Darwin Initiative for the Survival of Species: Molecular tools for promoting biodiversity in rainforest fragments of Borneo

Final Report

Mycalesis kina – an endemic species vulnerable to habitat fragmentation

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Front cover shows *Mycalesis kina*, a species endemic to Borneo, adversely affected by habitat disturbance that opens up the canopy in forest fragments.

Darwin Initiative for the Survival of Species

Final Report

1. Darwin Project Information

Project Reference No.	162/10/025
Project title	Molecular tools for promoting biodiversity in rainforest fragments of Borneo
Country	Sabah
UK Contractor	University of Leeds
Partner Organisation (s)	Universiti Malaysia Sabah; Forest Research Centre Sabah
Darwin Grant Value	£106,814
Start/End date	1st April 2001 for three years
Project website	http://www-users.york.ac.uk/~jkh6/index.htm
Author(s), date	Dr Keith Hamer, Dr Jane Hill, Dr Jeremy Searle. Oct. 2004

2. Project Background/Rationale

Tropical conservationists face three major challenges in identifying priorities for conservation in the face of limited funding resources and the continuing loss of biodiversity: (1) tropical communities contain many problematic species whose taxonomy is only poorly resolved, in some cases because they cannot easily be distinguished using traditional morphological methods. This is especially true of invertebrates, which comprise over 90% of eukaryote biodiversity; (2) limited resources need to be targeted towards those species with the highest conservation value, but most tropical countries lack the molecular genetic skills required to identify those species that have the greatest phylogenetic uniqueness and so contribute most to biodiversity; (3) isolation of populations within forest fragments can limit the dispersal of individuals, so reducing genetic diversity within populations and increasing the likelihood of local extinctions. Effective conservation in fragmented landscapes requires estimates of gene flow patterns within and among habitat fragments, in order to minimize the isolation of populations and consequent loss of biodiversity. Yet the molecular genetic tools for estimating gene flow patterns are almost completely lacking in tropical countries. This is a matter of urgent concern because in the near future, most remaining tropical forest will occur as fragments scattered among agriculture and urban development. Conservationists in temperate regions are well aware of the importance of size and isolation of habitat fragments for species survival, but this has rarely been considered in tropical communities. This is unfortunate given that a high proportion of tropical species are dependent on forest. The State of Sabah (Borneo) is the poorest financially in Malaysia and the vast majority of its income is generated through conversion of rainforest into oil palm plantation and other forms of silviculture. This increasingly leaves patches of rainforest interspersed among oil palm and other plantations. These rainforest patches may contribute significantly to the conservation of rainforest biodiversity and some have been gazetted as Forest Reserves to protect them from further disturbance. However resources for protection are highly limited and the choice of patches to preserve is largely arbitrary, because forest managers lack the means of establishing priorities for patches based on key criteria (species diversity, representation of species of high conservation value and importance within a network of local populations). This lack of vital information also excludes forest managers from making informed recommendations as to the size and placement of forest patches to be preserved in future agricultural developments.

3. Project Summary

The main purpose of the project was, in consultation with Sabahan forestry researchers and managers, to allow the development of strategies that balance conservation of rainforest biodiversity with agricultural development to meet local community requirements. To these ends (see Appendix I, logical framework), the project aimed to attain the following major objectives: (i) to train two Sabahan graduate biologists (Darwin Research Fellows) in molecular techniques for resolving species relationships and quantifying genetic diversity, and in ecological techniques for sampling and monitoring biodiversity in forest patches; (ii) to produce a comprehensive quantitative inventory of butterfly species in different sized forest fragments and a fully-labelled collection of specimens to be housed at Universiti Malaysia Sabah; (iii) to establish study plots in forest fragments for long-term monitoring of butterfly biodiversity; (iv) to evaluate the relationship between forest fragmentation (size and isolation) and the diversity and conservation value of forest-dwelling butterfly species; (v) to use molecular genetic techniques to resolve the taxonomy of problematic butterfly species and to attach conservation values to species on the basis of phylogenetic (evolutionary) distinctiveness; (vi) to estimate gene flow and genetic diversity within and among populations of a selected butterfly species.

These objectives were not modified and all were met within the project period. In addition, our two Darwin Fellows have used the training and data that they obtained during this project to register for PhDs at Universiti Malaysia Sabah (theses to be submitted early 2005): this will greatly increase the lasting legacy of the project beyond that originally envisaged. The project is best described by the following Articles under the Convention on Biological Diversity (Appendix II): Research and Training (Article 12), Identification and Monitoring (Article 7), In-Situ Conservation (Article 8), Public Education and Awareness (Article 13).

4. Scientific, Training, and Technical Assessment

Research

This study took place within 10 forest reserves within Eastern Sabah (see map [page 5] for locations of study sites and Table 1 for site descriptions). These are all sites that have been gazetted and provided with legal protection from commercial exploitation.

