Nov-17
Markis Pesco	Disappearance of insectivorous birds from tropical forest fragments	12-Jan-18
Redley Opasa	Assessing the Risk of Invasion by Tephritid Fruit Flies: Intraspecific Divergence Matters	19-Jan-18
Redley Opasa	Quantifying the biodiversity value of tropical primary, secondary, and plantation forests	16-Feb-18
Shen Sui	Surrounding habitats mediate the trade-off between land-sharing and land-sparing agriculture in the tropics	23-Feb-18
Billy Bau	Deep mtDNA divergences indicate cryptic species in a fig-pollinating wasp	23-Mar-18

Table 6. Example of Kokomo seminar programme: titles of the discussed papers and the student leaders of the discussion.

The students also presented their research at the Research Conference on the National Forest Inventory in Lae (PNG) in 2018 (Fig. 22).

Fig. 22. BRC students and staff at the Research Conference on the National Forest Inventory, BRC staff A. Mani presenting, and the title pages of the students' presentations.

BRC students also mentor BRC staff and field assistants working in the same specialization (Table 7). This is a two-way interaction as some of the staff has many years of experience with biological research.

BRC is also offering research stays for undergraduate students of Biology. This opportunity is regularly used by three universities sending students for 5-26 weeks to design and implement a small research project in biology (Table 8).

Student mentor	BRC staff	Field assistant	Specialization
Sentiko Ibalim	Raymond Laufa, Cassey Uvalu		Moth taxonomy & ecology
Billy Bau	Jonah Filip, Nancy Labun	Thomas Kiava	Plant taxonomy & ecology
Grace Luke	Austin Sau, Roll Lilip	Joel Jori	Insect ecology
Gibson Sosanika	Hayden Wagia, Kenneth Pomoh	Mentap Sisol	Plant taxonomy & ecology
Bulisa Iova	Luda Paul, Michael Kigl	Samson Yama	Bird taxonomy & ecology
Redley Opasa	Ruma Umari, Byron Siki	Saki Francis	Fruit fly taxonomy & ecology
Jacob Yombai	Alfred Mani, Joseph Kua	Loui Napa	Ant taxonomy & ecology
Jason Paliau	Buya Morgen, Joachim Yalang		Moth taxonomy & ecology

Table 7. BRC students each mentor 2-3 BRC staff and field assistants in their particular biological fields.

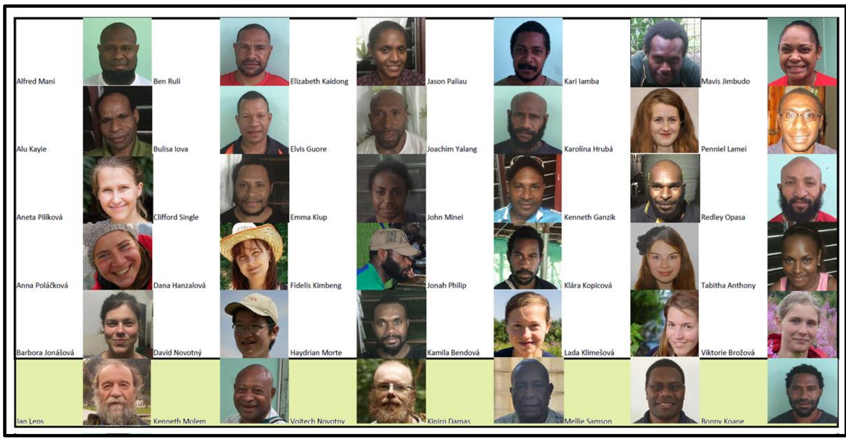
Student	Univ.	Weeks	Project	Year
Cassey Uvau	UNRE	8	Geometrid moth communities along the altitudinal gradient in West New Britain, Papua New Guinea	2016
Venessa Memo	UNRE	8	A comparison of butterfly species diversity in primary and secondary forest in the lowland forests of Papua New Guinea	2016
Ruben Maimo	UOG	26	Effect of forest fragmentation on plant diversity in lowland primary and secondary forest	2016
Joshuan Kawa	UOG	26	Habitat fragmentation and dispersal of butterfly species in Baitabag forest, Papua New Guinea	2016
Dange Barzirig	UOG	26	Biodiversity of geometrid moths in secondary and primary ranforests	2017
Stanis Kaensin	UOG	26	Importance or rolled leaf shelters for arthropod diversity	2017
Ivan Mainu	PAU	5	Vernacular language skills and enthobiological knowledge in young Papua New Guineans	2018

Table 8. BSc Biology students coming to BRC for practical research stay to design and complete their own small research projects. UNRE = Univ. of Natural Resource and Environment, UOG = Univ. of Goroka, PAU = Pacific Adventist Univ.

In August 2017, BRC organized the International Course in Ecology for 20 PNG and 10 European students, taught by overseas and PNG instructors (Fig. 23). The PNG participants (supported by DI), were selected on a competitive basis, and included 5 BRC paraecologists and 4 BRC students, plus 11 participants from nine PNG institutions including universities, research institutes, business companies and governmental agencies (Fig. 23). The course was

26 days long and included field trips, lectures, and practical small research projects (Figs. 24, 25). The course took place at BRC and in the Wanang Conservation Area, supported by our previous DI project. The 30 participants formed 10 research teams, each completing one research project and presenting it at a mini-conference at the end of the course (Fig. 26). The course was evaluated anonymously by the participants on the scale from 1 (excellent) to 5 (very poor) and scored excellent evaluation around 1.5 for most aspects (as did two previous courses in 2013 and 2011), except for the European-PNG collaboration that was scored around 2.5 – an illustration of large cultural differences between the two groups of students but also a useful lesson on such collaboration in the future for the participants (Fig. 25).

In conclusion, the project supported a comprehensive training programme focused on grassroots field assistants and para-ecologists, students of all levels and young researchers in PNG. The training was tied to practical research and also led to the submission of eight postgraduate theses, twice the number originally proposed.



Name	Institution	Position
Ben Ruli	NG Bin. Res. Ctr.	MSc student
Alfred Mani	NG Bin. Res. Ctr.	Paraecologist
Bulisa Iova	NG Bin. Res. Ctr.	Mphil student
Fidelis Kimbeng	NG Bin. Res. Ctr.	Paraecologist
Jason Paliau	NG Bin. Res. Ctr.	Mphil student
Joachim Yalang	NG Bin. Res. Ctr.	Paraecologist
Jonah Philip	NG Bin. Res. Ctr.	Paraecologist
Mavis Jimbudo	NG Bin. Res. Ctr.	Paraecologist
Redley Opasa	NG Bin. Res. Ctr.	MPhil student
Elizabeth Kaidong	Nat. Forestry A.	Researcher
Ken Ganzik	Mosquito-Zone	Technician
Elvis Guore	EH Prov Admin	Administrator
Kari Iamba	U. Technology	Researcher
Alu Kaiye	CEPA	Program Officer
Emma Kiup	James Cook U.	MSc student
John Minei	U. of PNG	Administrator
Haydrian Morte	U. Technology	MSc student
Penniel Lamei	Forestry Res. Inst.	Resercher
Clifford Single	U. Technology	MSc student
Tabitha Anthony	Pacific Adv. U.	BSc student

Fig. 23. International Ecology Course participants (white) and teachers (green) (L), and the list of institutions and positions for the 20 PNG participants (R).

Fig. 24. International Course in Ecology: group photo at the field station in the Wanang Conservation Area, botany identification practicals, demonstration of fruit traps, sorting of insect samples and mist netting of birds.

