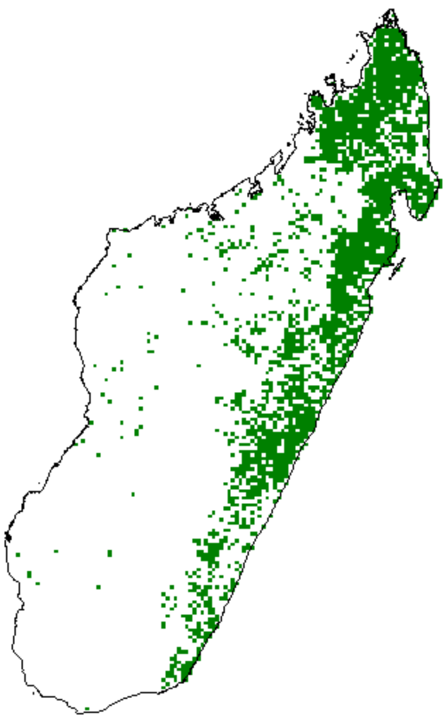
# Darwin Initiative Final Report: Sustainable Development of Madagascar's Littoral Forests



Gathering wood, southern Madagascar, 1/99.

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# Darwin Initiative for the Survival of Species

## *Final Report*

**Project title** Sustainable development of Madagascar's biologically unique littoral forests

**Country** Madagascar

**Contractor** Environmental Change Institute, University of Oxford
**Project Reference No.** 162/9/006

**Grant Value** £79,162

**Starting/Finishing dates** May 2000 – April 2003

**Cover photos courtesy of QMM, 1999.**

## Project Background/Rationale

### Location and circumstances of the project

The future persistence of the biologically unique littoral forests surrounding south-eastern Madagascar is uncertain due to pressures from local deforestation and the extensive deforestation associated with a proposed mining project which will be undertaken by QIT-Madagascar Minerals (QMM), our principal collaborator. This research has aimed to investigate patterns of species richness as related to present and future scenarios of degradation within the remaining forest fragments. The methodology included innovative techniques for the rapid assessment of forest canopy structure and vascular plant biodiversity. Results from these assessments are being used to determine where conservation should focus within the area and for assessing the impacts of development and local exploitation on this unique ecosystem.


**Figure 1. Map of Madagascar and the study region.**

## The problem that the project aimed to address:

The key problem this project aimed to address was to determine if and how biodiversity can be conserved in small, forest patches, which have been classified as degraded and are under pressure from local villagers and future impacts associated with a large-scale industrial mining project.

**Who identified the need for this project and what evidence is there for a demand for this work and a commitment from the local partner:**

The need for this work was identified by multiple stakeholders who had previously been working in this area. These stakeholders included representatives from international and local NGOs such as World Wide Fund for Nature (WWF) and Azafady, scientists from Missouri Botanical Gardens, Kew Gardens, University of Oxford, Hamburg University and the mining company, QMM.

## Project Summary

### The purpose and objectives of the project

The overall purpose of the project was to assist with biodiversity conservation in an area challenged by competing pressures from local exploitation of forest resources and exploitation associated with a future mining project.

The following set of objectives comprised this research:

- To develop an alternative methodological approach (based on photogrammetry, remote sensing and rapid survey techniques, integrated through GIS) to the mapping and analysis of the structure and community composition of forest fragments that can be used for future conservation and land use planning in the region and as an independent check on the approaches adopted as part of QMM's own Environmental Impact Assessment studies.
- To provide a detailed database of plant species in the region by using and comparing vernacular and scientific taxonomic systems of plant identification.
- To examine the integrity, completeness and the scope of the ongoing EIA process and the conclusions reached
- To contribute to local capacity building and training in ecological monitoring and assessment techniques.

**Please include the Logical Framework for this project (as an appendix) if this formed part of the original proposal or has been developed since, and report against this.**

A logistical framework for the long-term biodiversity assessment has been developed and is on-going. Please see attached draft.

**Were the original objectives or operational plan modified during the project period?**

A rescheduling of certain aspects of the project was necessary due to political conflicts in Madagascar from January- August 2002.

**If significant changes were made, when was approval given by the Darwin Secretariat?**

Approval was given by email correspondence in early 2002.

**Which of the Articles under the Convention on Biological Diversity (CBD) best describes the project? Summaries of the most relevant Articles to Darwin Projects are presented in Appendix I.**

Articles 7, 10, 8 and 12.

**Briefly discuss how successful the project was in terms of meeting objectives. What objectives were not achieved, or only partly achieved, and have there been significant additional accomplishments?**

- **Completion of objective 1:** *To develop an alternative methodological approach (based on photogrammetry, remote sensing and rapid survey techniques, integrated through GIS) to the mapping and analysis of the dynamics and community composition of the forest fragments that can be used for future conservation and land use planning in the region and as an independent check on the approaches adopted as part of QMM's own studies.*
    - This objective has been successfully completed by successive studies and scientific research into the relationship between information derived from photogrammetry and remotely sensed imagery to forest structural attributes. This has been supplemented by research on the relationship of remotely sensed data and forest structure to patterns of plant species richness and community composition. We have observed strong correlations between reflectance values in multi-spectral satellite imagery and basal area/$m^2$ of forest fragments and species diversity within forest fragments. Using multiple types of statistical and analytical methods, information on these relationships has been integrated with a Geographic Information System to create predictive maps of forest structure across the landscape. These maps will be useful for conservation planning and future monitoring.
- **Completion of objective 2:** *To provide a detailed database of plant species in the region by using and comparing vernacular and scientific taxonomic systems.*
    - We have compiled a database of the most common and endemic species found in the littoral forests by matching scientific names to the vernacular names of plant species in the region. Plant taxonomists at Kew Gardens and a local botanist in the area who knew the vernacular names of the plant species carried out this work. A pictorial guide of the plant species is ongoing and will be made available to local NGOs, QMM, the Libanona Ecology Center library, and online at the project website.
- **Completion of objective 3:** *To examine the integrity, completeness and the scope of the corporate Environmental Impact Assessment and the conclusions reached.*
    - We have participated in multiple planning workshops on the mining project organized by QMM, which have been attended by representatives of NGOs, consultants, and scientific and academic institutions. These workshops have provided valuable insight into the EIA process. The results of the scientific research have both confirmed and conflicted with the many findings and conclusions on the littoral forest ecosystems presented within the corporate EIA. These observations have provided an important understanding of the corporate EIA process and the strengths and weaknesses associated with it. These issues are of global interest since many EIA methods and protocols are designed in western countries but applied in tropical, developing countries where the natural and social

environment are often very different and poorly understood. A manuscript for publication is being prepared.

- **Completion of objective 4**: *To contribute to local capacity building and training in ecological monitoring and assessment techniques*

  - Students from the Universities of Oxford and Hamburg, Malagasy graduate students from the Universities of Tana and Tulear and Malagasy employees from QMM were trained in a 10 day training course in Fort Dauphin organized by QMM and coordinated by Dr. Jorg Ganzhorn.
  - Dr. Aaron Davis trained 3 Malagasy students in plant taxonomy and herbarium specimen preparation.
  - Dr. Dawson trained Hery Ranoharisoa, QMM staff, in aerial photography image acquisition and analysis.
  - Jane Carter Ingram trained three Malagasy foresters and one Swiss research assistant in forest flora biodiversity and structural assessment techniques.
  - Jane Carter Ingram assisted QMM staff in ecological experimental design and statistical analysis of ecological data.
  - Jane Carter Ingram and Dr. Terry Dawson trained GIS staff of WWF/the Libanona Ecology Center in image analysis and presentation techniques.
  - Helene Ralimanana from Madagascar came to England to work with Dr. Aaron Davis at Royal Botanic Kew Gardens to assist with completing scientific identifications of the vascular plant the database.
  - Jane Carter Ingram and Dr. Terry Dawson will assist WWF with the development of the curriculum for a GIS/remote sensing for ecological monitoring course to be taught to Malagasy graduate students at the Libanona Ecology Center in Fort Dauphin of May 2003. This was originally planned for May 2002 but it was rescheduled due to political conflicts in Madagascar from January- June 2002.
  - Terry Dawson and Jane Carter Ingram have provided consultations of aerial survey techniques for a community based conservation program in Ifotaka, which is being organized by WWF in Fort Dauphin.

## Scientific, Training, and Technical Assessment

**Please provide a full account of the project's research, training, and/or technical work.**

**Research -** this should include details of staff, methodology, findings and the extent to which research findings have been subject to peer review.

**Investigation into the relationship between structure and species richness within the littoral forest fragments**. This phase was divided into three phases: an initial pilot study in July 1999 and two follow up studies in June-August 2000 and October-December 2001

**Staff leaders**: Scott Henderson (phase 1, 1999), Rose Askew (phase 2, 2000), Jane Carter Ingram (phase 3, 2001)

**Support Staff**:

**1999**: Ramesy Edmond (Malagasy), Vola Romaine (Malagasy), Claude Herysoanary (Malagasy), Delphin Tovoniaina (Malagasy), Germain Randriamandimby (Malagasy), Julson Geny (Malagasy), Crescent Mosa (Malagasy)

**2000**: Ramesy Edmond (Malagasy), Jennifer Haworth (British), Ella Chase (British), Karl Bradford (British), Elinor Bremen (British), Nick Meyer (British)

**2002**: Ramesy Edmond (Malagasy), Lalaina Andriamiharisoa (Malagasy), Emmanuel Randriambinintsoa (Malagasy), Andry Rabemanantsoa (Malagasy), Christian Stamm (Swiss)

**Rationale for this research:** The human communities surrounding the forests of Mandena, Petricky and St. Luce are highly dependent on natural resources for their livelihoods. It is often thought that biodiversity is negatively impacted by high degrees of human exploitation. Insights into the degree of human impact on a forest can be obtained from measurements of forest structure such as mean tree diameter of breast height (DBH), basal area (BA) and/or stem density. A forest with a comparatively low DBH (or BA) and high stem density may represent a forest that is young and/or regenerating from a disturbance, either natural or anthropogenic. Repeated disturbance can prevent forest recovery or further regeneration and, thus, a forest may be arrested in a state of overall low DBH (or BA) and high stem density. A basic explanation of the way in which disturbance influences community composition can be described by the intermediate disturbance hypothesis which states that moderate degrees of disturbance may enhance species diversity. Thus, the relationship between species richness and disturbance is not linear. Although, moderate degrees of disturbance may enhance overall species richness in some situations, there is concern amongst conservationists that priority species may decrease as a result of increased disturbance. Our goal was 1) to assess structure of the forest in fragments classified as having different degrees of degradation (or anthropogenic disturbance) and 2) to assess how the structure of the forest (a proxy for disturbance) influences vascular plant community composition of forest fragments.