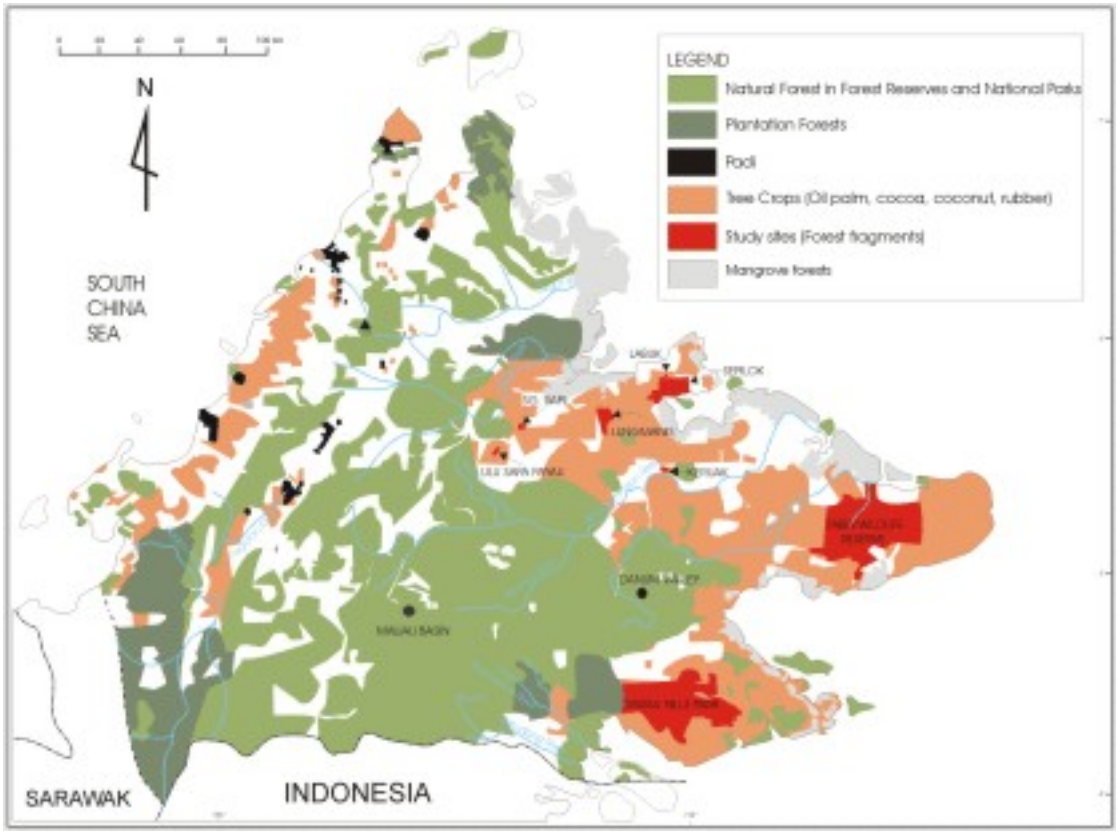
N
LEGEND
Natural Forest in Forest Reserves and National Parks
Plantation Forests
Padi
Tree Crops (Oil palm, cocoa, coconut, rubber)
Study sites (Forest fragments)
Mangrove forests
SOUTH
CHINA
SEA
SARAWAK
INDONESIA

Table 1. Study sites

No	Site Name	Size (ha)	Class	District	Elevation range (a.s.l)	Vegetation
Unfragmented forest						
1	Danum Valley Conservation Area	972,000	I (PFR)	Lahad Datu	120 – 760 m	Lowland mixed dipterocarp forest
2	Maliau Basin Conservation Area	972,000	I (PFR)	Kinabatangan	100 – 500 m	Lowland mixed dipterocarp forest
Large fragments						
3	Tabin Wildlife Sanctuary	122,539	VII (WR)	Kinabatangan	100 – 570 m	Lowland mixed dipterocarp forest; some secondary forest
4	Tawau Hills Park	91,587	I (PFR/NP)	Tawau	370 m	Lowland mixed dipterocap forest
Medium fragments						
5	Sepilok Kabili	4,294	VI (VJR)	Sandakan	0 - 60 m	Lowland mixed dipterocarp forest
6	Lungmanis	6,735	VI (VJR)	Labuk-Sugut	15 – 60 m	Lowland mixed dipterocarp forest; some secondary forest
Small fragments						
7	Labuk Road	120	VI (VJR)	Sandakan	60 m	Lowland mixed dipterocarp forest; some secondary forest
8	Sungai Sapi	625	VI (VJR)	Labuk Sugut	70 – 90 m	Lowland mixed dipterocarp forest; heath forest; some secondary forest
9	Keruak	640	VI (VJR)	Kinabatangan	50 – 100 m	Lowland mixed dipterocarp forest; riverine forest; secondary forest
10	Ulu Sapa Payau	720	VI (VJR)	Labuk Sugut	170 m	Lowland mixed dipterocarp forest; heath forest; secondary forest
Oil Palm Plantation						
11	Borneo Sumadera	-	-	Lahad Datu	100 m	Oil palm

Class: **VJR,** Virgin Jungle Reserve; **PFR,** Protection Forest Reserve; **WR,** Wildlife Reserve; **NP,** National Park