Day	Activity
1	Arrival to BRC, ecological lecture
2	Travel to Wanang Conservation Area
3	Field trips & lectures: Rainforest ecology plants, insects
4	Field trips & lectures: Rainforest ecology, birds, mammals
5	Field trips & lectures: Rainforest ecology
6	Research project design
7-15	Field work on research projects
16	Visit to Wanang village
17	Travel to BRC
18	Data analysis, field trip mangroves
19	Data analysis, mangroves
20	Data analysis, fiend trip reefs
21-22	Data analysis
23	travel to Bogia
24	Manam Island volcanic primary succession, field trip
25	Mini-conference on project results, farewell party
26	Departure

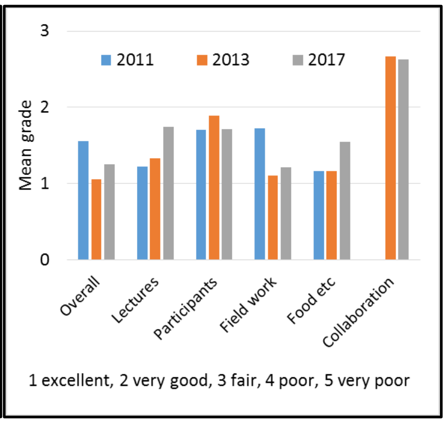


Fig. 25. Programme of the International Course in Ecology (L) and evaluation by the participants of the overall experience, lectures, competency of the participants, field work experience, food & logistics, and collaboration between participants (mean values for 2011, 2013 and 2017 courses, on the scale from 1 = excellent to 5 = poor).

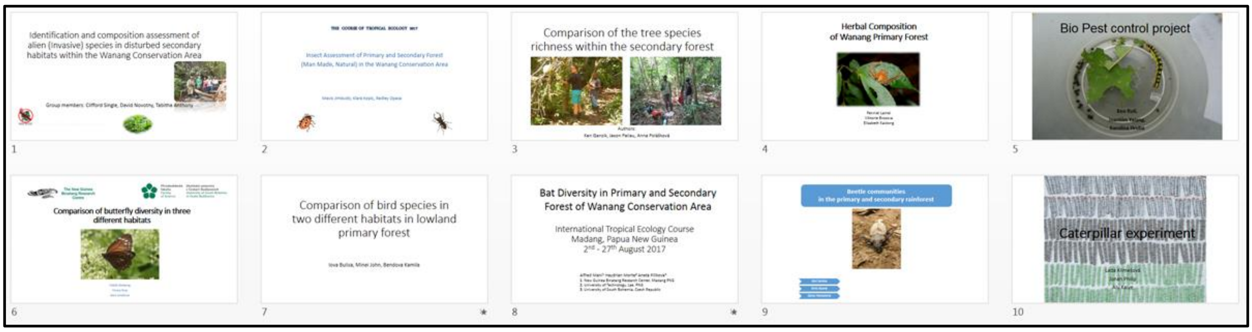


Fig. 26. Title pages for the presentations of all 10 research projects completed during the International Course in Ecology.

Output 4: *New forest conservation areas established by local landowners along CART*
Output 5: *Financial situation of indigenous forest owners improved along CART*

These two outputs are discussed simultaneously because the Conservation Area proposed is also the principal vehicle for livelihood improvement in the indigenous communities along CART.

PNG is exceptional among tropical countries as indigenous customary landowners own 97% of the land and are entitled to make decisions about the conservation, or commercial exploitation, of their forests. Land ownership is guided by local custom and tradition, and the land is typically not registered in any cadastral books. The essential step for conservation is thus to obtain consent from the indigenous landowners, who then are empowered to prevent any activities in conflict with conservation goals from taking place, and themselves monitor land use and conservation boundaries. There are only three larger (10,000 ha or more) conservation areas in PNG at present (Wanang (subject of our previous DI project), YUS and Managalas Conservation Areas). The low number of conservation areas in PNG is testament to the difficulties in obtaining consent from a number of clans and tribes, often historically in competition or conflict one with another, over a contiguous land area. The key activity to accomplish Output 4 was thus a series of discussions with individual landowner groups and at later stages larger communities, as well as detailed mapping of the land boundaries for the proposed conservation area by joint teams from BRC and the landowners.

The series of discussions on conservation started at each of the six research sites (200 – 2,700 m asl.; note that the 3,200-3,700 sites are already within the existing Mt Wilhelm National Park), then expanded to neighbouring communities. The community consultations started with local clan leaders and included meetings at BRC premises as well as in their communities (Fig. 27). These consultations took the first two years of the project as they included 39 clans (Table

9). The identity of landowners, land boundaries, current land use and future land use priorities had to be understood for all these 39 clans, as well as land areas under dispute identified. This process would be utterly impossible without strong participation from the BRC staff, including some recruited from the Mt. Wilhelm area, who could understand the political intricacies of land ownership. After successful completion of the discussion, BRC formed joint survey teams with each landowner group and surveyed the proposed boundaries of the Conservation Areas in the field, and marked them (using red paint on trees and other landmarks). This exercise was logistically demanding as the field teams were moving often in impenetrable terrain. The boundary teams spent 3.5 months in the field to complete the task. Each of the five tribal groups established Conservation Boards, comprising leaders of the member clans (3-10 members per Board, 39 in total). The Boards serve as management and enforcement agencies for the Conservation Area.

The final landowner agreement for the Mt. Wilhelm Conservation Area includes undisturbed rainforests from 200 to 3,200 m asl., directly connected to the existing Mt. Wilhelm National Park that protect ecosystems from 3,200 to 4,508 m asl. (Fig. 29). This makes it the third largest conservation area in PNG, and the leading area in terms of biodiversity included. There was interest from other landowners to join, but we limited the size of the area so that conservation, and the biological research coming with it, will represent a sufficient income to improve the livelihoods of the landowners, which is clearly expected from the exercise.

Fig. 27. Discussing the Mt Wilhelm Conservation Area with clan leaders at BRC premises (A) and in village communities (B,C).

Fig. 28. Landowners from Nombri (A), the BRC-landowner field team identifying Conservation Area lands (B) and marking the conservation boundaries in the field (C).

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

There are only two realistic sources of income: research teams coming to CART for ecological research, and tourists coming primarily to the summit of Mt. Wilhelm, but including also a visit to lower elevations with their forests. While the tourism option is feasible in the long term, as Mt Wilhelm is the second most visited tourist destination in PNG, it will require some time and further work to establish the location as a tourist attraction. BRC will continue working with the Conservation Area beyond the scope of this project to develop tourism there. A Silverback Films (Bristol, http://www.silverbackfilms.tv/) documentary featuring birds of paradise for Netflix, that we have secured for 2018, may help in this effort.

The present project focused on developing CART as a destination for international research. Our strategy focused on (i) training local teams of field assistants, porters, cooks, camp managers and other support personnel, (ii) information for village communities on how to manage visiting research teams, (iii) basic infrastructure in the series of eight research sites, and (iv) advertising CART in the international research community.