**Study site:**
This research was carried out in Mandena, St. Luce and Petricky forest sites (figure 2). Within Mandena and St.Luce, sampling was distributed across fragments classified as having different degradation levels by QMM. Petricky is, for the most part, one large forest parcel and not fragmented similar to St. Luce and Mandena. Therefore, sampling in Petricky was done in an area of moderate degradation only.

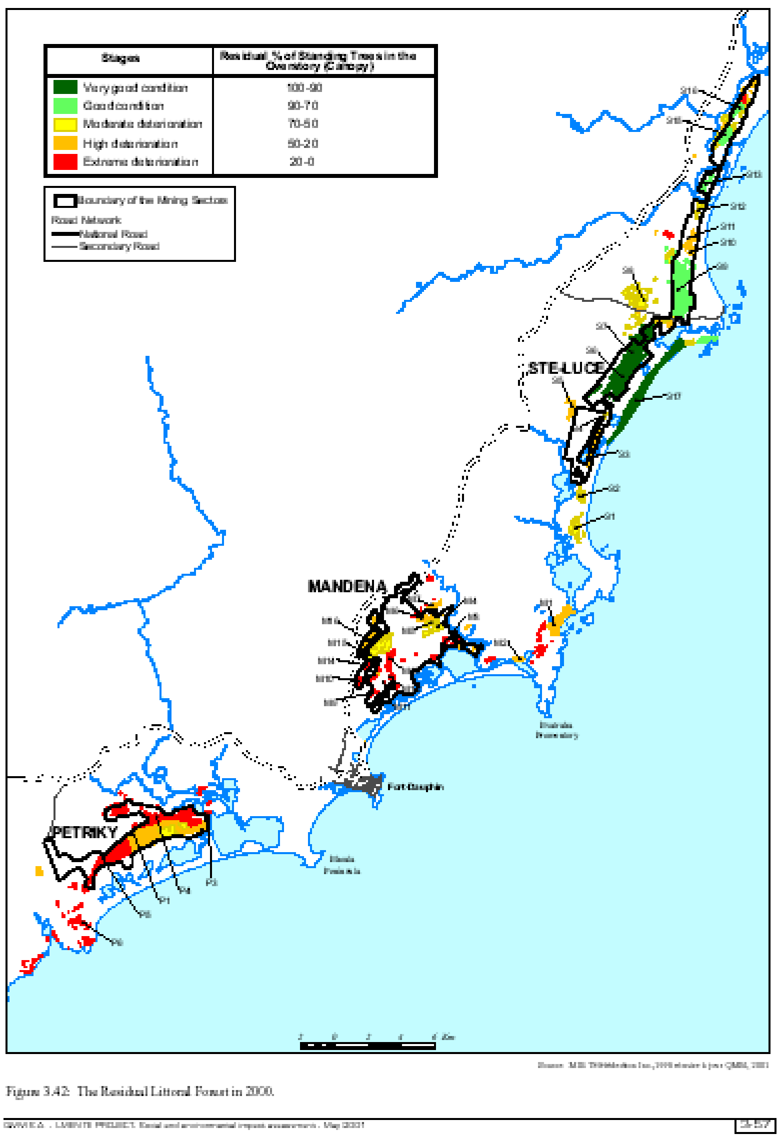


**Figure 2. QMM's classification of degradation status of the forest fragments in the three study sites.**

**Methodology**:

1. Modified Whittaker Plots (Stohlgren, 1995) were used for assessing vascular plant species diversity in forest fragments during each of the three ecological field trips. This method provides a rapid, yet effective, multi-scale assessment of plant species diversity and is the preferred method used by the Smithsonian Institution (Dallmeier & Comiskey 1998). Plots of varying size are placed within the large outer plot. The large outer plot is $1000m^2$, the inner plot (the C plot) is $100m^2$, two corner plots (the B plots) are $10m^2$ and the 10 small plots (the A plots) are $1m^2$ and are distributed equi-distantly along the inner perimeter of the outer plot. In the ten A subplots, all vascular plants present were identified and abundance of each species was recorded. In the B subplots, species abundances of all plants less than 5 cm diameter at breast height and taller than 1 cm were recorded. In the central C plot, the presence (not abundance) of all species not observed in the A or B plots was recorded.

2. Transects were used to measure forest structure in the area immediately surrounding each plot. The transects, which were 4 meters wide, emanated out of the center of the C plot and extended away from the plot for the designated distance. Along each transect, each tree located within the transect area was identified and the DBH (DBH taken to be approximately 1.3m) of all trees greater than 5cm DBH was measured and recorded. In the 2001assessment, dead, cut and fallen trees were also identified and recorded. The methodology was revised slightly in 2001 from the initial pilot study in 1999 and the field study in 2000 which utilized the variable area transect (VAT) methodology. Using the VAT method, structural information was obtained by dividing the vegetation into size classes based on a general visual stratification. This involved a division of trees into the following size classes: 5-10 cm, 10-15 cm and >15 cm diameter breast height. Each of these classes had a quota of individual trees, which was decided at 20 for the pilot study in 1999 and 40 for the 2000 study. Once the quota for each size class was reached, sampling of that size class ceased and the transect continued until the quota for all size classes was met. Once the transect reached 200m, all sampling ceased even if the size class quota was not fulfilled. In the 2001 study, quotas were not used and the transect size was shortened to 100m. These changes were done to a) minimize biases in the data associated with arbitrary quota designations and b) to more effectively capture the relationship between structure measured within the transects and the plant diversity measured within the plots. The structure of the forests were highly heterogeneous, changing considerably over a few meters, and, thus, it was thought that the relationship between structure and diversity could be lost in a transect spanning a distance of 200m.

3. **Global Positioning Systems**: A global positioning system was used in all phases of the field research to record geographical coordinates of the plots so that these plots could be re-located for monitoring purposes and geo-located on satellite images and aerial photographs. GPS points were pre-selected before the 2001 field expedition to ground truth areas of seemingly dense vegetation as indicated by the satellite imagery.

**Findings**:

Preliminary findings in phase 1 (pilot study) and phase 2 of the research suggested that there was a strong relationship between forest structure, or degradation, and species diversity. It was found that forest fragments characterized by moderate degrees of disturbance (or with moderate basal area and mean dbh) possessed the highest degrees of species richness (in phase 1). Areas with the most extreme degrees of degradation were depauperate in species richness and priority species. Abundance of endemic or priority species tended to be higher in fragments with less evidence of structural degradation, or areas classified as 'pristine'. It was suggested in the 2000 study that the current degradation classifications used by the mining company are not good indications of the conservation value of a forest fragment at moderate levels of degradation. This could be due to the fact that at moderate levels of disturbance, forest structure may not be the most dominant factor influencing species composition. Factors such as fragment size, biogeographical location, oceanic gradients, climatic gradients and edaphic factors may be as important as forest structure in determining vascular plant community composition, when disturbance regimes are moderate.

Phase 1 and phase 2 of the research pre-selected plot and transect sampling sites within each forest fragment such that each sampling site was characteristic of the degradation classification given to the overall forest fragment by QMM. In consideration of the above listed factors that may also have a strong influence on community composition of a forest fragment, in phase 3 of the research, we used random sampling within each fragment to remove any sampling artifact that may influence our interpretation of the relationship between structure and community composition. This methodological revision was based on the rationale that if there is a strong relationship between structure and biodiversity it should exist across all fragments. Thus, during phase 3, the relationship between structure and community composition was tested in fragments of varying degradation classes, size and location.

The results of phase 3 of the research revealed that structurally the forests are heterogeneous and that classification of a forest fragment with one degradation level may not capture the structural variation typical of the forest fragments in the area. This is an important consideration for conservation planning if there is indeed, as the evidence suggests, a relationship between structure and community composition. A cluster analysis (figure 3) of the transects, using basal area/$m^2$ as the variable for classification, revealed that the transects most similar to each other structurally are not necessarily of the same degradation classes.