At the beginning of the project in April 2001, we established a total of 200 permanent butterfly sampling plots, positioned at 100m intervals along 2 km of transects at each site (20 sampling plots per site). Fragmentation of rainforest can result in significant changes in vegetation structure and floral composition within remaining patches of forest. To assess this, every plot was divided into four quadrants and within each quadrant we measured the distance, height, diameter at breast height [dbh] and point of inversion (site of the first major branch) of the two nearest large trees (dbh > 60cm) and the two nearest small trees (dbh 10-60cm). We also identified these trees as dipterocarp, non-dipterocarp or *Macaranga* sp. (undisturbed rainforest in Borneo is dominated numerically by trees in the family Dipterocarpaceae but disturbance can lead to higher proportions of non-dipterocarps including a number of invasive species in the genus *Macaranga*). In addition, we estimated the percentage cover of vegetation at ground, low (2-5m), understorey and canopy layers, and we measured canopy openness using a spherical

densiometer. These data were analyzed by principal components analysis, which condensed the above variables into a small number of independent factors measuring different components of variation in vegetation structure and composition at each site. This enumeration and analysis of vegetation structure and composition was an addition to the original agreed project schedule.

Butterflies were sampled over a two-year period (November 2001-August 2003), using three different methods which were designed to sample different groups of species: (1) Fruit-feeding butterflies were sampled using fruit-baited traps, deployed at every plot for two separate periods of 12 days (4800 trap-days in total). (2) Carrion-feeding butterflies were sampled using traps baited with rotting fish and prawn paste, deployed at 5 plots per site for two separate periods of 12 days (an additional 1200 trap-days in total). (3) Family Lycaenidae (blues) were sampled by hand-netting along transects, for a total of 20 person-hours per site (200 person-hours in total). In addition we sampled noctuid moths (Family Noctuidae) in traps baited with fruit and carrion. We also sampled butterflies in oil palm plantation (site 11 in Table 1), using all three sampling methods above, to provide information on the ability of species to disperse between forest fragments embedded in a matrix of plantations. Sampling of carrion-feeders, Lyceanids, moths and species in oil palm were all additions to the original project schedule. Their inclusion not only provided additional valuable data and training to the two Darwin Research Fellows in novel sampling and identification techniques, but also added to the value of the permanent Darwin butterfly and moth collections that we have established at Universiti Malaysia Sabah and the Forest Research Centre Sabah.

In most cases, captured butterflies were identified in the field, marked with a unique number or a coloured dot (depending on body size) and released. All noctuid moths and individuals of new butterfly species, not previously sampled, were collected and preserved. All these specimens are housed in the permanent insect collections at Universiti Malaysia Sabah and the Forest Research Centre Sabah. In addition, a sample of individuals was collected from selected species for molecular genetic analysis. These included all potentially problematic species (genera *Taenacia* and *Euthalia*) and all species in the genus *Mycalesis*: this is one of the most species-rich genera of butterfly in Sabah and contains a mixture from endemic species (*M. kina, M. amoeba*) to species with very broad geographical distributions (e.g. *M. mineus*, occurring in both Oriental and Australasian regions), making it an ideal model genus to study phylogenetic distinctiveness. In addition, one species of *Mycalesis* (*M. orseis*) is confined to forest habitats but occurs at all study sites, making it an excellent model species to estimate gene flow and genetic structuring of populations.

Material for molecular genetic analysis was transported to the UK, under licence, for extraction, amplification and sequencing of mitochondrial DNA (mtDNA) using standard techniques. Extraction of mtDNA involved homogenization of thoracic tissue by microcentrifuge with a tissue lysis buffer, digestion using proteinase enzymes and removal of RNA, followed by precipitation, washing in ethanol and resuspension of mtDNA in a sterile buffer solution. Amplification was by polymerase chain reaction (PCR) using George and BtLYS primers. Sequencing was by agarose gel electrophoresis using an ethidium bromide stain.

We recorded a total of 6833 individuals from 84 species of butterfly during the study. There was no difference in local species diversity or abundance of butterflies sampled in relation to fragment size or isolation, but larger fragments contained a significantly higher proportion of species with restricted geographical ranges. Examination of vegetation structure, using principal components analysis, indicated that smaller fragments were more prone to disturbance, including edge effects, and that restricted-range butterfly species were particularly sensitive to such disturbance. Thus, impacts of forest fragmentation on local butterfly communities were due primarily to the greater vulnerability of small fragments to disturbance, rather than to any effect of fragment size or isolation *per se*.

Molecular genetic analysis of problematic species (genera *Taenecia* and *Euthalia*) has greatly resolved the taxonomy of this group: our analysis confirms the existence of two separate clades, supporting the retention of two genera, but indicates that some species are currently misclassified. Phylogenetic analysis indicates that this group is undergoing current rapid radiation, with a number of species showing very little separation in mtDNA: this supports the pattern obtained from morphological data (e.g. wing patterns and male genital morphology).