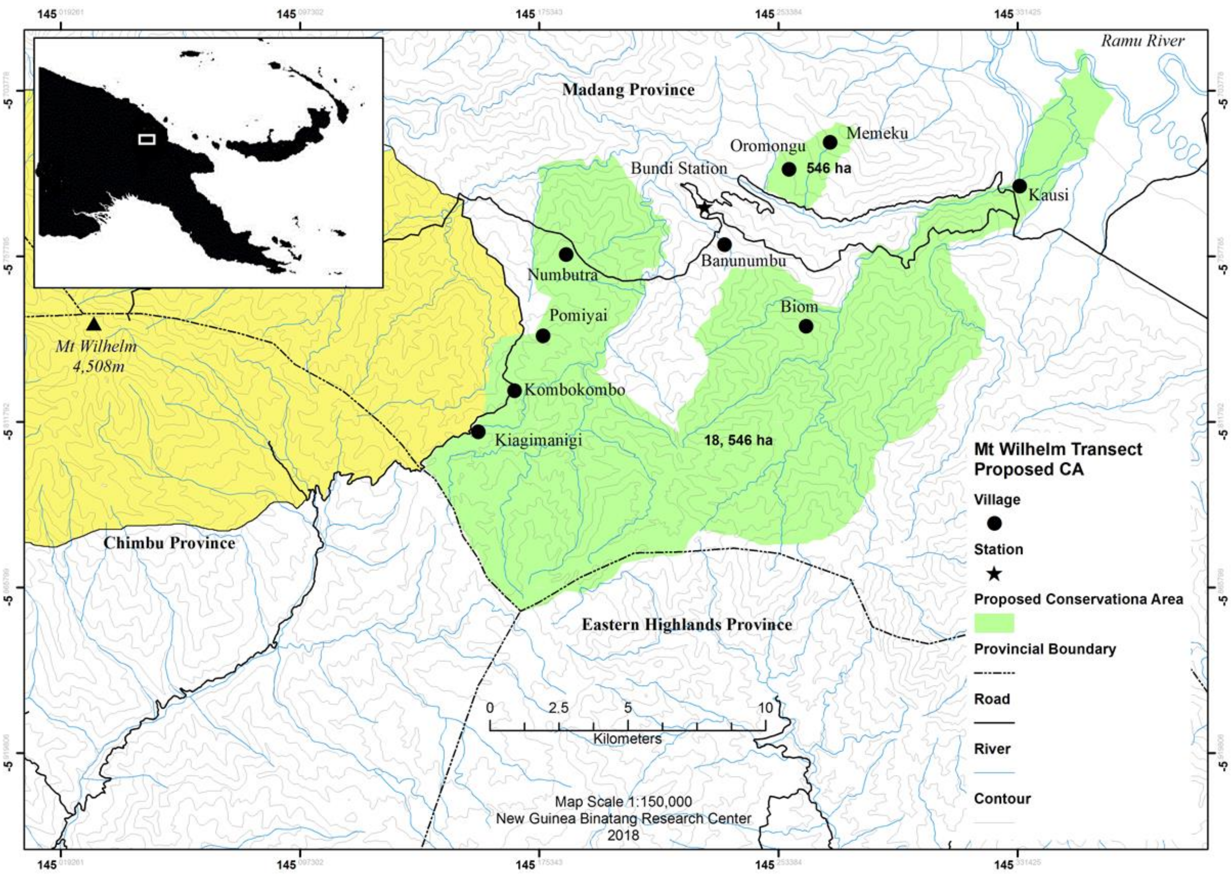


Fig. 29. The proposed 19,092 ha Mt Wilhelm Conservation Area (green), adjacent to the Mt Wilhelm National Park (yellow) and expanding thus the protected ecosystems from 3,200-4,508 m asl to 200-4,508 m asl.

The training efforts are detailed in the previous section. The basic training included 234 personnel. We have also trained 16 camp managers and their deputies, two per camp. Further, 35 field assistants received extensive training, typically for specific research projects. We also have recruited three BRC staff members from the CART area, and one of the MPhil students at BRC is also from there. This provides, in collaboration with BRC, all levels of expertise required to host research projects. We have also established a uniform pay structure for porters, accommodation, land use and field assistance across communities and research sites.

The development of basic infrastructure included rain shelters, pit toilets and basic cooking facilities at each field camp, plus more extensive lab and accommodation space at the main camp Numba between 700 and 1200 m asl., including solar power system and short-wave radio (Fig. 30). We have developed a website (http://www.entu.cas.cz/png/mtwilhelm/) featuring the logistical information as well as biological background data. Mt. Wilhelm CART is one of the few tropical Palaeotropical transects with undisturbed forest spanning from lowlands to the alpine zone. Comparison of publication activity from Mt. Wilhelm with the number of research papers from Mt. Kinabalu (the nearest other complete elevation transect), Mt. Cameroon (the only such transect in Africa) or Mt. Kilimanjaro show great potential for increased research activity and thus also income to indigenous communities along the Mt. Wilhelm transect (Fig. 32D). The promotion of Mt. Wihelm is helped by publishing research papers (www.entu.cas.cz/png/mtwilhelm/publications) and books, as well as organizing symposia at research conferences (Fig. 32).

The Mt Wilhelm transect attracted several external research projects. In particular, it supported six research projects funded from UK, USA and the Czech Republic (Table 10). 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.

We use the ongoing project from the Czech Academy of Sciences as an example of the concept of “income for conservation”. This project examines the impact of herbivores and predators on rainforest secondary succession, conducting experiments on abandoned gardens created by local slash-and-burn agriculture. Nine such experiments, each including six gardens 5x5 m with different experimental treatments (Fig. 33A), have been established at CART. The project employed 40 people for one month to establish the experiments, and continues to employ 14 assistants supervised by two BRC staff (Fig. 33B) for an entire year. It is locally managed (Fig. 33C), and the assistants supervise the gardens and apply experimental treatments, such as insecticide spaying (Fig. 33D). The project is thus bringing steady employment and income to local communities, even when no researchers are present. This ability to sustain long-term operations is a competitive advantage over many other tropical locations with a less well trained workforce.

In summary, we have managed to establish a new Conservation Area comprising 19,000 ha of highly diverse rainforest from 200 to 3,200 m asl with the local indigenous landowners. The size of the conserved area exceeds our target of 10,000 ha. Further, we have established a solid foundation for sustainable income to fund conservation by hosting biodiversity research. The current projects have exceeded the target income of GBP 12,000 per year and the prospects for the future remain good. This income was generated mostly by employment and as such could be shared relatively equitably among the households.

Fig. 30. Field camps at 200 m asl (A) and 700 m asl (B, C) are part of the research infrastructure that brings ecological research to CART, such as catering (D), providing employment and income to local communities, and market for local food produce.

Fig. 31 Local services and points of interest for research teams: food markets (A), porters (B), accommodation (C), rural lifestyle (D) and culture (E).

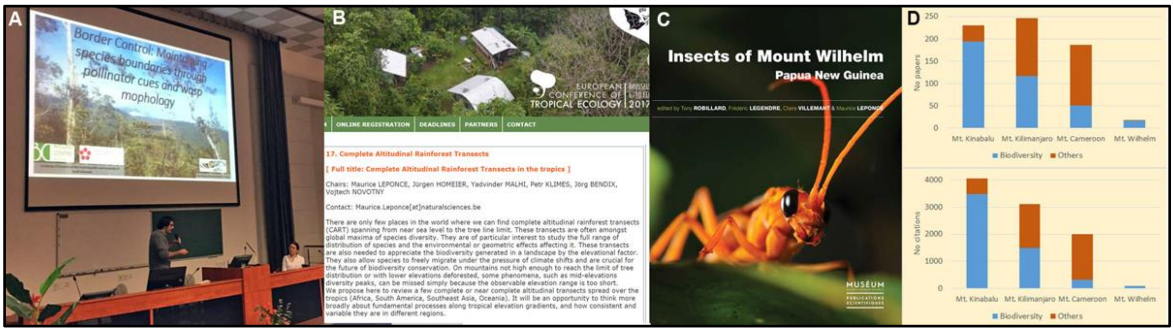


Fig. 32. Promoting Mt. Wilhelm CART: D. Souto presenting on his Mt. Wilhelm research at the Czech Ecology Society Conference (A), an altitudinal symposium organized at the Society for Tropical Ecology conference in Brussels 2016 (B), the Insects of Mount Wilhelm book (C). The Web of Science search results for the number of papers (D, top) and citations (D, bottom) for four long tropical elevation transects: Mt. Kinabalu, Mt. Kilimanjaro, Mt. Cameroon and Mt. Wilhelm in 2000-2017 show serious under-representation of Mt. Wilhelm in biodiversity (blue) and other (brown) research, and thus a potential for further growth.

Fig. 33 Experimental gardens (one of nine blocks) at CART (A), field laboratory with 14 local assistants for the project (B), the local management preparing salaries (C), and an assistant spraying insecticide on one of the experimental gardens (D).

Country	Funding Agency	Home Institution	Research topic	3 yrs DI	1 yr post-DI
CZ	Czech Science Foundation	Czech Academy of Sciences	Ficus - fig wasps phylogeny	6,500	0
CZ	Czech Science Foundation	Czech Academy of Sciences	Plant - herbivore food webs	18,000	6,500
UK	NERC	Oxford University	El Nino impact on agriculture	9,000	2,000
UK	Sussex Sustainability Res. Progr.	Sussex University	Health in rainforest communities	1,500	0
US	Ranforest Alliance	BRC	Rainforest conservation	2,100	2,900
US	Christensen Foundation	BRC	Student biodiversity research	5,200	2,000
UK	Netflix	Silverback Films	Film on birds of paradise	0	3,500
DK	Science Foundation Denmark	Nat. Hist. Mus. Denmark	Bird ecology	1,800	1,200
US	US Aid	Univ. of Technology Sydney	Livelihood improvement	1,000	1,000
Total				45,100	19,100

Table 10. External projects active at the Mt Wilhelm transect, with the funds (in GBP) paid for logistical support to Mt Wilhelm communities during 3-years DI project and confirmed for the post-project 1-year period (Apr 2018 – Apr 2019).