* * * * * * H I E R A R C H I C A L  C L U S T E R  A N A L Y S I S * * * * * *

Dendrogram using Ward Method

Rescaled Distance Cluster Combine

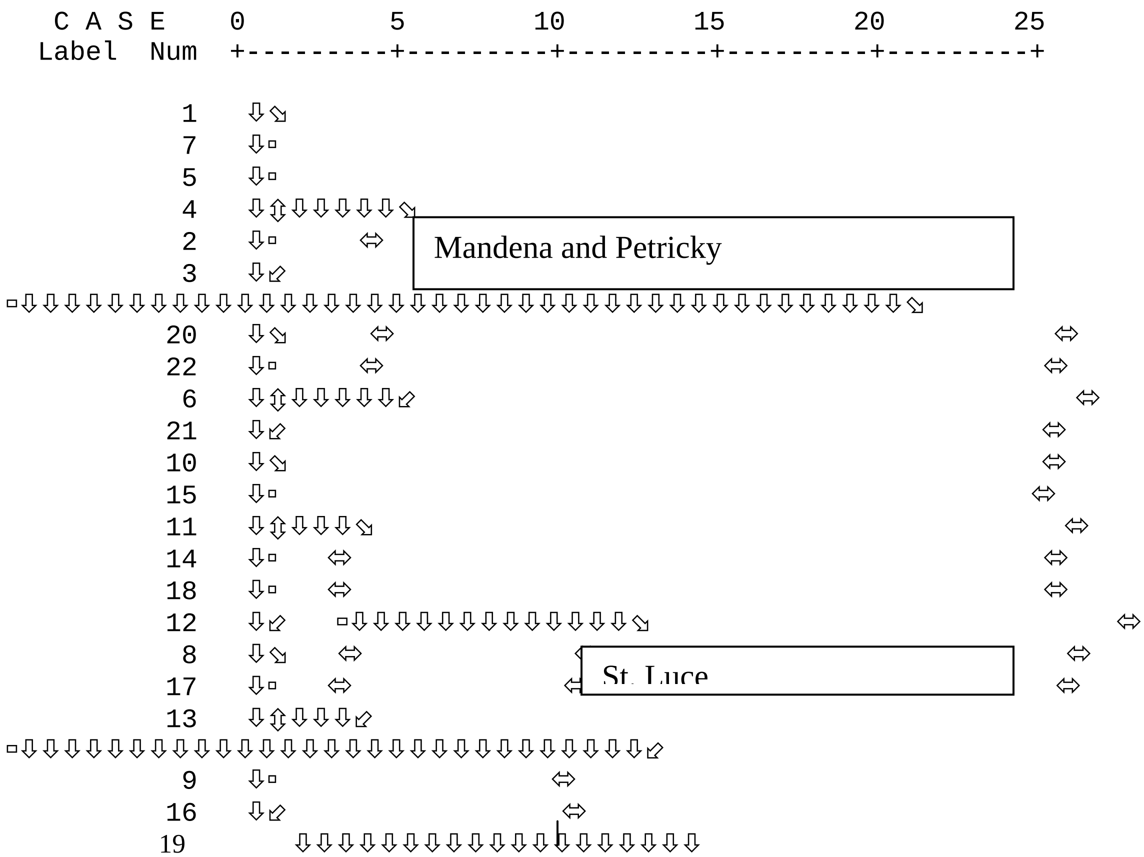


**Figure 3. Dendogram of transects based on basal area/m$^2$.**

Codes for transects: 1-4 are transects in M16 (moderate degradation), 5-7 are the transects in M4 (high degradation), 8-12 are the transects in S7 (very good condition), 13-16 are the transects in S8 (moderate degradation), 17-19 are the transects in S9 (good condition) and 20-22 are Petricky transects (all of which were placed in an area of moderate-high degradation).

In the dendogram of the cluster analysis, the first branching separates Mandena and Petricky from St. Luce. The next branching discriminates between Mandena and Petricky, with the exception of one transect from M4 (transect 6), which is grouped with Petricky. It is interesting that within Mandena, the structure of the forest is similar between forest fragments of different degradation classifications (moderate and high). St.

Luce transects did not cluster by forest fragment indicating that there is no distinct similarity between basal area/$m^2$ of transects based on the pre-defined degradation levels. The clearest distinction of transects was S9 number 19 from all of the other St. Luce transects. S9.19 included several occurrences of *Boaka Be*, the tree with the largest DBH in the area. It appears from this cluster analysis that forest site (i.e. St. Luce, Mandena, Petricky) is a more dominant factor than degradation level in influencing structural parameters of the forest, such as basal area, since the transects do not cluster into the assigned degradation levels classified by QMM.

The structural data was correlated with community composition information in the area. Although, these relationships are strong and significant for the transect diversity data (Table 1), the relationships of structural parameters to diversity of plants measured within the plots was not as strong (Table 2). The strong relationship between structure and tree diversity measures is most likely due to the selective use and harvesting of certain tree species which effects structure and species measures simultaneously. The weaker relationship between forest structural parameters to diversity measures of vascular plants recorded within the plots indicates that there are other factors, in addition to structure, which influence the vascular plant community composition of forest fragments. The contribution of these other factors deserves more research. Thus, conservation priority setting based purely on degradation or structure as a proxy for species richness and other measures of diversity may not provide effective protection of plant species and communities of interest for conservation. Further research is now looking at the distribution of various types of species across the landscape (such as utilitarian and endemic species) and the relationship of their distribution to forest fragment size, location as well as to structural parameters

**Table 1. Non-parametric Spearman's correlations between transect structural measures and tree diversity measures. The values represent the relationship of structural parameters to tree diversity in the transects.**

| | basal area/$m^2$ | stem density/$m^2$ | mean DBH | species number | equitability |
|---|---|---|---|---|---|
| basal area/$m^2$ | 1.0 | | | | |
| stem density/$m^2$ | .469* | 1.0 | | | |
| mean DBH | .857** | .107 | 1.0 | | |
| species number | .739** | .370 | .756** | 1.0 | |
| equitability | .700** | .224 | .764** | .926** | 1.0 |

**Table 2. Non-parametric Spearman's correlations between transect structural measures and plot diversity of vascular plants measures.**

| | basal area/m$^2$ | stem density/m$^2$ | mean DBH | species number | equitability |
|---|---|---|---|---|---|
| basal area/m$^2$ | 1.0 | | | | |
| stem density/m$^2$ | .469* | 1.0 | | | |
| mean DBH | .857** | .107 | 1.0 | | |
| species number | .646** | .431 | .580** | 1.0 | |
| equitability | .320 | .147 | .430* | .756** | 1.0 |

**Publication status**: manuscript being prepared for submission in October 2003.

**Remote Sensing for assessment of forest structure**

**Staff: Dr. Terry Dawson and Jane Carter Ingram**

**Rationale:** Assessments of biodiversity and ecosystem condition are time consuming, expensive and often logistically difficult to conduct at a landscape scale. Yet, landscape analyses are vital for conservation and development planning. In situations where conservation dollars and time are limited and where corporations are faced with urgent deadlines for Environmental Impact Assessments, accurate and efficient methods for conducting rapid assessments of forest structure, condition and biodiversity across a landscape are needed. This research aimed to contribute to developing a methodology for such purposes while providing a landscape assessment of forest structure across our study sites.

**Methods:**
**1. Aerial Photography**: In November 2000, aerial photographs were made of the Petricky, Mandena, and St. Luce forests. Photographs were taken at a height of 8,500 feet with a Nikon D1 digital camera, which was interfaced to a lap top computer and Geographical Positioning System. The series of images have been mosaiked together and geo-referenced for an analysis of canopy structure and degradation of the forests. This analysis has been conducted with Erdas Imagine and Idrisi software.

**2. Satellite imagery:** Satellite imagery from January 2002 provided by the Landsat Thematic Mapper has been used to assess the relationship of forest structure to reflectance values measured at different wavelengths of the electromagnetic spectrum. These images have been geometrically and radiometrically corrected and analysed within Imagine and Idrisi software.

**Findings**
**1. Aerial photography**: Analysis of the utility of aerial photographs for assessing forest structure has demonstrated that the most useful application of the photographs is for verifying observations made within the satellite imagery. The high spatial resolution of approximately 2 meters has made the aerial photography an invaluable data source when used in combination with the satellite imagery of coarser spatial resolution but higher spectral resolution. The aerial photographs span the blue, green and red wavelengths of the electromagnetic spectrum. However, the high variability in solar and view-angle geometry limited the potential for quantitative assessments of mosaiked images over large areas due to the changing illumination and surface reflectances. This effect, together with the limited spectral resolution means that applications of the photographs were limited to visual inspection to support the satellite image analysis.

**Publication status:** Paper and presentation at the International Society of Remote Sensing Conference in London, September 2001. Title: *The use of digital aerial photography for understanding the relationship between forest canopy structure and biodiversity.* Please see attached document for full text.

**2. Landsat Thematic Mapper**: The relationship of forest structure to remotely sensed imagery has been assessed using Landsat Thematic Mapper imagery from January 2002 at a spatial resolution of approximately 30 meters in combination with the ground collected transect data on forest structure. We used multiple statistical tests and artificial neural networks (ANNs) to quantify strong relationships between reflectance values in the mid-infrared, red and near infrared bands of the sensor to basal area/$m^2$. Using these relationships, we have created a predictive map of basal area for the forests of St.Luce, Mandena and Petricky (figures 4 and 5). The basal area predictive map is similar to QMM's overall classification of degradation based on qualitative visual assessment techniques (figure2). However, the classification using remotely sensed data and basal area captures more of the variance in structure across forest fragments, which can be seen in the Mandena site (figure 5). This trend is especially obvious as one moves from the edge of the forest to the center. The degradation classifications used by QMM do not account for edge towards inner gradients of structure or canopy openness across a fragment. A cluster analysis of the remotely sensed imagery alone, without basal area information, was also conducted using the Idrisi software program (figure 6) and compared to the predictive map (figure 5), which combines both basal area and remotely sensed information. The classification provided by the cluster analysis using only remote sensing data is fairly similar to the predictive map of basal area created using the remotely sensed imagery and the structural information. A preliminary interpretation of the cluster analysis indicates that individual clusters represent different habitat types and/or different structural types within a single habitat. For example, cluster 4 represents moist, swamp type habitats and dense forest. Thus, the spectral signal between these two habitats is very similar which indicates that ground-truthing is necessary in such analyses. Cluster 1 represents the broad class of littoral forest but does not distinguish structural differences within the littoral forest as well as the predictive map of basal area, which used the ground data in combination with the remotely sensed data. Clusters 2 and 3 represent the edges of littoral forest (which often have different structural characteristics from the inner areas of a fragment) and areas of vegetation re-growth. Although the predictive map using ground data provides more detail into forest structure variations than the remote sensing data used alone, as shown in the cluster analysis, the high similarity between the two maps suggests the utility of remote sensing data for providing initial information about a study site when a ground survey may not be possible in the first instance. Ground-truthing should always be conducted when possible and, especially, when working in a site unfamiliar to the researchers, since it can be difficult to differentiate habitat types with remotely sensed reflectance values alone.