Phylogenetic analysis of species in the genus *Mycalesis* produced a well-resolved and consistent phylogeny, but indicated that a number of species have separated only relatively recently. We are currently examining how phylogenetic similarities among species relate to similarities in their morphology, ecology and geographical distribution. More detailed analysis of *M. orseis* indicated that there was significant local sub-structuring of population genetic diversity. However this structuring was not related to recent patterns of habitat fragmentation. Rather, it appears to reflect the impact of topographical obstructions to gene flow on populations re-expanding from Pleistocene refugia.

These data have been presented at international conferences and are currently being prepared for submission to peer-reviewed journals.

Training and capacity building

Two Darwin Fellows were each appointed to the project for a period of three years from 1st April 2001. They were chosen on the basis of their exemplary performance during our previous Darwin Initiative project, because they had already received the necessary basic training in butterfly sampling and identification techniques during that project, and because they are likely to be in a strong position to move on to paid employment within biological conservation in Sabah at the end of the current project. During the project, both Fellows received training in the theoretical basis of molecular genetic analysis, followed by first-hand experience of DNA extraction from butterfly material, amplification using PCR techniques, sequencing of PCR-products, construction of phylogenies and analysis of population genetic structure from DNA sequences. They also received training in advanced morphological identification techniques including interpretation and refinement of bifurcating keys, dissection and preparation of genitalia, and quantitative analysis of wing-spot pattern. In addition, we trained a further Sabahan biologist (Mr Nasir Abd Majid) in ecological sampling techniques including forest inventory, butterfly capture and identification skills. The two Darwin Fellows also received additional training in forest inventory techniques, which they put into practice by collecting data from each of the forest fragments to allow changes in vegetation structure and composition to be included in the analytical comparison between fragments. The training in advanced identification techniques and forest enumeration, along with the training given to Mr Nasir Abd Majid, were all additional to the agreed project schedule.

The quality of the work carried out by the two Fellows has been assessed in two ways: (1) by independent corroboration of their results, including checking of species identifications and molecular genetic data by senior members of the project team; (2) through oral and poster presentations to peers at conferences and seminars. We are pleased to note, in this context, that one of our Darwin Fellows (Ms Nazirah Mustaffa) was awarded the prize for the best poster at the International Conservation Conference at Cambridge University in March 2002, for her poster on work carried out during this project; (3) both Fellows are registered for PhDs at Universiti Malaysia Sabah. They are currently writing up their theses, with expected submission before the end of March 2005 (i.e. within four years of commencing their work, in keeping with the time-frame expected at UK universities). The theses will be critically examined by one external examiner (an acknowledged expert in the field, not connected with any of the project's host institutions) and one internal examiner (a member of academic staff in the Institute of Tropical Biology and Conservation at Universiti Malaysia Sabah, not connected with the

project). Both Fellows are progressing well with their write-up and we do not anticipate any major difficulties.

5. Project Impacts

There is currently much debate within Sabah as to the most appropriate management strategy for forest fragments, with increasing pressure to convert them into commercial (principally oil palm) plantations. In support of this strategy, palm oil producers and plantation managers have suggested that isolated forest fragments have little conservation value, and so there is no argument for retaining such fragments in terms of protecting biodiversity. Data collected by this project have made a substantial contribution to this debate because we have demonstrated very clearly that in fact, even small forest fragments retain a large potential for supporting biodiversity (see Research above). In particular, small forest patches not only maintained local species diversity but also maintained genetic diversity within species. Moreover we have shown that the main threat to biodiversity within forest fragments arises through their increased vulnerability to disturbance (for instance collection of firewood and small-scale crop planting) that alters vegetation structure: this can be dealt with relatively simply by appropriate policing to enforce legal protection measures. This information has been forwarded to the Sabah Foundation (Mr Peter Chong) and the Sabah Department of Forestry (Mr Waidi Sinin) in our Project Report and will inform future discussions regarding the most appropriate policy for forest fragments.

The project has in particular helped the host country to meet its obligations under Articles 7, 8, 12 and 13 of the Convention on Biological Diversity (see Appendix II). Through training of Darwin Fellows, establishment of permanent study plots and reference collections and publication of research papers, the project has promoted research contributing to the conservation and sustainable use of biological diversity in Sabah (Article 12). Through our Project Report to the Sabah Foundation and the Sabah Department of Forestry, the project has promoted protection of habitats and provided guidelines for management of protected areas (Article 8) and assisted with identifying and monitoring components of biological diversity (Article 7). Through our provision of educational material for use by Education Officers at DVFC, we have assisted in promoting public education and awareness (Article 13).

The two Darwin Fellows are currently completing the process of obtaining PhDs. If successful, this will place both Fellows in a very strong position to obtain permanent employment in the field of biodiversity and conservation within Sabah, and we are very hopeful that they will obtain posts at the Forest Research Centre (Ms Suzan Benedick) and at Universiti Malaysia Sabah (Ms Nazirah Mustaffa). To this end, both Fellows are currently, in addition to completing their PhD theses, working part-time as teaching and research assistants at the Institute of Tropical Biology and Conservation at Universiti Malaysia Sabah. Nazirah Mustaffa has also been interviewed for a permanent post and placed on a reserve list subject to obtaining her PhD.