Table 11. The outputs of the project against indicators from the logframe:

	Project's results	Source of evidence
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.	Specimens' records collected for 700 bats, 2,500 birds, 14,500 insects and 1,800 plants along CART. These ecological data are supported by 5,275 specimens. Results = 325% of the target	Database records, BRC and overseas collections, published papers
Indicator 1.2: Molecular information (COI sequences) obtained for 2,000 insect specimens, building molecular identification database for CART biota	COI sequences obtained for 300 ants, 1,350 insect herbivores (including 800 geometrid moths), 250 fig wasps, 150 birds (and their parasites) and 180 amphibians. Results = 111% of the target	Barcode of life database (http://www.boldsystems.org/), publications Clark et al. 2018, Segar et al. 2017, Souto-Villaros et al. 2017, S. Ibalim's MSc Thesis (see also Fig. 10 above)
Indicator 1.3: 3 papers on CART biodiversity published in international research journals	15 papers published Results = 500% of the target	Reprints and on-line versions of the papers
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 from CART received basic training of 3 days each, 19 assistants 30 days each, 5 assistants 65 days each, total 1,597 person-days Results = 399% of the target	Employment and training records
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)	32 BRC para-ecologists each received on average 45 days training each in field survey methods and analysis of ecological data, total 1,440 person-days. Results = 267% of the target	Employment and training records
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)	6 BRC para-ecologists each receiving 20 days training in UK and 15 days in the Czech Republic, 4 para-ecologists also 3 days in Singapore and 4 para-ecologists 14 days in Malaysia, total 272 person-days of overseas training. Results = 302% of the target	Training programme, hosts at the receiving institutions.
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)	One researcher (F. Dem) received 25 days of training and 3 PhD students from PNG (J. Moses, P. Toko, C. Dahl) received 28 days of training each ; total 109 person-days Results = 121% of the target	Employment and training records
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	2 BSc Honours students graduated Results = 100% of the target	Theses, university records
Indicator 3.2: 2 MSc students trained and	5 MSc students completed and submitted their dissertations, awaiting	Theses, university records

graduated by end of project	graduation, 1 student graduated Results = 300% of the target (counting also submitted Theses)	
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	One conservation area (comprising 2 separate areas, 18,546 ha and 546 ha) established. Results = 191% of the target	Landowners' agreements.
Indicator 4.2: Two Conservation Boards established for the Conservation Areas management	Six Conservation Boards, corresponding to individual tribes, established, covering the Conservation Area Results = 100% of the target	Minutes of the Board's meetings.
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 employed for between 5 and 950 days, total 3,110 person-days of employment Results = 194% of the target	Payment records
Indicator 5.2: £12,000 of sustainable annual income (£36,000 total during the project) received by CART communities from research and tourism	£45,100 of income received across 6 CART communities for assistance with biodiversity surveys and research during the project, £19,100 secured for 1-year post-project phase. Results = 125% of the target	BRC financial records.

3.2 Outcome

The project has fully achieved the planned outcome: It has established a new conservation area protecting 19,000 ha of rainforest from 200 to 2,700 m asl, harbouring some of the highest-diversity ecosystems in the world. The conservation project is coupled with concentrated biodiversity research which has established Mt. Wilhelm as one of the most intensively studied altitudinal gradients in the tropics. This research activity, now attracting teams from various countries, has also brought significant income to the indigenous communities, improving their living standards and thus maintaining their commitment to conservation.

Table 12. The outputs of the project against indicators from the logframe:

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.	
	Project's results	Source of evidence
Indicator 1: Quantitative biodiversity data on focal taxa from CART – number of samples and specimens	Specimens' records collected for 19,500 biodiversity data points (specimens recorded) supported by 5,275 preserved specimens and 2,230 DNA sequences, were obtained from CART, establishing one of the best altitudinal information data sets for tropical rainforests, published in 15 research papers	Research publications, specimens in biological collections and specimen database records
Indicator 2: Number of field assistants, para-ecologists and researchers trained;	- 234 personnel from CART received basic training, 24 personnel extensive training for field assistants,	Records of training, tests and personal projects completed to monitor the results of training

number of person-days of training	total 1,597 person-days - 32 BRC para-ecologists received training in field survey methods and analysis of ecological data, total 1,440 person-days. - 6 BRC para-ecologists received 272 person-days of overseas training. - One researcher and 3 PhD students from PNG received total of 109 person-days training	
Indicator 3: Hons. and MSc completed degrees by PNG nationals	2 BSc Hons and 1 MSc students graduated, 5 MSc students completed and submitted their dissertations, awaiting graduation	Hons. and MSc dissertations, university records
Indicator 4: Community conservation areas established – number and size	Mt. Wilhelm Conservation Area established covering 19,092 ha of tropical rainforest from 200 to 2,700 m asl.	Community conservation agreements
Indicator 5: Income generated for indigenous forest owners – amount per year	234 persons from CART communities employed for 3,110 person-days, £45,100 of income received across 6 CART communities, £19,100 secured for 1-year post-project phase.	Financial reports by at BRC

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

The project has achieved significant impact (i) globally for the conservation of tropical biodiversity, (ii) country-wide impact in biodiversity research training in Papua New Guinea, and (iii) locally in improving economic situation of under-privileged indigenous communities. The quantitative details are reported in Sections 3.1 and 3.2 above, but here we evaluate their significance.

The Mt Wilhelm CART transect is within one of the six most diverse areas in the world for plants (Barthlott et al. 2007, Erdkunde 61:305), and harbours for instance 238 bird species (based on our data, Fig. 3), i.e. more than 50% of all species in mainland PNG. There are very few complete rainforest altitudinal gradients, spanning from lowlands to the timberline, in the Palaeotropics. The Mt Wilhelm Conservation Area is thus of global significance. The 19,000 ha protected area is the third largest in PNG and has one of the two highest values of terrestrial biodiversity. Conservation does not happen easily in PNG as is has to be consensually accepted by highly fragmented communities of indigenous landowners, including 39 clans in the present case. The biodiversity thus protected is approximately 70% endemic, i.e. unique to PNG.

Our training of para-ecologists and postgraduate students is significant nation-wide as the team of para-ecologists is one of the top teams for the study of biodiversity in the country and one of the leaders of para-ecologist training in the tropics (e.g. Simons 2011. Science 2:298). The group of postgraduate biology students at BRC is the largest in the country, and the number of BSc Hons and MSc theses resulting from the present project represents approximately half of the nation-wide theses completed in the past 3 years.

The project represented one of the few employment opportunities in the remote communities, approximately half of which do not have road access. The £45,000 income may seem rather modest for ~400 members of local communities over three years, but these communities historically live on less than £1.00 per person per day income. The project thus represents a significant improvement in income, as indirectly reflected by the enthusiasm of the CART communities for the conservation project. Importantly, the project can provide a role model in PNG for other similar projects.

4. Contribution to Darwin Initiative Programme Objectives

4.1 Contribution to Global Goals for Sustainable Development (SDGs)

The project goals were aligned with SGD #15 (Protect terrestrial ecosystems, sustainably manage forests and halt biodiversity loss), and #04 (Ensure inclusive and equitable quality education) by (i) protecting 19,000 ha of high value tropical rainforest with high biodiversity, (ii) providing training and formal education for often under-privileged trainees and students selected on merit, including 24 field assistants, 32 para-ecologists, 2 BSc Hons, 6 MSc and 3 PhD students. The project had also positive effects on goals #08 (Promote economic growth, full and productive employment), #01 (End poverty), and #02 (End hunger and improve nutrition) by bringing £45,000 income to remote, highly disadvantaged and economically poor communities that gained employment opportunities through the project, and thereby improved their quality of life. Finally, the project facilitated local and international collaboration in biodiversity conservation and research, contributing thus to goal #17 (Strengthen the global partnership for sustainable development).

4.2 Project support to the Conventions or Treaties (CBD, CITES, Nagoya Protocol, ITPGRFA)

According to its (latest available) Fourth Report on the CBD (2010), PNG planned to increase protected areas from 4.5% to 10% of the country in 2011-2015 and improve their management. Although not fully achieved, the Conservation and Environment Protection Agency (CEPA) of the PNG Government is working towards these goals and has included Mt. Wilhelm Conservation Area as a part of this strategy.