**Publication status:** Submission to a peer reviewed journal is expected in fall 2003.

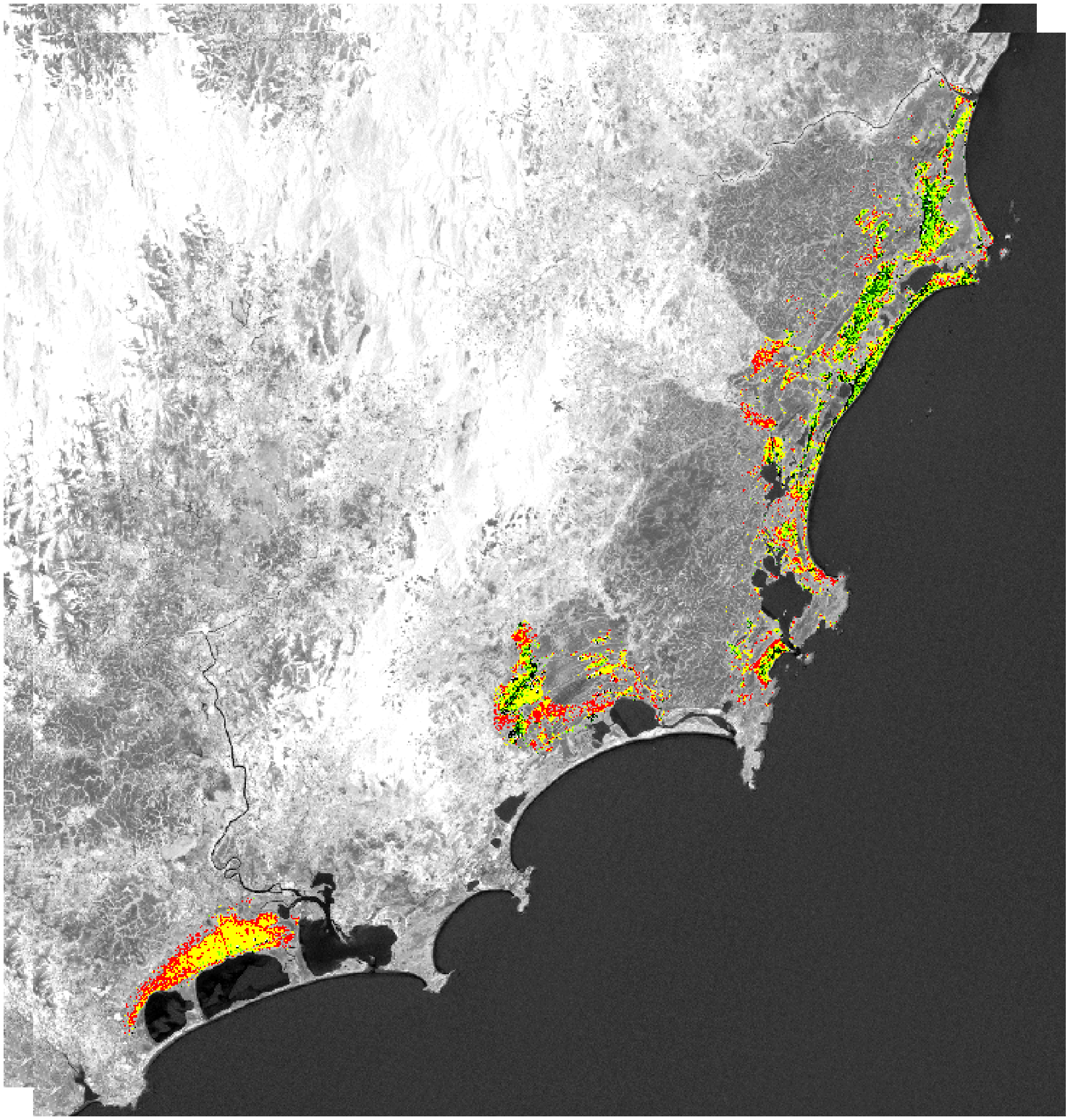

**Figure 4. Predictive map of basal area/$m^2$ for Petricky, St.Luce, and Mandena using transect data and the red, near infrared and mid-infrared bands of the Landsat TM 2002 image as training data within the artificial neural network. The scale is a gradation from red to green. Red colors represent areas with low basal area/$m^2$, yellow represents moderate values of basal area/ $m^2$, and green represent high values of basal area/$m^2$.**

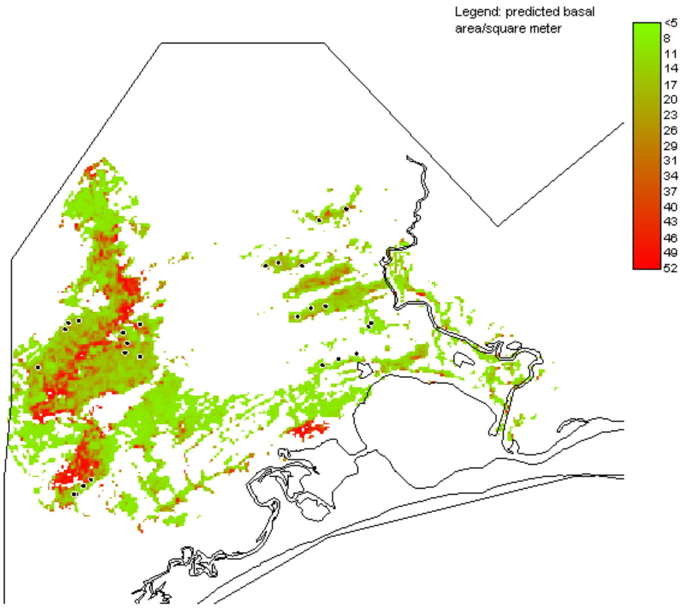


**Figure 5. Basal area/m$^2$ predicted for Mandena using red, near-infrared and mid-infrared bands of the Landsat TM 2002 image and transect data on basal area/m$^2$. The legend depicts the color scheme of predicted basal area/m$^2$ of the littoral forest fragments. The black points represent sampling sites and the black outlines represent the outer boundaries of the exploration zone in Mandena.**

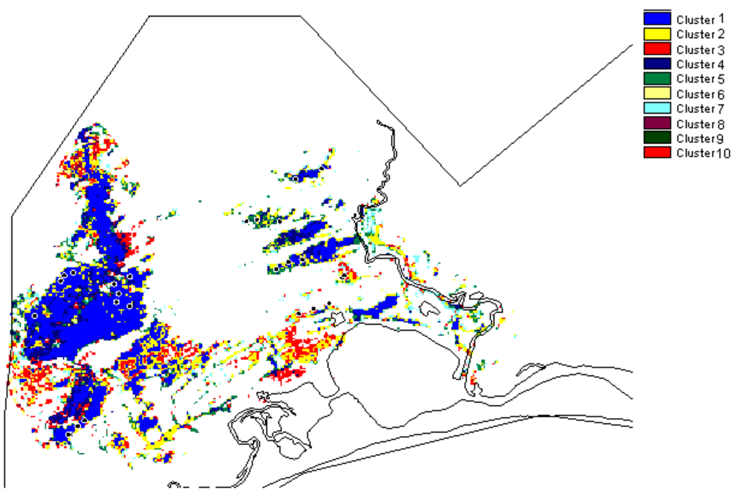


**Figure 6. Cluster analysis of the spectral reflectance values in the red, near infrared and mid-infrared bands and normalized difference vegetation index (NDVI) from Landsat TM 2002 of the littoral forest in Mandena. This analysis utilized only remote sensing data. The black points represent sampling sites and the black outlines represent the outer boundaries of the exploration zone in Mandena.**

**Remote sensing for assessment of patterns of forest change**

**Staff: Dr. Terry Dawson and Jane Carter Ingram**

**Rationale:** There has been considerable debate on deforestation estimates at global and national levels. This is especially true in Madagascar where there have been conflicts in national assessments of forest cover and deforestation estimates. Yet, deforestation rates have been a crucial factor in Madagascar's prioritization as a global biodiversity hotspot and for prioritising conservation efforts within the country. Estimates of linearly increasing deforestation have also provided a convincing argument for the development of the mining project in Fort Dauphin: if the forest site of Mandena is not used for mining there will be little to no forest present by the year 2020 if the current rates of local deforestation continue. This study aimed to assist in national conservation planning by clarifying some of the conflicts in vegetation change within forest areas at a national scale and seeking to understand the processes and patterns of deforestation at a local scale, which has been previously poorly understood (Lowry *et al*. 1999).

**Methods:**

**1. National scale assessment of vegetation change within forest areas:** The catalyst for this exploration has been a growing awareness of the conflicts and misperceptions inherent in many deforestation estimates both globally and nationally, within Madagascar, and the importance of these estimates in influencing conservation and development planning. This national scale investigation was undertaken using 18 continuous years of monthly satellite data from the National Oceanic and Atmospheric Administration's (NOAA) Advanced Very High Resolution Radiometer (AVHRR). We assessed changes in vegetation from 1982-1999 using the mean of the Normalised Difference Vegetation Index (NDVI) within evergreen forest boundaries. NDVI is a widely used index for measuring the amount of green vegetation present within a pixel and is derived from a ratio of reflected solar radiation in the red (chlorophyll absorption) and near-infrared (leaf internal scattering) wavebands. Multi-temporal NDVI images have been related to the state and productivity of vegetation, to classify and discriminate land cover types and to monitor vegetation change such as deforestation. By calculating significant changes in NDVI between successive years, we have also identified 'hotspots' of significant vegetation change on the island throughout the time period to aid conservation planning and priority setting within the country. The results from these analyses have provided a national context of vegetation change within which we can situate forest change in the forest sites surrounding Fort Dauphin to assess how this area fits into national conservation strategies. Please see attached documents in appendices for a more detailed description of methods and findings.

**2. Local scale assessment of forest change:** We are also investigating patterns of forest change at a local scale using NDVI images from the Landsat Thematic Mapper for the years 1984, 1992, 1999 and 2002. The objective of this study has been to assess spatial and temporal patterns of forest change in the forest sites of St. Luce, Petricky and Mandena to determine if rates of forest change as depicted by the mining company (see figure 7) are continuing and if these trends are similar across all of the forest sites. An assessment of spatial and temporal patterns of change will permit a better understanding of how the different communities surrounding Petricky, St. Luce and Mandena impact and utilize forest resources.

We are in the process of exploring various change detection techniques for assessing forest loss using multi-temporal satellite images. Pre-processing of the images was required before analyses could be undertaken. The first step was to calibrate the NDVI images to each other by using one image as a reference image, the 2002 image. The other images were then calibrated to the reference image using the relative method of calibration. This method involves regressing each image against the reference image. The slope and intercept values of the regression equation are then used to calibrate each image to the reference image. Once the images are calibrated to each other, it is possible to employ change detection methods. One of the simplest, effective and most widely used change detection methods is image differencing. A difference image was created by subtracting the 1984 NDVI Landsat TM image from the 2002 NDVI Landsat TM image. In the difference image, pixels with a negative value represented those pixels which had a higher NDVI value in 1984 than in 2002. We then retained only those pixels that had experienced significant negative change between the two dates (significant change was defined as pixels with a value of 2 standard deviations below the mean difference between the images). In order to limit our analysis to forest areas, we created a forest mask using an NDVI thresholding technique. It was determined that an NDVI threshold of 178 in the 1984 image would retain only pixels that included forest areas. Using this threshold, we created a forest area mask by re-classing all pixels as forest that had NDVI values of 178 or higher in the 1984 image. We then overlaid this mask over the difference image to isolate our assessment of vegetation loss, indicated by a significant decrease in NDVI, to pixels classified as forest in 1984.