This project has substantially enhanced the collaboration between UK and local partners and has already led to further related work on additional taxa (carrion-feeding butterflies, lycaenid butterflies and noctuid moths; see above). It has also helped to forge stronger links between Universiti Malaysia Sabah and the Forest Research Centre Sabah, and between both these institutions and the Sabah Foundation (Yayasan Sabah).

In terms of social impact, the main beneficiaries of the project were the two Darwin Fellows. However, the project also provided support for infrastructure and staff at DVFC and provided occasional employment for technicians and field assistants. To the best of our knowledge, the project has had no unexpected impacts on individuals or local communities.

6. Project Outputs

The main outputs from the project are described in Appendix III: these do not differ from the agreed schedule except that we have not yet submitted 10 manuscripts for publication in peer-reviewed journals. This delay is mainly because, following recommendations arising from annual report reviews (see Section 10 below), we are training and assisting our Darwin Research Fellows in writing such manuscripts themselves, and this has inevitably slowed their production. Publications and material that can be publicly accessed are described in Appendix IV. Information relating to project outputs and outcomes has been disseminated through research papers and reports, through workshops and seminars in the host country and the UK, and through the establishment of a project website. The target audiences for this information are: (i) forest managers, policy makers and practitioners in Sabah; (ii) the international academic community including postgraduate students; (iii) undergraduate students of ecology and conservation biology; (iv) interested members of the public. This dissemination of information will continue in the future through publication of further research papers in international peer-reviewed journals, through presentations at further conferences, workshops and seminars in the host country, the UK and internationally, and through regular updating of the project website. Where appropriate, any costs resulting from these activities will be met by the University of Leeds.

7. Project Expenditure

This is detailed in the table below. Expenditure was in accordance with the project schedule. The only substantive change from the original schedule is that the Darwin Fellows undertook their laboratory training at the University of York, not Durham: this was entailed by the project Director moving university during the first year of the project.

	2001/2002	2002/2003	2003/2004

8. Project Operation and Partnerships

There were two main local partners in the project: Professor Maryati Mohamed (Universiti Malaysia Sabah) and Dr Chey vun Khen (Forest Research Centre Sabah; see Appendix IV). Both have important roles in biodiversity issues in Sabah; Professor Maryati is Director of the Institute for Tropical Biology and Conservation at Universiti Malaysia Sabah and represents the Institute on a number of prominent and influential committees within Sabah; Dr Chey is Head of Entomology at the Forest Research Centre Sabah. Both were closely involved in the project from early in the planning stage, and both were actively involved throughout the project, including initial selection of Darwin Fellows, training in entomological techniques, provision of library and computing facilities and day-to-day logistic support in Sabah.

During the project lifetime, there was no formal collaboration with similar projects elsewhere in Sabah, but members of other projects were invited to seminars and workshops given as part of this project. In addition, UK staff, Darwin Fellows and local partners met members of other projects informally on a number of occasions, especially during fieldwork at DVFC. This greatly facilitated exchange of ideas and information between projects. There was no Biodiversity Strategy Office in Sabah during the lifetime of the project but the role of such an office was largely fulfilled by the Sabah Foundation, with whom we met for consultation at least once per year throughout the project. There were no international partners in this project.

Local partners have continued to be highly active after the end of the project. In addition to her role as Director of the Institute for Tropical Biology at Universiti Malaysia Sabah, Professor Maryati plays a leading role in a number of key conservation organisations in Sabah and more broadly in SE Asia, including the ASEAN network. Dr Chey has played a leading role in drawing up the guidelines for insect conservation as part of Sabah's National Biodiversity Conservation Strategy.

9. Monitoring and Evaluation, Lesson learning

The progress of the project was monitored by UK staff via evaluation meetings held every six months, using the indicators and milestones set out in the initial Project Schedule agreed with DEFRA, and coinciding with the production of interim project reports for DEFRA. Progress was additionally monitored via meetings with local partners in Sabah every 6-12 months. The work carried out by the project was also independently evaluated through oral presentations and written reports to independent research staff at York and Leeds Universities, and will be externally evaluated through independent peer review of PhD theses and research papers.

The only major problem that the project encountered was in extracting DNA from some species. This problem was quickly identified and was solved by drawing upon the great wealth of expertise and experience available within the Project Molecular Genetics Manager's research group at York, to refine and improve the Darwin Fellows' procedures. The key lesson to be drawn from the experience of this project was the great importance of having strong links with local partners from an early stage. This greatly facilitated planning and instigation of the project and contributed immensely to ensuring that the project fulfilled all its major objectives.

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

Previous reviews were favourable of the quantity, quality and importance of our research and training activities, but identified a need to prioritise the production and circulation of our education packs and the enhancement of our project web site. These have all been done. The reviewer also raised the question of whether we could encourage our Darwin Fellows to write more papers themselves. This is one of the key purposes of the additional training that we have given to both Fellows as part of their PhD study programs, and we are hopeful that it will bear fruit in the near future.