PNG is also facing problems with the management and sustainable funding of the existing protected areas, and Mt. Wilhelm CA could become a role model for other conservation areas in securing finances and community benefits, as one of the few conservation areas thriving in direct competition with logging options that are also available to the local communities.

The project is 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). In particular, Mt. Wilhelm CA has become one of the leading research sites in PNG for biodiversity studies

The Nagoya protocol strives for fair and equitable access to genetic resources and appropriate transfer of relevant technologies. Our project played an important role in biodiversity research and documentation of the country's biodiversity, as well as the training of biodiversity professionals on all levels, from local communities to PhD level researchers. This research and training includes the study and management of genetic information for the country's species. BRC is a member of the Barcode of Life project cataloguing biodiversity using DNA barcoding and keeping data public, with significant contribution of DNA information from the present project. Such locally based research and training directly contributes to active roles by PNG citizens in managing their biodiversity resources, including genetic information.

4.3 Project support to poverty alleviation

The project brought new income of £41,000 to ~400 members of highly disadvantaged, remote indigenous communities living with scarce employment opportunities.

The financial benefits were brought as salaries for assistance to research work and were thus distributed on merit, work performance and interest in work. However, the distribution of income was highly egalitarian and some types of work, such as porters and field guides, were made available to a large part of the population. We employed ~50 personnel on a longer-term basis (at least 6 months), and approximately 150 personnel for casual work distributed widely among different segments of the community.

The benefits were in the form of salaries, i.e. freely usable by the recipients. The income appeared to improve living standards including nutrition and household equipment, but we have not investigated the precise ways in which the income was spent.

4.4 Gender equality

BRC, the in-country partner, 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 postgraduate students recruited is female; so is the Deputy Director of BRC. However, BRC staff remains dominated by males, as a reflection of the wider situation in PNG society.

In particular, there is a strong legacy of a male-dominated society at the village level so that it is socially and politically virtually impossible to promote women to roles of responsibility, as these would not be accepted by village communities. BRC does encourage women from the village communities to apply for work and provides 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.

It is therefore fair to say that our project has made only a limited positive contribution to gender equality in PNG.

4.5 Programme indicators

- **Did the project lead to greater representation of local poor people in management structures of biodiversity?**

Yes. The Mt. Wilhelm Conservation Area is under control of indigenous landowners. Some of under-privileged community members received an opportunity to train for para-ecologists, which opens career opportunities for biodiversity research and management, as well as for further studies (up to PhD level).

- **Were any management plans for biodiversity developed?**

Yes. The six Conservation Boards allocated land to zones (conservation, swidden agriculture, settlements) and set the conservation rules for the 19,000 ha Conservation Area.

- **Were these formally accepted?**

These rules are of self-governing indigenous landowners. They were agreed upon by the communities in question.

- **Were they participatory in nature or were they ‘top-down’? How well represented are the local poor including women, in any proposed management structures?**

The decisions on conservation were entirely local. The rules were discussed with discussion guided by BRC staff, with examples of rules from other Conservation Areas, but the decisions were always subject to local approval. The decisions were driven by traditional power structure in tribal societies, i.e. they were most influenced by senior male leaders with limited input from women. This situation was impossible to remedy (see above).

- **Were there any positive gains in household (HH) income as a result of this project?**

Yes, approximately £45,000 in communities of 400 people. Although precise economic assessment is not available, we estimated (based on interviews) that the project increased the overall mean household income by 15-20% across the entire community. Note that this is increase in cash income, not overall consumption (a significant portion of food is home grown).

- **How many HHs saw an increase in their HH income?**

The highly egalitarian nature of indigenous communities combined with our care to hire members of different households means the entire community of 400 members benefited to some extent.

- **How much did their HH income increase (e.g. x% above baseline, x% above national average)? How was this measured?**

Our estimate (based on interviews of household members) is a mean income of £200 per person per year. The project-generated income of £45,100 (total for 3 years) thus increased the mean income by 15-20%. The target communities are definitely well below the national average for PNG, but we were not able to find any published household income values.

4.6 Transfer of knowledge

Transfer of knowledge was one of the principal goals of the project. It included international transfer of expertise, with researchers and PhD students coming to PNG to train local biodiversity conservationists, researchers and students, as well as PNG para-ecologists being trained overseas. Local transfer of knowledge among PNG researchers, students, para-ecologists and field assistants was equally important (Fig. 11). The beneficiaries of the training were from PNG, including 24 field assistants, 32 para-ecologists, 13 BSc Hons, MPhil and MSc students, 3 PhD students, and 20 young professionals working in biological fields. This included 6 MSc and 2 BSc Hons degrees obtained as a result of the project. The skills obtained were further shared with partner governmental departments, local universities, research institutes and NGOs (listed in Table 1).

4.7 Capacity building

BRC para-ecologists and researchers have seen their status rise in PNG research community in response to their research activities and publications. In particular, members of the DI project from BRC were invited to join the National Forest Inventory as principal partners responsible for zoological surveys, were engaged in community conservation and livelihood programmes by the PNG office of UNDP, requested to consult on environmental issues by industry (Exxon Mobil LNG PNG project), and also presented research results at domestic and international conferences (Association for Tropical Biology and Conservation Conference 2018). The students were successful in applying for competitive overseas studentships for workshops and conferences (Fig. 20).

5 Sustainability and Legacy

In PNG, indigenous landowners have a legal right to decide on the use of their lands, including forest conservation, logging or conversion to agriculture. The 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). The future of the conservation area thus depends on the ability of BRC 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 was 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. 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 now will be supported by sustained research traffic in the area, managed by BRC and funded by visiting researchers. A successful Mt Wilhelm project will have an important impact on the governmental conservation policy by CEPA as a successful example of sustainable funding for conservation.

There is an excellent prospect for our DI training efforts to have positive impact on careers beyond the duration of the project, based on the past record of BRC. BRC students have been awarded 12 Hons and seven MSc degrees prior to the present project, and all their recipients continue in biological research or further studies. It is therefore highly likely that the trainees and graduates from the present project will be able to benefit from their DI training and develop their careers in biodiversity research and conservation. Two MSc students have already received offers for PhD studies overseas. All DI-trained para-ecologists remain on BRC staff after the end of the project except for two who left for further university studies (in Australia and New Zealand).

The project helped to raise the profile of postgraduate training in PNG which remains under-funded. The lack of postgraduate students represent one of the key obstacles for developing biodiversity expertise and research in PNG. Examples of successful BSc Hons and MSc training will be used in attempts to change the educational policy in favour of postgraduate training for research.

The biodiversity data and analyses have been published, or are going to be, and widely shared in the biological community locally and internationally, ensuring their continued impact.

6 Lessons learned

The project has developed well and more or less according to our expectations, based on the experience from four previous DI projects in PNG and over 20 years of local experience by BRC, the local partner of the project.

We expected a generally positive response from the indigenous landowners to establish a conservation area, but also complicated negotiations. However, we had underestimated the complexity of negotiations required which took almost two years of the project, followed by very demanding field expeditions to establish the boundaries in the field. We have accomplished the task, but more slowly and with greater difficulties than originally expected.

One area we found difficult to deal with was gender equality, as it conflicted with some deeply ingrained customs of traditional communities. However, reserving a portion of training positions for female candidates would probably be a feasible path towards more equal gender representation in future projects.

6.1 Monitoring and evaluation

We have not made any major changes to the original project goals or design.

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 para-ecologists and students (Table 13). The students are evaluated by their peers, the Student Team leader, their Supervisor and also the Postgraduate Committee at the university. The para-ecologists 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 tests. 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 encouraged 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. The results of our monitoring is shown in Fig. 34 (note that the tests are intentionally made difficult so achieving full scores is not expected; this is a way to separate excellent performers from the rest). We also care about the general work satisfaction of students and staff and monitor it annually by anonymous feedback, such as for the International Course in Ecology (Fig 25).