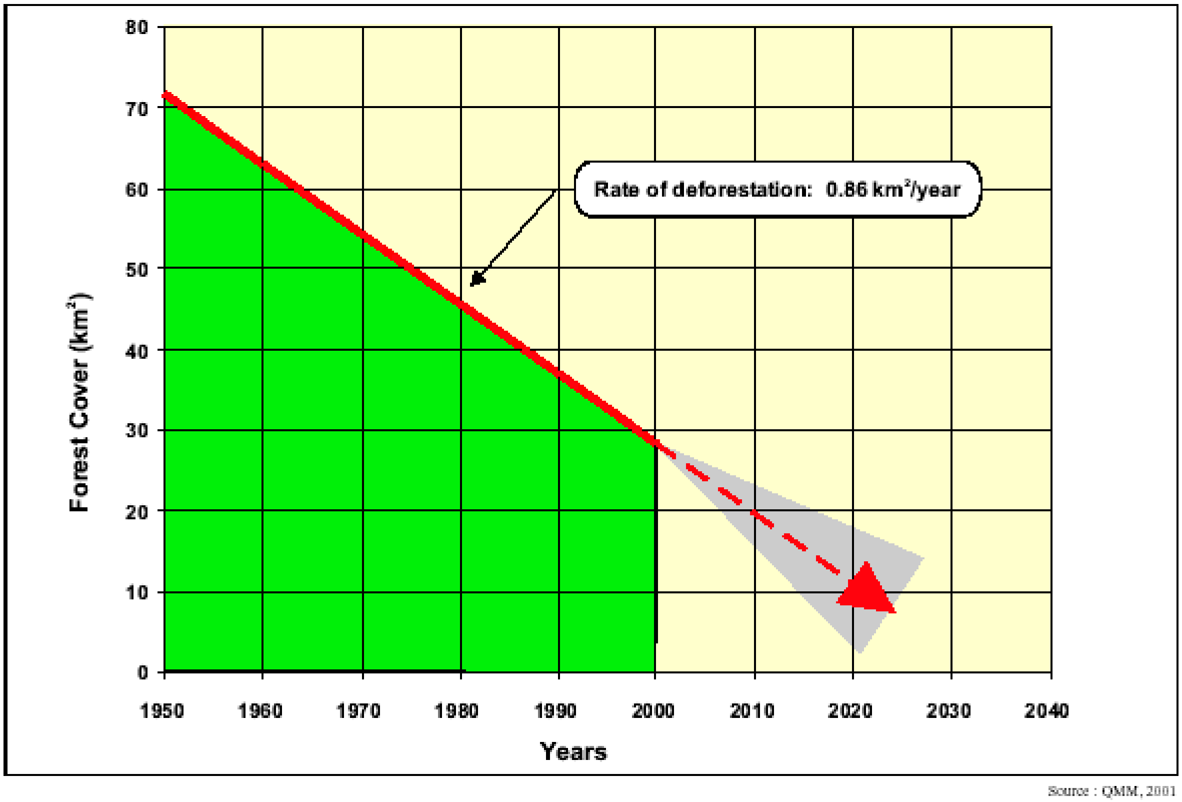


Figure 3.69: Curve of the Evolution of the Forest Cover in Mandena From 1950 to 2000.

**Figure 7. Estimation of forest cover in Mandena from 1950-2000.**

**Findings:**

**1**. **National scale study**: We determined that vegetation as indicated by the NDVI was highly dynamic temporally and was largely controlled by climatic variables. We did not see a trend of continual vegetation loss emerge from the dominant pattern of climatic variation. Two main areas were identified as having high frequencies of vegetation change: the central western portion of the eastern evergreen forest and the northwest portion of the island. Status as a protected area did not prevent vegetation change from occurring within protected area boundaries.

**Publication status:** Two papers based on this work have been submitted to peer reviewed journals*: Dynamic patterns of vegetation change within the forests of Madagascar* and *Inter-annual analysis of deforestation hotspots in Madagascar from high temporal resolution satellite observations*. Please see appendices for the full texts. The paper entitled *Dynamic patterns of vegetation change within the forests of Madagascar* has been recommended as an editor's choice article in Science pending publication.

**2. Local scale study:** From preliminary analyses, it is apparent that the three sites of Petricky, Mandena and St. Luce have experienced different patterns of forest change throughout the time period. Such findings support recent research in continental Africa, which has revealed that forest loss rates and patterns can vary substantially across short distances and throughout time. The reasons for such variation are often due to the fact that deforestation is a consequence of complex interactions between social, economic and environmental factors. Ongoing analyses will permit a more detailed quantification of these processes within each forest site from 1984 to 2002.

Preliminary analyses of the image differencing of the NDVI images from 1984 and 2002 have indicated that between these years only 2.26% of the forested area in the Landsat TM scene (figure 8) changed significantly in a negative direction.

**Figure 8. Significant negative change between Landsat TM 1984 and 2002 images of the southeastern region of Madagascar. Pixels that have experienced a significant negative change from 1984-2002 are colored in black. The mining exploration zone is outlined in black.**

**Tracing Radiation and Architecture of Canopies (TRAC) for measurement of canopy closure**

**Staff: Dr. Terry Dawson and J. Carter Ingram**

**Rationale:** Quantification of canopy closure from ground measurements has historically been difficult with the commonly used methods of hemispherical photography and spectrometers. These methods are time consuming, can be expensive and the measurements can only be made at points. The Tracing Radiation and Architecture of Canopies (TRAC) meter provides a quantitative, easy method for measuring forest canopy gap fractions, leaf area index (LAI) and fraction of photosynthetically active radiation absorbed by the canopy (fPAR), a driver of net primary productivity. These parameters are measured continuously along transects versus point measurements collected with hemispherical photography and spectrometers. As a useful supplement to the structural analyses of forest condition, this research aimed to determine the utility of the TRAC meter for application in tropical forests**.**

**Methods**: Monitoring of the forest with a TRAC light meter was conducted along previously marked transects throughout the St. Luce, Mandena and Petricky forests. The TRAC meter is held by the researcher so that it receives incoming and ground reflected radiation. The fraction of incoming/reflected radiation is then calculated at the end of the transect and downloaded onto a computer. The researcher holding the TRAC has to walk at a constant pace along each transect so that the data is continuous. GPS measurements were taken continuously along each transect so that we may be able to determine if there are correlations between the light meter readings on the ground and the interpretations of canopy texture and structure visible in the aerial photographs and satellite images. Such a relationship would provide a quantitative method for assessment of canopy closure, which has previously been assessed by QMM staff members with a visual qualitative classification system.

**Preliminary findings**: This meter has not been used widely in tropical forests. The dense understory of the littoral forests made it difficult to maintain the steady pace necessary for accurate readings of the meter. Additionally, the equipment has to run on batteries and data must be downloaded onto a computer after acquisition. The remoteness of many of our field sites and no electricity meant that we were unable to use the equipment to obtain sufficient data at St. Luce. Despite these limitations a number of readings were successfully collected. The research on the application of the TRAC is ongoing.

**Scientific and vernacular plant identifications**

**Staff: Dr. Paul Smith, Dr. Aaron Davis, Rolland Ranaivojaona, Frank Rakotonasolo, Helene Ralimanana**

**Rationale:** The extensive knowledge of the forest tree and plant species in the Fort Dauphin region has remained within the minds of a very few people. This research sought to match the scientific names with vernacular names of plant species and create a visual database so that this knowledge can be recorded and maintained throughout time.

**Methods:** Voucher specimens were collected within belt transects established at previously sampled locations (during the 1999 and 2000 field trips). Each voucher specimen was then taken to Antananarivo for identification. Where identification was not possible, vouchers were brought back to the United Kingdom to the Royal Botanic Gardens Kew for identification. Helen Ralimanana came to the UK from Madagascar to assist with the identifications and to be trained in the protocols used by Royal Botanic Kew and Herbarium in Paris May 2002.

**Findings:** There were differences between the scientific naming system and the vernacular identification system for vascular plants in the study area. For example, one Malagasy word may be used for a plant that is considered to be several different species by the scientific system and vice versa. Despite these differences, the overall correlation between the vernacular system and the scientific system was high with approximately 90% agreement between the two systems. This is one of the highest degrees of similarity between a vernacular naming system and scientific naming system observed by taxonomists at Royal Botanic Kew (Paul Smith, pers. com. 2002). Please see attached database of plant identifications and field report.

**Assessment of the potential for eco-tourism in Fort Dauphin**

**Researcher: Amanda Kennedy**

Amanda Kennedy, a graduate student from Oxford University's Environmental Change Institute, has recently conducted an assessment of the potential for eco-tourism in the Fort Dauphin region (MSc thesis completed September 2001). Please see attached abstract.

**Assessment of avifauna in littoral forests**

**Researchers: Dr. Terry Dawson and James Watson**

The aim of this research is to describe the bird communities that inhabit littoral forest remnants in three different sub-regions of southeastern Madagascar to determine the national importance of these forests for bird conservation. A total of 77 bird species were found inhabiting 14 littoral forest remnants. Of these species, 40 are endemic to Madagascar and a further 21 are endemic to the Indian Ocean sub-region consisting of Madagascar, the Comoros and the Mascarenes. The littoral forests contained more bird species than their neighbouring lowland humid forest and spiny forest and also possessed different bird species assemblages to these two forest habitats. Eleven bird species that have been previously described as being habitat-restricted endemics to either spiny forests or humid forests were also found in littoral forest remnants. The matrix habitats (*Melaleuca* forests, Marikage swamp forest, *Eucalyptus* plantations and *Erica* grassland) that immediately surround the littoral forests were depauperate of bird species and contained few species that were found within the littoral forests. These results suggest that the littoral forests may play an important transitional role between the two other major habitats (spiny forest and humid forest) of southeastern Madagascar. We recommend that the conservation of littoral forest remnants become a priority in eastern Madagascar.

**Publication status:** submitted to Biodiversity and Conservation journal. Please see attached manuscript.

**Training and capacity building activities** – this should include information on selection criteria, content, assessment and accreditation.