11. Darwin Identity

Strenuous efforts have been made during the project to publicise the Darwin Initiative. The Darwin Initiative logo has been used extensively on posters and leaflets, websites, reports and at workshops and seminars, and is prominently displayed on each butterfly case and on the catalogues of the Darwin Initiative Butterfly Collection at Universiti Malaysia Sabah, where the

collection will be permanently housed in purpose-built accommodation, and of the Darwin Initiative Butterfly and Moth Collection at the Forest Research Centre Sabah. In addition, an international Darwin Initiative conference was held in September 2001 at Universiti Malaysia Sabah, with presentations from all current and past Darwin Initiative projects based in Sabah. This conference was widely publicized including national press and television coverage. UK staff also held a Darwin symposium at the International Conference on Tropical Ecology and Conservation held at Aberdeen University in July 2003, organized by the British Ecological Society and the American Association for Tropical Biology and Conservation: the symposium included presentations by the Project Leader and Dr Chey vun Khen, and was attended by conference delegates from a wide range of countries in Europe, Africa, Asia and North America. Both Darwin Fellows were proud to use these titles and habitually did so (and still do).

Within Sabah, the Darwin Initiative is familiar to staff in the Sabah Foundation, the Forest Research Centre Sabah and Universiti Malaysia Sabah. They generally recognize the Darwin Initiative as a scheme to provide funding for biodiversity projects in developing nations and many have a more detailed knowledge. Our particular project was clearly recognized as a distinct project with its own identity.

12. Leverage

The project provided leverage in forming a major part of the case for providing the two Darwin Fellows each with a further teaching and research fellowship at Universiti Malaysia Sabah, whilst they complete their PhDs. The likelihood that these will lead to permanent posts (see Project Impacts above) hugely increases the capacity for continued funded work of this nature after the lifetime of the project. Our project also played host to the UK Minister for the Environment (Elliot Morley MP) during his visit to Sabah in 2003, and we hope that this may have contributed in a small way to ensuring continued UK government support for the Darwin Initiative.

13. Sustainability and Legacy

The most enduring achievement of the project is likely to be a continued contribution by the two Darwin Fellows to work on biodiversity in Sabah. With their level of training and anticipated research publications and qualifications to PhD level, both Fellows will be in a very strong position to obtain permanent employment, and we are very hopeful that they will obtain posts with our two partner institutions (Universiti Malaysia Sabah and Forest Research Centre Sabah) once they have acquired their PhDs. Other enduring achievements include permanent additions to the published literature and the availability of reference collections and permanent study plots for use by future workers. We are maintaining frequent contact with both Darwin Fellows and local partners in connection with writing of PhD theses and further research papers and with development of further projects for the future (including an application for Darwin Initiative funding for a novel project with our two local partners, submitted Oct 2004). In addition, the Project Director and Fieldwork Manager have each been successful in recently obtaining PhD studentships for projects in Sabah (combined value ca. £100,000), partly as a result of the achievements of this project.

14. Value for money

We consider that this project represents excellent value for money. We hope that our reasons for reaching this conclusion are evident from this report and we are pleased to note that an ECTF review of an interim report considered that our project ‘represents a large amount of important research and training for a small sum of money’.

15. Appendix I. Logical framework

Project summary	Measurable indicators	Means of verification	Important assumptions
Goal To assist conservationists, ecologists and forest managers in Sabah with promoting responsible economic growth that balances maximizing agricultural development with minimizing the impacts of loss and fragmentation of rainforest on biodiversity	At end of project, guidelines on the most appropriate sizes and placements of forest fragments will be incorporated into economic planning, and molecular genetic techniques firmly established for measuring and promoting biodiversity	Reports and guidelines received and accepted by State Agencies. Trained Sabahan staff in post and using molecular genetic facilities at UMS to develop new projects.	N/A
Purpose To provide clear practical advice on the sizes and placements of forest patches necessary to preserve species richness and genetic diversity. To leave a lasting legacy of trained Sabahan staff using molecular genetic techniques to measure and promote biodiversity within Sabah and throughout SE Asia.	Practical assistance given to forest managers and conservationists (March 2004). Molecular genetic tools used to resolve otherwise intractable taxonomic uncertainties and identify cryptic species (Sep 2002). Darwin Research Fellows able to use molecular genetic and ecological techniques to develop further projects (March 2004).	Management guidelines written to assist in maintenance and promotion of biodiversity in forest fragments. Biodiversity inventories and guides updated after resolution of taxonomic difficulties.	Forest managers and conservationists have a meaningful input into economic planning. This is guaranteed by the State legislature. Molecular genetics facilities are maintained at UMS beyond the life of the project. Internal funding has already been approved at UMS, subject to availability of suitably trained staff.
Outputs Quantitative elucidation of how species diversity and genetic diversity within species relate to forest patch size and isolation. Training of two Sabahan Darwin Research Fellows in ecological and molecular techniques for measuring species richness and quantifying genetic diversity.	Research papers written up (March 2004). Successful completion of training courses by Darwin Research Fellows (September 2002 for DRF I, September 2003 for DFR II).	Research papers published in peer-reviewed scientific journals. Darwin Research Fellows attain appropriate standard in written, oral and practical examinations.	Darwin Research Fellows take up posts at UMS and FRC. This is almost certainly guaranteed by the recruitment process. Research leads to clear guidelines.
Activities Collection and analysis of data on biodiversity in selected forest fragments. Attendance by Darwin Research Fellows of training course at Durham with additional training for both Fellows in Sabah.	Fieldwork sites established (Sep 2001), material collected (Apr 2001-Sep 2003), Darwin Research Fellows attend courses and receive in-house training at Durham (Oct 2001-Sep 2002 and Oct 2002-Sep 2003).	Map of study sites produced; collection of material established; Darwin Research Fellows appointed and arrive in Durham.	Successful recruitment of Darwin Research Fellows and establishment of study plots in forest fragments. Both of these are greatly facilitated by the close links that we have with our collaborating institutions in Sabah.