Student evaluation					Paraecologist & trainees evaluation				
Activity	Evaluated parameters	Periodicity	Evaluator(s)	Evaluation	Activity	Evaluated parameters	Periodicity	Evaluator(s)	Evaluation
Kokomo seminar	Attendance & activity	Weekly	Student Team Leader	oral	Research	Performance, work attendance	Weekly	Team Leader	oral
Interim evaluation	Research progress	Quarterly	Thesis Supervisor	oral	Annual evaluation	Performance, training progress	Annually	BRC management	written
Progress report	Research progress	Annually	Postgraduate Committee	written	Annual evaluation	Performance, team work	Annually	BRC staff	written
Essay	Grasp of research topic, writing skills	Annually	Thesis Supervisor	written	Knowledge & skills test	Progress in training, skills, knowledge	Annually	BRc Director	written
Kokomo seminar	Paper presentation & discussion	Annually	Student group	written	Patrol debriefing	Field work performance	End of field work	Team Leader	oral
Thesis	Research results, publication potential	End of study	Postgraduate Committee	written	Thesis	Research results, publication potential	End of study	Postgraduate Committee	written

Table 13. The monitoring system for BRC-based students, paraecologists and trainees recruited from the local communities.

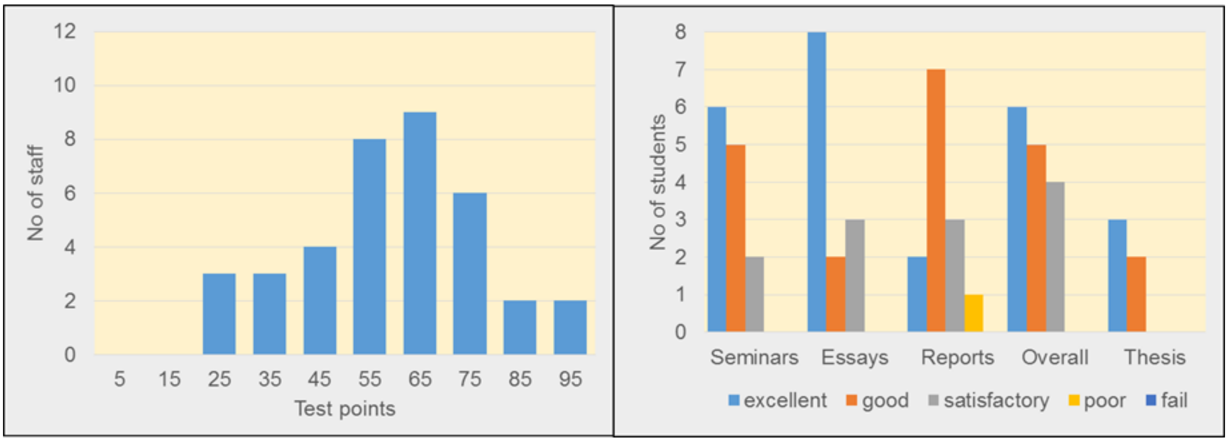


Fig 34. Performance monitoring and evaluation. The test points (from maximum 100) achieved by 30 BRC para-ecologists (L) and the evaluation of the postgraduate students resident at BRC by their supervisors, grading their seminar presentations, essays and progress reports (R)

7 **Darwin Identity**

The contribution of the Darwin Initiative is acknowledged on publications and 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. Our review paper on the role of para-ecologists in scientific research (Schmiedel et al., 2016) compares four parabiologist schemes around the world, including BRC, and refers to the Darwin Initiative as one of the principal funders of projects at BRC.

The Darwin Initiative contribution is acknowledged 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).

The Darwin Initiative is well known among biologists and conservationists in PNG. Interestingly, NGOs appear to be much more willing and successful partners of UK institutions than local universities and research institutes. This probably reflects a greater flexibility and openness amongst NGOs towards overseas collaboration which can be stifled by administrative rules at larger institutions including universities.

8 Finance and administration

8.1 Project Expenditure

Project spend (indicative) since last annual report	2017/18 Grant (£)	2017/18 Total actual 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				

Staff employed (Name and position)	Cost (£)
TOTAL	

Capital items – description	Capital items – cost (£)
TOTAL	

Other items – description	Other items – cost (£)
TOTAL	

8.2 Additional funds or in-kind contributions secured

The cost shares were raised as anticipated in the project proposal. Further, we have secured additional GBP 47,200 for the post-project activities at the Mt. Wilhelm Conservation Area and BRC.

Source of funding for project lifetime	Total (£)
Biology Centre, Czech Academy of Sciences, Czech Rep.	
Grant Agency of the Czech Republic	
New Guinea Binatang Research Center, PNG	
University of Sussex	
Christensen Fund, USA	
TOTAL	

Source of funding for additional work after project lifetime	Total (£)
Biology Centre, Czech Academy of Sciences, Czech Rep.	
Grant Agency of the Czech Republic	
Rainforest Alliance	
NERC UK	
Christensen Fund, USA	
Silverback Films	
USAid	
Natural History Museum Denmark	
New Guinea Binatang Research Center, PNG	
TOTAL	

8.3 Value for Money

The project was able to secure significant cost shares as well as post-project funding, thus leveraging the DI funds. Further, the high percentage of the overall budget spent on PNG personnel and activities also suggests efficiency, as well as the fact that the project exceeded most of the targets, some of them significantly.

It is difficult to compare the costs/results ratio for establishing a conservation area in PNG as there are very few conservation areas in the first place, each situation is unique, and the costs of other projects is often not publicly known. However, overseas-driven development and conservation activities in PNG have often been criticised for high costs spent on expatriate experts' salaries and other costs, to the detriment of the investment in PNG personnel and activities (e.g., West, P., 2016. *Dispossession and the Environment: Rhetoric and Inequality in Papua New Guinea*, Columbia Univ. Press). These concerns do not apply to the present project, unlike those driven by large international conservation organizations for instance. These considerations lead us to believe that our project has been more efficient than the average in the PNG context.

Table 1 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 Project's original (or most recently approved) logframe, including indicators, means of verification and assumptions.

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	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)

	identification database for CART biota 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, 10,000 ha total, spanning 200-2700 m asl 2. Two Conservation Boards established for the Conservation Areas management	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 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 2 Report of progress and achievements against final project logframe for the life of the project

Project summary	Measurable Indicators	Progress and Achievements
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.		The project contributed to CBD Aichi Biodiversity 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) by establishing 19,000 ha of rainforest at Mt. Wilhelm as an indigenous Conservation Area with exceptionally high biodiversity, and turning it into one of the most active altitudinal research transects in the tropics while making nationally important contribution to training of para-ecologists and postgraduate students in Papua New Guinea, country rich in biodiversity but poor 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. Specimens' records collected for 19,500 biodiversity data points (specimens recorded) supported by 5,275 preserved specimens and 2,230 DNA sequences, were obtained from CART, establishing one of the best altitudinal information data sets for tropical rainforests, published in 15 research papers 2. 234 personnel from CART received basic training, 24 personnel extensive training for field assistants , total 1,597 person-days 32 BRC para-ecologists received training in field survey methods and analysis of ecological data, total 1,440 person-days. 6 BRC para-ecologists received 272 person-days of overseas training. One researcher and 3 PhD students from PNG received total of 109 person-days training 3. 2 BSc Hons and 1 MSc students graduated, 5 MSc students completed and submitted their dissertations, awaiting graduation 4. Mt. Wilhelm Conservation Area established covering 19,092 ha of tropical rainforest from 200 to 2,700 m asl. 5. 234 persons from CART communities employed for 3,110 person-days, GBP 45,100 of income received across 6 CART communities, GBP 19,100 secured for 1-year post-project phase.