1. Dr. Jorg Ganzhorn from the University of Hambourg delivered a training course in ecological assessment and monitoring techniques to 24 people in Fort Dauphin which was organized by QMM: 8 Malagasy graduate students from the Universities of Tana and Tulear, 5 Malagasy QMM employees and 11 visiting students from the Universities of Hamburg and Oxford, 24 July – 4 August 2001. This course was conducted in French.

2. Ramesy Edmond, QMM's primary botanist, has been a crucial part of every field phase of the research aimed at investigating the relationship between structure and community composition of forest fragments. He now takes a pro-active role in leading the Modified Whittaker plot and transect methodologies used throughout this research.

3. Dr. Terry Dawson trained Hery Ranoharisoa, QMM staff, in aerial photographic acquisition and analysis techniques, May 2001.

4. J. Carter Ingram attended the Smithsonian Institution Assessment and Monitoring of Biodiversity for Adaptive Management Course, May-June, 2001 (she was awarded a scholarship placement).

5. Three Malagasy foresters and one research assistant from Switzerland were selected based on previous training to work on the 2001 field expedition and were trained in application of forestry techniques towards biodiversity assessment and monitoring and analytical procedures. Malagasy foresters were selected because of their previous training. The Swiss research assistant was chosen due to his environmental science education, ability to speak French, and was self funded to assist with the research.

6. J. Carter Ingram and Terry Dawson trained Malagasy World Wildlife Fund staff, Pascal Andriamanambina, in Geographical information system (GIS) techniques in December 2001.

7. J. Carter Ingram assisted QMM's Malagasy botanist in experimental design and biodiversity analyses techniques. We have provided him with the software and initial assistance necessary for analyzing complex environmental data, November 2001.

8. Helene Ralimanana was selected due to her excellent knowledge of the Malagasy flora and outstanding field work skills to come to Europe 15$^{th}$ April – 30$^{th}$ June 2002. She spent four weeks at the Laboratoire de Phanérogamie, Muséum National d'Histoire

Naturelle in Paris and six weeks at Royal Botanic Gardens Kew in London training and assisting with the plant database for the Darwin project.

10. Terry Dawson and J. Carter Ingram attended a People Oriented Research course at the Royal Geographic Society in London, UK on 16 April 2003.

11. QMM organized three environmental and social workshops in London, UK on mining in Madagascar and biodiversity planning, which brought together Darwin partners and representatives from Madagascar, NGOs, consultants, academic institutions and other stakeholders. 19-20 October 2000, 24 October 2002.

12. Darwin partners have also participated in three biodiversity planning workshops in Montreal, Canada, which was coordinated by the Smithsonian Institution (6-8 September 2000), London, UK, which was organized by QMM (5-6 June 2002), and Paris, France which was organized by QMM (24 May 2000).

## Project Impacts

**What evidence is there that project achievements have led to the accomplishment of the project purpose? Has achievement of objectives/outputs resulted in other, unexpected impacts?**

The overall purpose of the project was to assist with biodiversity conservation in an area challenged by competing pressures of local exploitation of forest resources and exploitation associated with a future mining project

- The University of Oxford has provided data and research included in QMM's Environmental Impact Assessment and Biodiversity Action plans.
- The Darwin partners have been participants in three workshops led by Rio Tinto and QMM for planning in the region. *Dilemmas of mining* and *Developing a biodiversity plan for the southeastern region of the country,* London, England, 19-20 October 2000*; Mining in Madagascar* workshop, London, England, 24 October 2002
- Jane Carter Ingram and Terry Dawson both provided input to inform the Conservation International response to the QMM SEIA.
- Terry Dawson and Paul Smith have been invited to become members of the External Advisory Committee for the QMM Biodiversity Conservation and Restoration Program.
- Through the lifetime of the project, 17 Malagasy conservationists and QMM staff have been trained in ecological assessment techniques.
- A pictorial database of the different plant species found within the region is in progress and has been put online on the project website.
- The research has developed novel methods for rapid assessment and monitoring of forest condition and biodiversity across the region.
- The research has quantitatively assessed and assisted in the corporate Environmental Impact Assessment process through the assessment of forest structure and patterns of forest change throughout time.
- The scientific research has collected data, which, once the analysis is complete, will provide useful insights into the impact of human exploitation on community composition of forest fragments. This aspect of the project is still under investigation but will provide a better understanding of the role of humans on the natural environment in Madagascar, which is crucial information for natural resource management and conservation in a landscape where humans are highly dependent on natural resources for their livelihoods.
- The project has resulted in the production of thematic maps, which will be useful for conservation planning and priority setting across the landscape.
- The research has resulted in comprehensive biological inventories of flora and avifauna community composition of the three forest sites.

**To what extent has the project achieved its goal, i.e. how has it helped the host country to meet its obligations under the Biodiversity Convention (CBD), or what indication is there that it is likely to do so in the future? Information should be provided on plans, actions or policies by the host institution and government resulting directly from the project that building on new skills and research findings**.

- The results from our study will be presented to the mining company and NGOs in the region for planning purposes. In May 2003, we plan to go to national and local NGOs to discuss how to make our results more useful to them.
- We have contributed to a better understanding of the processes of deforestation nationally and locally, which have previously been poorly understood in Madagascar as demonstrated by the conflicting estimates and accounts of forest loss in the country. This project has helped to clarify some of those issues. This research is still underway
- We have assisted with conservation priority setting on the island by identifying areas that have undergone intense degrees of vegetation change over the past 20 years, which should be prioritised for further investigation. Priority setting such as this is an important component of the country's National Environmental Action Plan. We are waiting for this manuscript to be peer reviewed before disseminating it.
- We have provided extensive training to Malagasy foresters, botanists and conservationists working in the country.
- Staff members of the Darwin project have participated in multiple stakeholder workshops led by the mining company to explore ways of sustaining Madagascar's biodiversity under different scenarios of conservation and development.
- All of the work done at a regional level will also aid the country in meeting national goals of the CBD since this area comprises many regionally endemic species and the last stretches of the ecologically unique south-eastern littoral forests.

**Please complete the table in Appendix I to show the contribution made by different components of the project to the measures for biodiversity conservation defined in the CBD Articles.**

**If there were training or capacity building elements to the project, to what extent has this improved local capacity to further biodiversity work in the host country and what is the evidence for this? Where possible, please provide information on what each student / trainee is now doing (or what they expect to be doing in the longer term).**

We plan to contact Andry, Lalaina, Emmanuel and Pascal in during our upcoming trip to Madagascar. Contact is difficult when many of them do not have access to email.

- Andry Rabemanantsoa
- Lalaina Andriamiharisoa
- Emmanuel Randriambinintsoa
- Pascal Andriamanambina, working for WWF
- Helene Ralimanana (please see attached report for further details)
- Rolland Ranaivojaona (please see attached report for details)
- Frank Rakotonasolo ((please see attached report for details)

**Discuss the impact of the project in terms of collaboration to date between UK and local partner. What impact has the project made on local collaboration such as improved links between Governmental and civil society groups?**

This project has had the challenging task of being impartial in the midst of a very political charged atmosphere where the mining company and local NGOs had not always been working effectively together towards conservation goals. This project is the first in the region to integrate collaboration from the mining company as well as the other conservation organizations involved in the area. Although, the task of collaborating with groups possessing different objectives and ideologies within the small village of Fort Dauphin has at times been difficult due to mistrust that exists between groups, it has set a good precedent in demonstrating that the situation is not as binary as commonly perceived. We have shown that association with the corporate sector does not mean that conservation outputs and goals are compromised.

**In terms of social impact, who has benefited from the project? Has the project had (or is likely to result in) an unexpected positive or negative impact on individuals or local communities? What are the indicators for this and how were they measured?**

The most direct and conspicuous benefits are the economic benefits we have thus far brought to the region. Local community members have benefited from the project by the presence of researchers in the community through our general contribution to the local economy (through purchases at local stores and restaurants) and jobs such as cooking, driving, guiding us through the forests and guarding the camps. The communities in St. Luce and Petricky have now established a forest access agreement whereby scientists and tourists pay a fee to visit and/or conduct research in the local forests, which also brings an economic benefit to the communities.

**Impact**: This could have a positive impact if conservation and the environment become viewed as potential sources of income and, therefore, worth maintaining. Alternatively, economic benefits associated with visiting scientists could be negative if the link between why we are present (the natural environment) and the economic benefits are not clearly understood. For this reason, it is very important to explain the project to the local communities (which was undertaken at each forest site).

**Indicators of impact:** Increase in well being of people and communities; Decrease in forest loss

We have provided mining company employees, WWF staff, Malagasy graduate students and foresters with ecological training and skills, which will make them more competitive in the conservation job market and give them useful skills for environmental monitoring.

**Impact**: Positive

**Indicators of impact**: Progress of students after training; location of students after training (do they stay in the local community, go to the capital or leave the country), employment status of students

The mere presence of outsiders in a community's forest is bound to have social impacts. Especially, in many of our forest sites, such as Petricky, where very few outsiders visit. Upon arrival to any of the forest sites, we were required to visit surrounding communities and introduce ourselves. In one instance, it was explained to the community that we were not monsters as commonly believed who would eat the organs of their children if we encountered them in the forest!

**Impact:** Positive if through our presence we were able to dispel some commonly held beliefs of westerners.

**Indicators of impact:** Community response to the researchers when encountered in the forest; Future interactions between local people and researchers, which is currently limited.

## Project Outputs

**Quantify all project outputs in the table in Appendix II using the coding and format of the Darwin Initiative Standard Output Measures.**

**Explain differences in actual outputs against those in the agreed schedule, i.e. what outputs were not achieved or only partly achieved? Were additional outputs achieved? Give details in the table in Appendix II.**

**In preparation:**

**Training material in fieldwork techniques**: We are planning to collaborate with WWF on development of an ecological assessment training course at the Libanona Ecology Center in Fort Dauphin in May 2003. This was originally planned for 2002 but was delayed due to national political conflicts.

**Report: '**The corporate EIA process and its relationship to biodiversity in developing countries: A case study in Madagascar' is aimed to be completed by October 2003. This report is a holistic integration and assessment of the research findings and the ongoing EIA process. Thus, a discussion on the entire project, our findings and the outcomes from an upcoming planning workshop (one of which is planned in Madagascar for June 2003) can only be initiated once the project has been completed.