16. Appendix II. Project Contribution to Articles under the Convention on Biological Diversity

Article No./Title	Project %	Article Description
6. General Measures for Conservation & Sustainable Use		Develop national strategies that integrate conservation and sustainable use.
7. Identification and Monitoring	25	Identify and monitor components of biological diversity, particularly those requiring urgent conservation; identify processes and activities that have adverse effects; maintain and organise relevant data.
8. In-situ Conservation	25	Establish systems of protected areas with guidelines for selection and management; regulate biological resources, promote protection of habitats; manage areas adjacent to protected areas; restore degraded ecosystems and recovery of threatened species; control risks associated with organisms modified by biotechnology; control spread of alien species; ensure compatibility between sustainable use of resources and their conservation; protect traditional lifestyles and knowledge on biological resources.
9. Ex-situ Conservation		Adopt ex-situ measures to conserve and research components of biological diversity, preferably in country of origin; facilitate recovery of threatened species; regulate and manage collection of biological resources.
10. Sustainable Use of Components of Biological Diversity		Integrate conservation and sustainable use in national decisions; protect sustainable customary uses; support local populations to implement remedial actions; encourage co-operation between governments and the private sector.
11. Incentive Measures		Establish economically and socially sound incentives to conserve and promote sustainable use of biological diversity.
12. Research and Training	40	Establish programmes for scientific and technical education in identification, conservation and sustainable use of biodiversity components; promote research contributing to the conservation and sustainable use of biological diversity, particularly in developing countries (in accordance with SBSTTA recommendations).
13. Public Education and Awareness	10	Promote understanding of the importance of measures to conserve biological diversity and propagate these measures through the media; cooperate with other states and organisations in developing awareness programmes.
14. Impact Assessment and Minimizing Adverse Impacts		Introduce EIAs of appropriate projects and allow public participation; take into account environmental consequences of policies; exchange information on impacts beyond State boundaries and work to reduce hazards; promote emergency responses to hazards; examine mechanisms for re-dress of international damage.

15. Access to Genetic Resources		Whilst governments control access to their genetic resources they should also facilitate access of environmentally sound uses on mutually agreed terms; scientific research based on a country's genetic resources should ensure sharing in a fair and equitable way of results and benefits.
16. Access to and Transfer of Technology		Countries shall ensure access to technologies relevant to conservation and sustainable use of biodiversity under fair and most favourable terms to the source countries (subject to patents and intellectual property rights) and ensure the private sector facilitates such assess and joint development of technologies.
17. Exchange of Information		Countries shall facilitate information exchange and repatriation including technical scientific and socio-economic research, information on training and surveying programmes and local knowledge
19. Bio-safety Protocol		Countries shall take legislative, administrative or policy measures to provide for the effective participation in biotechnological research activities and to ensure all practicable measures to promote and advance priority access on a fair and equitable basis, especially where they provide the genetic resources for such research.
Total %	**100%**	**Check % = total 100**

17. Appendix III. Project outputs

Code	Total to date (reduce box)	Detail (←expand box)
Training Outputs		
1a	Number of people to submit PhD thesis	2: Ms Suzan Benedick and Ms Nazirah Mustaffa
1b	Number of PhD qualifications obtained	
2	Number of Masters qualifications obtained	
3	Number of other qualifications obtained	
4a	Number of undergraduate students receiving training	
4b	Number of training weeks provided to undergraduate students	
4c	Number of postgraduate students receiving training (not 1-3 above)	
4d	Number of training weeks for postgraduate students	304
5	Number of people receiving other forms of **long-term** (>1yr) training not leading to formal qualification(i.e not categories 1-4 above)	
6a	Number of people receiving other forms of **short-term** education/training (i.e not categories 1-5 above)	1: Mr Nasir Abd Majid
6b	Number of training weeks not leading to formal qualification	34
7	Number of types of training materials produced for use by host country(s)	3: Education Pack plus Manual of Molecular Genetic Techniques, donated to the Institute for Tropical Biology, Universiti Malaysia Sabah; Education Pack on forest fragmentation donated to Ms Sylvia Yorath, Education Officer, Innoprise Corp, Sabah
Research Outputs		
8	Number of weeks spent by UK project staff on project work in host country(s)	56
9	Number of species/habitat management plans (or action plans) produced for Governments, public authorities or other implementing agencies in the host country (s)	1: Project Report given to local staff (Sabah Foundation, Innoprise Corp, Dept Forestry and Wildlife, Forest Research Centre Sabah)
10	Number of formal documents produced to assist work related to species identification, classification and recording.	2. Catalogues of Darwin butterfly collections at University Malaysia Sabah and Forest research Centre Sabah
11a	Number of papers published or accepted for publication in peer reviewed journals	1: see Appendix IV. Many more in preparation
11b	Number of papers published or accepted for publication elsewhere	
12a	Number of computer-based databases established (containing species/generic information) and handed over to host country	4: Databases for (i) fruit-feeding butterflies, (ii) carrion-feeding butterflies, (iii) lycaenid butterflies, (iv) vegetation characteristics in different forest fragments handed to staff at Universiti Malaysia Sabah
12b	Number of computer-based databases enhanced (containing species/genetic information) and handed over to host country	
13a	Number of species reference collections established and handed over to host country(s)	Darwin butterfly and moth collection established at