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. Specimens' records collected for 700 bats, 2,500 birds, 14,500 insects and 1,800 plants along CART. These ecological data are supported by 5,275 specimens. Results = 325% of the target 2. COI sequences obtained for 300 ants, 1,350 insect herbivores (including 800 geometrid moths), 250 fig wasps, 150 birds (and their parasites) and 180 amphibians. Results = 111% of the target 3. 15 papers published. Results = 500% of the target
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.		Completed.
Activity 1.2 Design and test sampling protocols for the six focal taxa (plants, ants, moths, butterflies, amphibians and birds); execute the sampling		Completed.
Activity 1.3 Process the specimens, sort into species, using morphological and DNA evidence, and database the results.		Completed.
Activity 1.4 Analyse the data, write and publish in research journals		Completed.
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	1. 234 personnel from CART received basic training of 3 days each, 19 assistants 30 days each, 5 assistants 65 days each, total 1,597 person-days. Results = 399% of the target 2. 32 BRC para-ecologists each received on average 45 days training each in field survey methods and analysis of ecological data, total 1,440 person-days. Results = 267% of the target 3. 6 BRC para-ecologists received each receiving 20 days training in UK and 15 days in the Czech Republic, 4 para-ecologists also 3 days in Singapore and 4 para-ecologists 14 days in Malaysia, total 272 person-days of overseas training. Results = 302% of the target

	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)	4. One researcher (F. Dem) received 25 days of training and 3 PhD students from PNG (J. Moses, P. Toko, C. Dahl) received 28 days of training each; total 109 person-days. Results = 121% of the target
Activity 2.1 Select suitable candidates for training from local communities and BRC		Completed.
Activity 2.2 Design training programme, then implement training with regular feedback from the trainees in PNG		Completed.
Activity 2.3 Design training programme, then implement training with regular feedback from the trainees in UK		Completed.
Activity 2.4 Review results of training using practical tests and questionnaires		Completed.
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. 2 BSc Honours students graduated. Results = 100% of the target 2. 5 MSc students completed and submitted their dissertations, awaiting graduation, 1 student graduated. Results = 300% of the target (counting also submitted Theses)
Activity 3.1 Select four candidate students, enrol them at University of PNG and select suitable dissertation topics		Completed.
Activity 3.2 Continuous supervision during the field work and laboratory training, including weekly seminars		Completed.
Activity 3.3 Data analysis, dissertation writing, submission and defence		Completed.
Activity 3.4 Publication of results in research journals		Completed.
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	1. One conservation area (comprising 2 separate areas, 18,546 ha and 546 ha) established. Results = 191% of the target 2. Six Conservation Boards, corresponding to individual tribes, established, covering the Conservation Area. Results = 100% of the target

	management	
Activity 4.1 Conduct detailed consultations with communities interested in conservation; identify land ownership in the field		Completed.
Activity 4.2 Form Conservation Boards; set rules for Conservation Areas,		Completed.
Activity 4.3 Sign Conservation Deeds and declare Conservation Areas		Completed.
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 persons from CART communities employed for between 5 and 950 days, total 3,110 person-days of employment. Results = 194% of the target 2. GBP 45,100 of income received across 6 CART communities for assistance with biodiversity surveys and research during the project, GBP 19,100 secured for 1-year post-project phase. Results = 125% of the target
Activity 5.1 Prepare research and tourist infrastructure (trails, accommodation, research camps)		Completed.
Activity 5.2 Develop community management for research and tourist activities, structure of fees, financial management, and visitor rules		Completed.

Annex 3 Standard Measures

Code	Description	Total	Nationality	Gender	Title or Focus	Language	Comments
Training Measures							
1a	Number of people to submit PhD thesis	1	UK	M	Effects of Elevation on Avian Frugivory in Papua New Guinea	English	
1b	Number of PhD qualifications obtained	0					
2	Number of Masters qualifications obtained	6	PNG	6 M	Biodiversity along altitudinal gradients	English	1 graduated, 5 submitted Theses awaiting graduation
3	Number of other qualifications obtained	2	PNG	M	Biodiversity along altitudinal gradients	English	BSc Hons.
4a	Number of undergraduate students receiving training	7	PNG	2F 5M	Biodiversity along altitudinal gradients	English	BSc Biology
4b	Number of training weeks provided to undergraduate students	125	PNG	34M 91M	Biodiversity along altitudinal gradients	English	
4c	Number of postgraduate students receiving training (not 1-3 above)	14	PNG	2F 12M	Rainforest ecology	English	PhD MSc MPhil

							BScHons
4d	Number of training weeks for postgraduate students	88	PNG	12F 76M	Rainforest ecology	English	
5	Number of people receiving other forms of long-term (>1yr) training not leading to formal qualification (e.g., not categories 1-4 above)	32	PNG	2F 29M	Ecology research	English	para-ecologists
6a	Number of people receiving other forms of short-term education/training (e.g., not categories 1-5 above)	234	PNG	28F 206M	Ecology research	English	field assistants
6b	Number of training weeks not leading to formal qualification	607	PNG	32F 575M	Ecology research	English	paraecologists + field assistants
7	Number of types of training materials produced for use by host country(s) (describe training materials)	0					
Research Measures		**Total**	**Nationality**	**Gender**	**Title**	**Language**	**Comments/ Weblink if available**
9	Number of species/habitat management plans (or action plans) produced for Governments, public authorities or other implementing agencies in the host country	0					
10	Number of formal documents produced to assist work related to species identification, classification and recording.	0					
11a	Number of papers published or accepted for publication in peer reviewed journals	15	Annex 5	Annex 5	Annex 5	English	Annex 5
11b	Number of papers published or accepted for publication elsewhere	0					
12a	Number of computer-based databases established (containing species/generic information) and handed over to host country	1	PNG		Insecta Niugini: Mt Wilhelm insects	English	Managed by BRC

12b	Number of computer-based databases enhanced (containing species/genetic information) and handed over to host country	0					
13a	Number of species reference collections established and handed over to host country(s)	3	PNG		insects, Plants, Amphibians at Mt Wilhelm	English	Managed by BRC
13b	Number of species reference collections enhanced and handed over to host country(s)	3	PNG		Insects: National Agriculture Res. Inst., vertebrates: PNG Nat. Museum, Plants: Forest Res. Inst.	English	

Dissemination Measures		**Total**	**Nationality**	**Gender**	**Theme**	**Language**	**Comments**
14a	Number of conferences/seminars/workshops organised to present/disseminate findings from Darwin project work	1			Complete altitudinal rainforest transects in the tropics	English	Brussels 2017, symposium at the Society for Tropical Ecology conference
14b	Number of conferences/seminars/ workshops attended at which findings from Darwin project work will be presented/ disseminated.	2			Altitudinal trends in insect communities8	English	Society for tropical Ecology Conference

Dissemination Measures		Total	Nationality	Gender	Theme	Language	Comments
							Zurich 2016, Paris 2018

Physical Measures		Total	Comments
20	Estimated value (£s) of physical assets handed over to host country(s)	29,500	Landcruiser 4WD vehicle
21	Number of permanent educational, training, research facilities or organisation established	1	Mt Wilhelm Conservation Area
22	Number of permanent field plots established	8	Permanent research stations along Mt Wilhelm altitudinal transect

Financial Measures		Total	Nationality	Gender	Theme	Language	Comments
23	Value of additional resources raised from other sources (e.g., in addition to Darwin funding) for project work	240,751					See table 8.2

Annex 4 Aichi Targets

	Aichi Target	Tick if applicable to your project
1	People are aware of the values of biodiversity and the steps they can take to conserve and use it sustainably.	X
2	Biodiversity values have been integrated into national and local development and poverty reduction strategies and planning processes and are being incorporated into national accounting, as appropriate, and reporting systems.	
3	Incentives, including subsidies, harmful to biodiversity are eliminated, phased out or reformed in order to minimize or avoid negative impacts, and positive incentives for the conservation and sustainable use of biodiversity are developed and applied, consistent and in harmony with the Convention and other relevant international obligations, taking into account national socio economic conditions.	X
4	Governments, business and stakeholders at all levels have taken steps to achieve or have implemented plans for sustainable production and consumption and have kept the impacts of use of natural resources well within safe ecological limits.	
5	The rate of loss of all natural habitats, including forests, is at least halved and where feasible brought close to zero, and degradation and fragmentation is significantly reduced.	X
6	All fish and invertebrate stocks and aquatic plants are managed and harvested sustainably, legally and applying ecosystem based approaches, so that overfishing is avoided, recovery plans and measures are in place for all depleted species, fisheries have no significant adverse impacts on threatened species and vulnerable ecosystems and the impacts of fisheries on stocks, species and ecosystems are within safe ecological limits.	
7	Areas under agriculture, aquaculture and forestry are managed sustainably, ensuring conservation of biodiversity.	X
8	Pollution, including from excess nutrients, has been brought to levels that are not detrimental to ecosystem function and biodiversity.	
9	Invasive alien species and pathways are identified and prioritized, priority species are controlled or eradicated, and measures are in place to manage pathways to prevent their introduction and establishment.	
10	The multiple anthropogenic pressures on coral reefs, and other vulnerable ecosystems impacted by climate change or ocean acidification are minimized, so as to maintain their integrity and functioning.	
11	At least 17 per cent of terrestrial and inland water, and 10 per cent of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed, ecologically representative and well connected systems of protected areas and other effective area-based conservation measures, and integrated into the wider landscapes and seascapes.	
12	The extinction of known threatened species has been prevented and their conservation status, particularly of those most in decline, has been improved and sustained.	
13	The genetic diversity of cultivated plants and farmed and domesticated animals and of wild relatives, including other socio-economically as well as culturally valuable species, is maintained, and strategies have been developed and implemented for minimizing genetic erosion and safeguarding their genetic diversity.	X
14	Ecosystems that provide essential services, including services related to water, and contribute to health, livelihoods and well-being, are restored and safeguarded, taking into account the needs of women, indigenous and local communities, and the poor and vulnerable.	X