**Additional outputs not planned in original proposal:**

Master's dissertation: Ecotourism report by Amanda Kennedy

Paper submitted to peer reviewed journal: Assessment of avifauna in littoral forests by James Watson and Terry Dawson (see attached document)

Paper submitted to peer reviewed journal: Dynamic patterns of vegetation change within the forests of Madagascar, by J.Carter Ingram and Terry Dawson (see attached document)

Paper submitted to peer reviewed journal: Inter-annual analysis of deforestation hotspots in Madagascar from high temporal resolution satellite observations, by J.Carter Ingram and Terry Dawson (see attached document)

Documentary on mining in Madagascar: 'A littoral balance'

**Provide full details in Appendix III of all publications and material that can be publicly accessed, e.g. title, name of publisher, contact details, cost. Details will be recorded on the Darwin Monitoring Website Publications database, which is currently being compiled.**

**How has information relating to project outputs and outcomes been disseminated? Will this continue or develop after project completion and, if so, who will be responsible and bear the cost of further information dissemination?**

Project outcomes and output have been disseminated through international conference presentations; presentations at the University of Oxford, University of Edinburgh, University of Reading, Smithsonian Institution; submission of results and papers to peer reviewed journals; and regular updates as well as the plant database in progress are posted on the project website. The work was also presented in a documentary entitled 'A littoral balance'. A trip to Madagascar in May 2003 will involve dissemination of the final report to project partners as well as exploratory discussions with local NGOs and institutions as to how to make our work and results useful to them.

## Project Expenditure

**Tabulate grant expenditure using the  categories in the original application**

**Highlight agreed changes to the budget**

**Explain any variation in expenditure where this is +/- 10% of the budget**

Financial statement and audit form to follow.

## Project Operation and Partnerships

**How many local partners worked on project activities and now does this differ to initial plans for partnerships? Who were the main partners and the most active partners, and what is their role in biodiversity issues? How were partners involved in project planning and implementation? Were plans modified significantly in response to local consultation?**

**Main local partners**: Because this project is so multi-faceted, we have interacted regularly with local partners on different aspects of the project. We have continually consulted with all of our local partners about our project plans and their knowledge has been crucial to the development of our work. Our main local partners have been QMM, Azafady and WWF.

QMM staff was vital for the execution of our fieldwork. QMM staff provided transport, field assistance, cooks, interpreters and extensive logistical assistance. We were dependent upon QMM botanist, Ramesy Edmonds, for identifications so we planned our project around his availability. In the field, he also assisted with experimental design.

Azafady provided us with valuable insight into the Lokaro and St. Luce forests and informed us about the similar, previous research which had been conducted there. Thus, with limited time and money we chose not to sample sites which their researchers had already done using similar methods. Their knowledge of the area, previous research and feedback has been very helpful in development of the project.

WWF has played a vital part in directing us in the capacity building component of our project. They have helped us define our role in a training course on GIS/Remote sensing for environmental monitoring. We will work closely with them to develop course materials and course curricula.

**During the project lifetime, what collaboration existed with similar projects elsewhere in the host country? Was there consultation with the host country Biodiversity Strategy (BS) Office?**

Eucare project, University of Edinburgh and Institut Halieutique & des Sciences Marines

Project Ifotaka, University of Durham

Ranamofauna National Park, Dr. Patricia Wright, Stony Brooke University in New York

World Wildlife Fund

**How many international partners participated in project activities? Provide names of main international partners.**

David Richards, Rio Tinto

Alfonso Alonso, Smithsonian Institution

Jorg Ganzhorn, University of Hambourg

Frank Hawkins, Conservation International

Alison Jolly, Sussex University

Porter Lowry, Missouri Botanical Gardens

Roger Safford, Birdlife International

All of the above people including the Darwin partners, Paul Smith and Terry Dawson, are international members of the external biodiversity advisory committee and will continue to serve on this indefinitely.

**To your knowledge, have the local partnerships been active after the end of the Darwin Project and what is the level of their participation with the local biodiversity strategy process and other local Government activities? Is more community participation needed and is there a role for the private sector?**

More community participation is needed and is part of continuing research within the region. There is a major role for the private sector to play in conservation since the Fort Dauphin area has not been prioritised nationally for conservation by many well funded international NGOs or government to date.

## Monitoring and Evaluation, Lesson learning

**Please explain your strategy for monitoring and evaluation (M&E) and give an outline of results. How does this demonstrate the value of the project? e.g. what baseline information was collected (e.g. scientific, social, economic), milestones in the project design, and indicators to identify your achievements (at purpose and goal level).**

We have had 6 monthly management meetings at the Environment and Development Group in Oxford, QMM, Kew and at the University of Oxford.

During the project period, has there been an internal or external evaluation of the work or are there any plans for this?

**External**: Our work has been submitted to peer reviewed journals and presented at international conferences and other universities.

**Internal:** We have held numerous discussions with other project staff on how to develop the project and to make the data and results more useful to stakeholders. The work has also been internally peer reviewed by staff and colleagues within the ECI and the School of Geography and the Environment at the University of Oxford.

**What are the key lessons to be drawn from the experience of this project? We would welcome your comments on any broader lessons for Darwin Initiative as a programme or practical lessons that could be valuable to other projects, as we would like to present this information on a website page.**

We discovered early on that there is a very important need to be flexible within the field and as the research develops. Several things we tried did not work out as planned and so we had to redesign several approaches/methods.

The need to not only be objective but also insure that one appears objective is very important when working in politically charged atmospheres such as this. Even as scientists it is always necessary to consider one's social impact and positionality within a community.

Conservation strategies are needed even though the individual Darwin project will have a limited lifespan. It is important to engage local institutions and communities in processes, which can be maintained after project completion.

The effectiveness of a conservation action is difficult to measure within the average 2-3 years of a project. It would be worthwhile for Darwin to consider longer term 'partnerships' between host nation institutions and British counterparts (i.e. minimum of 5 years). This could form the basis of a mentoring scheme whereby the funding is used for collaboration workshops and student exchanges.

## Darwin Identity

**What effort has the project made to publicise the Darwin Initiative, e.g. where did the project use the 'Darwin Initiative' logo, promote Darwin funding opportunities or projects? Was there evidence that Darwin Fellows or Darwin Scholars/Students used these titles**?

The Darwin foundation was acknowledged with the Darwin logo in presentations at multiple international conferences: International Geophysical Conference in Nice, France, March 2001, International Remote Sensing Society Conference in London, England, September 2001, International Canopy Conference, Cairns, Australia, June 2002.

The Darwin logo has also been used within presentations made by Terry Dawson at the University of Edinburgh, the University of Reading and the University of Oxford. J. Carter Ingram has made presentations, which promote Darwin and have included the Darwin logo at the University of Oxford and to the international participants and staff of the Smithsonian Monitoring and Assessment of Biodiversity for Adaptive Management Course.

The Darwin Initiative was publicised on a recent documentary on mining in Madagascar entitled: A Littoral Balance.

The Darwin foundation has been publicised through the project website at www.eci.ox.ac.uk.

All publications have included acknowledgements to the Darwin foundation.

The Darwin Initiative was publicised in the Friend's Provident newsletter featuring Terry Dawson, summer 2001 (attached).

**What is the understanding of Darwin Identity in the host country? Who, within the host country, is likely to be familiar with the Darwin Initiative and what evidence is there to show that people are aware of this project and the aims of the Darwin Initiative?**

All of the local collaborators and contacts we have made while working in Madagascar are now familiar with the organization.

**Considering the project in the context of biodiversity conservation in the host country, did it form part of a larger programme that dwarfed Darwin funding or was it recognised as a distinct project with a clear identity?**

This project is very much an independent project although we have worked and collaborated with the local and international partners. It is locally referred to as the "Darwin Project".

Within the larger programme of the SEIA (Social and Environmental Impact Assessment) being undertaken by QMM our role was primarily seen as 'independent' and impartial of QMM. In this context, we served as valuable liaisons in fostering understanding of the often divergent perspectives held by the various stakeholders.

## Leverage

**During the lifetime of the project, what additional funds were attracted to biodiversity work associated with the project, including additional investment by partners?**

Counterpart funding from QMM as an enabler of conservation and social and environmental strategies was crucial throughout the project.

Rose Askew was funded by the University of Oxford Expedition Society.

James Watson was funded by the Rhodes Trust.

J. Carter Ingram received a scholarship from the Smithsonian Institution to participate in the Smithsonian Monitoring and Assessment of Biodiversity for Adaptive Management Course.

**What efforts were made by UK project staff to strengthen the capacity of partners to secure further funds for similar work in the host country and were attempts made to capture funds from international donors?**

J. Carter Ingram applied for the BP conservation award but was unsuccessful.

J. Carter Ingram assisted the Smithsonian in developing the framework for a national scale training course in ecological assessment techniques. During this time, she was developing funding applications for conservation in Madagascar to be submitted to the Global Environment Facility and the Critical Ecosystems Partnership fund offered by Conservation International.

Terry Dawson has recently submitted a grant with Dr. Patricia Wright in Ranomofauna National Park and the Global Canopy Program to develop ecotourism and promote biodiversity in the Ranomofauna area.

Terry Dawson has submitted a proposal to work on the development of a marine biosphere reserve in the western part of the country with Andrew Cook, a conservation consultant to the Malagasy government.

The NGO Azafady has invited the University of Oxford to assess the feasibility of assisting them with GIS and remote sensing applications in developing a community conservation project in St. Luce. They have recently applied to the EU for funding of this project.

We have provided consultations to World Wildlife Foundation on remote sensing, aerial surveys and GIS.  A representative of WWF Madagascar has recently received funding from Conservation International to pursue community conservation work in Ifotaka and aerial surveys will be a crucial part of this. We have provided on going advice on how to conduct the surveys and process the data.

## Sustainability and Legacy

What project achievements are most likely to endure? What will happen to project staff and resources after the project ends? Are partners likely to keep in touch?