Code	Total to date (reduce box)	Detail (←expand box)
		Forest Research Centre Sabah
13b	Number of species reference collections enhanced and handed over to host country(s)	Darwin butterfly collection enhanced at Universiti Malaysia Sabah
Dissemination Outputs		
14a	Number of conferences/seminars/workshops organised to present/disseminate findings from Darwin project work	2: Darwin Initiative conference at Universiti Malaysia Sabah, 2001; Darwin Symposium at international tropical ecology conference, Aberdeen, 2003
14b	Number of conferences/seminars/ workshops **attended** at which findings from Darwin project work will be presented/ disseminated.	7: Presentations at three International Conservation Conferences and at British Ecological Society conference in UK; seminars at Danum Valley Research Centre Sabah and University of York, UK
15a	Number of national press releases or publicity articles in host country(s)	1. Sabah Times
15b	Number of local press releases or publicity articles in host country(s)	
15c	Number of national press releases or publicity articles in UK	
15d	Number of local press releases or publicity articles in UK	
16a	Number of issues of newsletters produced in the host country(s)	
16b	Estimated circulation of each newsletter in the host country(s)	
16c	Estimated circulation of each newsletter in the UK	
17a	Number of dissemination networks established	Web site established to disseminate information on project
17b	Number of dissemination networks enhanced or extended	
18a	Number of national TV programmes/features in host country(s)	Two interviews with Professor Maryati Mohamed
18b	Number of national TV programme/features in the UK	
18c	Number of local TV programme/features in host country	
18d	Number of local TV programme features in the UK	
19a	Number of national radio interviews/features in host country(s)	
19b	Number of national radio interviews/features in the UK	
19c	Number of local radio interviews/features in host country (s)	
19d	Number of local radio interviews/features in the UK	
Physical Outputs		
20	Estimated value (£s) of physical assets handed over to host country(s)	Commercial value of butterfly collections probably in excess of £1,000
21	Number of permanent educational/training/research facilities or organisation established	
22	Number of permanent field plots established	200
23	Value of additional resources raised for project	

18. Appendix IV: Publications

Type * (e.g. journals, manual, CDs)	**Detail** (title, author, year)	**Publishers** (name, city)	**Available from** (e.g. contact address, website)	**Cost £**
journal	Hamer, K.C., Hill, J.K., Benedick, S., Mustaffa, N., Sherratt, T.N., Maryati, M. & Chey, V.K. (2003). Ecology of butterflies in natural and selectively-logged forests of northern Borneo: the importance of habitat heterogeneity. *Journal of Applied Ecology* 40: 150-162.	Blackwell	http://www.blackwellpublishing.com	
PhD thesis	Benedick, S (2005) Species and genetic diversity of butterflies in rainforest fragments of Sabah Borneo	Universiti Malaysia Sabah	Institute of Tropical Biology, Universiti Malaysia Sabah, Kota Kinabalu, Sabah Malaysia	
PhD thesis	Mustaffa, N (2005) Molecular genetics of butterflies in rainforest fragments of Sabah Borneo	Universiti Malaysia Sabah	Institute of Tropical Biology, Universiti Malaysia Sabah, Kota Kinabalu, Sabah Malaysia	

19. Appendix V: Darwin Contacts

To assist us with future evaluation work and feedback on your report, please provide contact details below.

Project Title	Molecular tools for promoting biodiversity of rainforest fragments in Borneo
Ref. No.	162/10/025
UK Leader Details	
Name	Dr Keith Hamer
Role within Darwin Project	Project Director
Address	Earth Biosphere Institute and School of Biology, University of Leeds
Phone	
Fax	
Email	
Other UK Contact (if relevant)	
Name	Dr Jane Hill
Role within Darwin Project	Project Fieldwork Manager
Address	Department of Biological Sciences, University of York
Phone	
Fax	
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Partner 1	
Name	Professor Maryati Mohamed
Organisation	Institute of Tropical Biology, Universiti Malaysia Sabah
Role within Darwin Project	Logistic support and liaison
Address	PO Box 2073, 88999 Kota Kinabalu, Sabah Malaysia
Fax	
Email	
Partner 2 (if relevant)	
Name	Dr Chey vun Khen
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