15	Ecosystem resilience and the contribution of biodiversity to carbon stocks has been enhanced, through conservation and restoration, including restoration of at least 15 per cent of degraded ecosystems, thereby contributing to climate change mitigation and adaptation and to combating desertification.	X
16	The Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization is in force and operational, consistent with national legislation.	X
17	Each Party has developed, adopted as a policy instrument, and has commenced implementing an effective, participatory and updated national biodiversity strategy and action plan.	
18	The traditional knowledge, innovations and practices of indigenous and local communities relevant for the conservation and sustainable use of biodiversity, and their customary use of biological resources, are respected, subject to national legislation and relevant international obligations, and fully integrated and reflected in the implementation of the Convention with the full and effective participation of indigenous and local communities, at all relevant levels.	X
19	Knowledge, the science base and technologies relating to biodiversity, its values, functioning, status and trends, and the consequences of its loss, are improved, widely shared and transferred, and applied.	X
20	The mobilization of financial resources for effectively implementing the Strategic Plan for Biodiversity 2011-2020 from all sources, and in accordance with the consolidated and agreed process in the Strategy for Resource Mobilization should increase substantially from the current levels. This target will be subject to changes contingent to resource needs assessments to be developed and reported by Parties.	

Annex 5 Publications

Type (e.g. journals, manual, CDs)	Title	Detail (authors, year)	Nationality of Lead Author	Nationality of Institution of Lead Author	Gender of Lead Author	Publishers (name, city)	Available from (e.g.weblink or publisher if not available online)
Journal	Fruit sizes and the structure of frugivorous communities in a New Guinea lowland rainforest	Ctvrtecka, R., Sam, K., Miller, S. E., Weiblen, G. D., & Novotny, V. 2016. *Austral Ecology* **41**, 228-237	Czech	Czech	Male	Wiley	DOI: 10.1111/aec.12326
Journal	The role of paraecologists and parataxonomists in leading citizen science into the biodiversity-rich world.	Schmiedel, U., Araya, Y., Bortolotto, I. M., Boeckenhoff, L., Hallwachs, W., Janzen, D., Kolipaka, S. S., Novotny, V., Palm, M., Parfondry, & M., Smanis, A. & Toko, P. 2016. *Conservation Biology* **30**, 506-519	German	German	Female	Wiley	DOI: 10.1111/cobi.12661
Journal	Midpoint attractors and species richness: Modeling the interaction between environmental drivers and geometric constraints.	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	USA	USA	Male	Wiley	DOI: 10.1111/ele.12640
Journal	Spatial patterns of tree species distribution in the primary and secondary plots of a lowland rain forest.	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,	Czech	Czech	Male	Wiley	DOI: 10.1111/jvs.12363
Journal	Speciation in a keystone plant genus is driven by elevation: a case study in New Guinean *Ficus*.	Segar, S. T., Volf, M., Zima, J., Isua, B., Sisol, M., Sam, L., Sam, K., Souto-Vilaros, D. & Novotny, V. 2017. *Journal of Evolutionary Biology*, **30**, 512-523	UK	Czech	Male	Wiley	DOI: 10.1111/jeb.13020
Journal	Low host specificity and abundance of frugivorous	Sam K, Ctvrtecka R., Miller, S. E., Rosati, M. E., Molem, K., Damas, K.,	Czech	Czech	Female	PLOS	doi.org/10.1371/journal.pone.

	Lepidoptera in the lowland rain forests of Papua New Guinea.	Gewa, B. & Novotny, V. 2017. *PLoS ONE* 12: e0171843					0171843
Journal	Network re-organisation and breakdown of an ant-plant protection mutualism with elevation	Plowman, N. S., Hood, A.S.C., Moses, J., Redmond, C., Novotny, V., Klimes, P., Fayle, T. M. 2017. *Proceedings of the Royal Society, Biol. Sci. B* 284: 20162564	UK	Czech	Female	Royal Society	DOI: 10.1098/rspb.2016.2564
Journal	Predation on artificial and natural nests in the lowland forest of Papua New Guinea.	Chmel, K., Riegert J, Paul, L., Mulau, M. and Novotny, V. 2018. *Bird Study* in press	Czech	Czech	Male	Taylor & Francis	DOI: 10.1080/00063657.2017.1420751
Journal	Vertical stratification of an avian community in New Guinean tropical rainforest.	Chmel, K., Riegert, J., Paul, L. & Novotny, V. 2016. *Population Ecology* 58, 535-547	Czech	Czech	Male	Springer	DOI: 10.1007/s10144-016-0561-2
Journal	Diet of land birds along an elevational gradient in Papua New Guinea.	Sam, K., Koane, B., Jeppy, S., Sykorova, J. & Novotny, V. 2013. *Scientific Reports* **7**, 44018	Czech	Czech	Female	Nature Publication Group	DOI: 10.1038/srep44018
Journal	Climate, host phylogeny and the connectivity of host communities govern regional parasite assembly.	Clark, N. J., Clegg, S. M., Sam, K., Goulding, W., Koane, B. & Wells, K. 2018. *Diversity and Distribution* 24, 13-23.	USA	USA	Male	Wiley	DOI: 10.1111/ddi.12661
Journal	Community structure of insect herbivores is driven by defensive traits with contrasting evolutionary dynamics: the role of trait escalation and divergence in Ficus.	Volf M., Segar S.T., Miller, S. E., Isua B., Sisol M., Aubona G., Simek P., Moos M., Salminen, J.-P., Zima J., Rota, J., Weiblen, G. D., Wossa, S. & Novotny V. 2017. *Ecology Letters*, 21, 83-92.	Czech	Czech	Male	Wiley	DOI:10.1111/ele.12875
Journal	Tropical forest dynamics in unstable terrain: a case study from New Guinea.	Vincent, J. B., Turner, B. L., Alok, C., Novotny, V., Weiblen, G. D. & Whitfeld, T. J. S. 2018. *Journal of Tropical Ecology,* in press	USA	USA	Male	Cambridge Univ. Press	DOI: 10.1017/S0266467418000123

Journal	Reproductive isolation along an elevational gradient mediated by floral scent and pollinator compatibility in the fig and fig-wasp mutualism.	Souto-Vilaros, D., Proffit, M., Buatois, B., Rindos, M., Sisol, M., Kuyaiva, T., Michalek, J., Darwell, C. T., Hossaert-McKey, M., Weiblen, G. D., Novotny, V., Segar, S. T. 2017. *J. Ecology* in press	Mexico	Czech	Male	Wiley	DOI: 10.1111/1365-2745.12995
Journal	Explaining the species richness of birds along a complete rain forest elevational gradient in the tropics: Habitat complexity and food resources matter.	Sam, K., Koane, B., Jeppy, S., Bardos, D. C. & Novotny, V. 2018. *Journal of Biogeography* in press	Czech	Czech	Female	Wiley	N/A

Annex 6 Darwin Contacts

Ref No	22-002
Project Title	**Complete Altitudinal Rainforest Transect for research and conservation in PNG**
Project Leader Details	
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