- Online plant database
- Training
- We have developed a framework for monitoring forest condition using field collected data and satellite imagery, which will be transferred to local organizations and people once methods are refined.
- Thematic Maps for conservation planning: We have actively been disseminating the aerial photograph mosaic of Mandena to local collaborators who want to use it for conservation planning and will disseminate thematic maps of basal area and biodiversity (once completed) to interested parties.
- All of the project members are planning to stay active in the area after the project has ended.
- Terry Dawson and Paul Smith are members of the Biodiversity planning External advisory committee for QMM, which will be operating in the area for 50 years if the mining proceeds.
- It is planned that all research findings will be submitted for publication and disseminated to the host country in the formats most useful to them (which will be determined in May 2003).

**Have the project's conclusions and outputs been widely applied? How could legacy have been improved?**

At this stage, we are still finishing analyses and preparing reports for dissemination. The legacy will be more measurable after these reports and results have been completed and disseminated.

**Are additional funds being sought to continue aspects of the project (funds from where and for which aspects)?**

Yes. Three years is a short amount of time to understand the natural environment and to then assist with the development of conservation programs that are appropriate for this area. Thus, we are seeking more funding for research and conservation in the region and in other parts of Madagascar. The knowledge and relationships we have gained over the last three years are, themselves, valuable and take time and effort to build. Thus, such a knowledge base and relationships should be maintained as part of an ongoing commitment to Madagascar and its people.

## Value for money

**Considering the costs and benefits of the project, how do you rate the project in terms of value for money and what evidence do you have to support these conclusions?**

Conservation practice needs to be based upon sound scientific research and the independent role of universities is central to this. However, to ensure that the research is targeted and used effectively, it is crucial to engage those stakeholders, who are actively involved in and impacted by biodiversity conservation. QMM will have an enormous impact in the region through their mining operation. Throughout the Darwin project and beyond and through the on-going advisory committee, our role together with our collaborating partners has aimed to ensure that corporate biodiversity conservation strategies are based upon research and environmental and social ‘best practice’. Our advice has been given to QMM and often adopted by QMM’s environmental team. Thus, in contributing to biodiversity conservation and livelihood security, the project value is priceless.

**Author(s) / Date**

30 April 2003-04-28

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## Appendix I: Project Contribution to Articles under the Convention on Biological Diversity (CBD)

Please complete the table below to show the extent of project contribution to the different measures for biodiversity conservation defined in the CBD Articles. This will enable us to tie Darwin projects more directly into CBD areas and to see if the underlying objective of the Darwin Initiative has been met. We have focused on CBD Articles that are most relevant to biodiversity conservation initiatives by small projects in developing countries. However, certain Articles have been omitted where they apply across the board. Where there is overlap between measures described by two different Articles, allocate the % to the most appropriate one.

| **Project Contribution to Articles under the Convention on Biological Diversity** | | |
|---|---|---|
| **Article No./Title** | **Project %** | **Article Description** |
| **6. General Measures for Conservation & Sustainable Use** | 5 | Develop national strategies which 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 which have adverse effects; maintain and organise relevant data. |
| **8. In-situ Conservation** | 20 | 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** | 20 | 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** | 20 | 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** | 5 | 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** | 5 | 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** |

## Appendix II Outputs

Please quantify and briefly describe all project outputs using the coding and format of the Darwin Initiative Standard Output Measures.

| Code | Total to date (reduce box) | Detail (←expand box) |
|---|---|---|
| **Training Outputs** | | |
| 1a | Number of people to submit PhD thesis | 4, J. Carter Ingram, James Watson, Helene Ralimanana, Franck Rakotonasolo |
| 1b | Number of PhD qualifications obtained | |
| 2 | Number of Masters qualifications obtained | 2, Scott Henderson and Amanda Kennedy |
| 3 | Number of other qualifications obtained | 1, Rose Askew, BA degree |
| 4a | Number of undergraduate students receiving training | 6, training with Jorg Ganzhorn |
| 4b | Number of training weeks provided to undergraduate students | 1, training course with Jorg Ganzhorn |
| 4c | Number of postgraduate students receiving training (not 1-3 above) | 13, training course with Jorg Ganzhorn<br>1, Smithsonian Biodiversity Course |
| 4d | Number of training weeks for postgraduate students | 5, Smithsonian Biodiversity Course<br>1,course taught by Jorg Ganzhorn |
| 5 | Number of people receiving other forms of **long-term** (>1yr) training not leading to formal qualification( i.e. not categories 1-4 above) | 1, Helene Ralimanana who has worked on the project from 2001-2002<br>1, Ramesy Edmonds who has participated in every field campaign |
| 6a | Number of people receiving other forms of **short-term** education/training (i.e not categories 1-5 above) | 5, QMM staff presented with aerial photography techniques by Terry Dawson<br>5, QMM staff trained by Jorg Ganzhorn in ecological assessment techniques<br>1, J. Carter Ingram and Terry Dawson assisted WWF Malagasy staff in GIS and remote sensing techniques<br>1, J. Carter Ingram assisted QMM botanist in experimental design and analysis<br>3, J. Carter Ingram trained Malagasy foresters in ecological assessment techniques<br>1, J. Carter Ingram trained research assistant in ecological assessment |

| Code | Total to date (reduce box) | Detail (←expand box) |
|---|---|---|
| | | techniques |
| 6b | Number of training weeks not leading to formal qualification | 11 |
| 7 | Number of types of training materials produced for use by host country(s) | 1 plant database/pictorial guide<br>1 GIS/Remote Sensing guide book (in progress)<br>1 Video on mining in Madagascar<br>1 Website with project details and online plant database |
| **Research Outputs** | | |
| 8 | Number of weeks spent by UK project staff on project work in host country(s) | 8, Terry Dawson<br>20, J. Carter Ingram<br>3, Aaron Davis<br>2, Scott Henderson |
| 9 | Number of species/habitat management plans (or action plans) produced for Governments, public authorities or other implementing agencies in the host country (s) | |
| 10 | Number of formal documents produced to assist work related to species identification, classification and recording. | 1, plant data base and manual of scientific and vernacular names and photographs of endemic species |
| 11a | Number of papers published or accepted for publication in peer reviewed journals | |
| 11b | Number of papers published or accepted for publication elsewhere | 1<br>3 submitted |
| 12a | Number of computer-based databases established (containing species/generic information) and handed over to host country | 1, plant data base |
| 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) | 1, to be handed over in May 2003 |
| 13b | Number of species reference collections enhanced and handed over to host country(s) | |

| | | |
|---|---|---|
| **Dissemination Outputs** | | |
| 14a | Number of conferences/seminars/workshops organised to present/disseminate findings from Darwin project work | 6 |
| 14b | Number of conferences/seminars/ workshops **attended** at which findings from Darwin project work will be presented/ disseminated. | 4 |
| 15a | Number of national press releases or publicity articles in host country(s) | |
| 15b | Number of local press releases or publicity articles in host country(s) | |
| 15c | Number of national press releases or publicity articles in UK | 1 |
| 15d | Number of local press releases or publicity articles in UK | 1 |
| 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 | 35 |
| 17b | Number of dissemination networks enhanced or extended | 5 |
| 18a | Number of national TV programmes/features in host country(s) | |
| 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) | |
| 21 | Number of permanent educational/training/research facilities or organisation established | |
| 22 | Number of permanent field plots established | |
| 23 | Value of additional resources raised for project | |

**Appendix III: Publications**

Provide full details of all publications and material that can be publicly accessed, e.g. title, name of publisher, contact details, cost. Details will be recorded on the Darwin Monitoring Website Publications Database that is currently being compiled.

Mark (*) all publications and other material that you have included with this report

| **Type *** (e.g. journals, manual, CDs) | **Detail** (title, author, year) | **Publishers** (name, city) | **Available from** (e.g. contact address, website) | **Cost £** |
|---|---|---|---|---|
| ***Conference proceedings** | The use of digital aerial photography for understanding the relationship between forest canopy structure and biodiversity, Ingram, J.C., Henderson, S. & Dawson, T. (2001) | Remote Sensing & Photogrammetry Society, Nottingham, UK | Jane Carter Ingram, cingram@eci.ox.ac.uk | N/A |
| ***Journal (submitted)** | Dynamic patterns of vegetation change within the forests of Madagascar, Ingram, J.C., Dawson, T. and R. Whittaker (2003) | Environmental Conservation, Newcastle, UK | Jane Carter Ingram, cingram@eci.ox.ac.uk | N/A |
| ***Journal (submitted)** | Inter-annual analysis of deforestation hotspots in Madagascar from high temporal resolution satellite observations, Ingram, J.C. and T. Dawson (2003) | International Journal of Remote Sensing, Dundee, UK | Jane Carter Ingram, cingram@eci.ox.ac.uk | N/A |
| ***Journal (submitted)** | Assessment of avifauna in littoral forests, Watson, J. and T. Dawson (2003) | Biodiversity and Conservation, Canterbury, UK | James Watson james.watson@geog.ox.ac.uk | N/A |

## Appendix IV: Darwin Contacts

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

| | |
|---|---|
| **Project Title** | Sustainable development of Madagascar's littoral forests |
| **Ref. No.** | 162/9/006 |
| **UK Leader Details** | |
| Name | Terry Dawson |
| Role within Darwin Project | Principal Investigator |
| Address | Environmental Change Institute,<br>1a Mansfield Road, Oxford, OX1 3SZ |
| Phone | |
| Fax | |
| Email | |
| **Other UK Contact (if relevant)** | |
| Name | Jane Carter Ingram |
| Role within Darwin Project | Project Manager, affiliated to the Environment and Development Group and seconded by the University of Oxford for this project |
| Address | Environmental Change Institute,<br>1a Mansfield Road, Oxford, OX1 3SZ |
| Phone | |
| Fax | |
| Email | |
| | |
| **Partner 1** | |
| Name | Paul Smith |
| Organisation | Royal Botanic Gardens, Kew |
| Role within Darwin Project | Co-investigator |
| Address | Royal Botanic Gardens, Kew<br>Seed Conservation Department<br>Wakehurst Place<br>Ardingly, W. Sussex RH17 6TN<br>U.K. |
| Fax | |
| Email | |

## References not included in attached manuscripts

Lowry, P., Smith, P. and Raymond Rabevohitra (1999) Review of MIR Télédetection Inc. Deforestation Study in the Region of Fort-Dauphin (Tolagnaro), Madagascar. Submitted by Missouri Botanical Garden, USA.

Smith, Paul (2001) International co-ordinator for Southern Africa & Madagascar, Royal Botanic Gardens, Kew, personal communication.