Biodiversity surveys of Mariarano and Matsedroy tropical dry forests and associated wetlands, Western Madagascar

2010 - 2012

Status report

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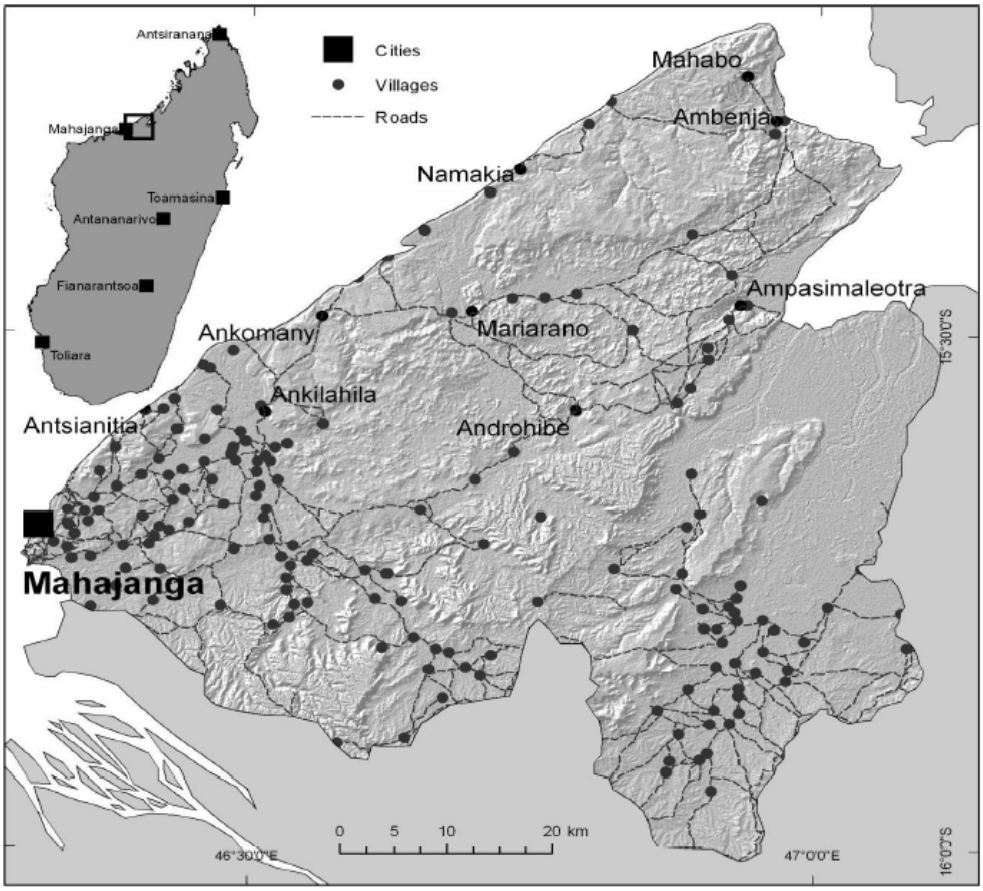
Introduction

The Mahamavo region in Western Madagascar contains relatively large blocks of intact western dry forests and wetland ecosystems. A consortium comprising Development and Biodiversity Conservation Action for Madagascar (DBCAM), Operation Wallacea and the University of Oxford has been conducting a programme of biodiversity surveys and monitoring since 2010 in this area. DBCAM is a grass-roots Malagasy conservation NGO. Operation Wallacea is an international volunteer-based NGO which supports conservation research through academic partnerships. The University of Oxford is a research intensive university.

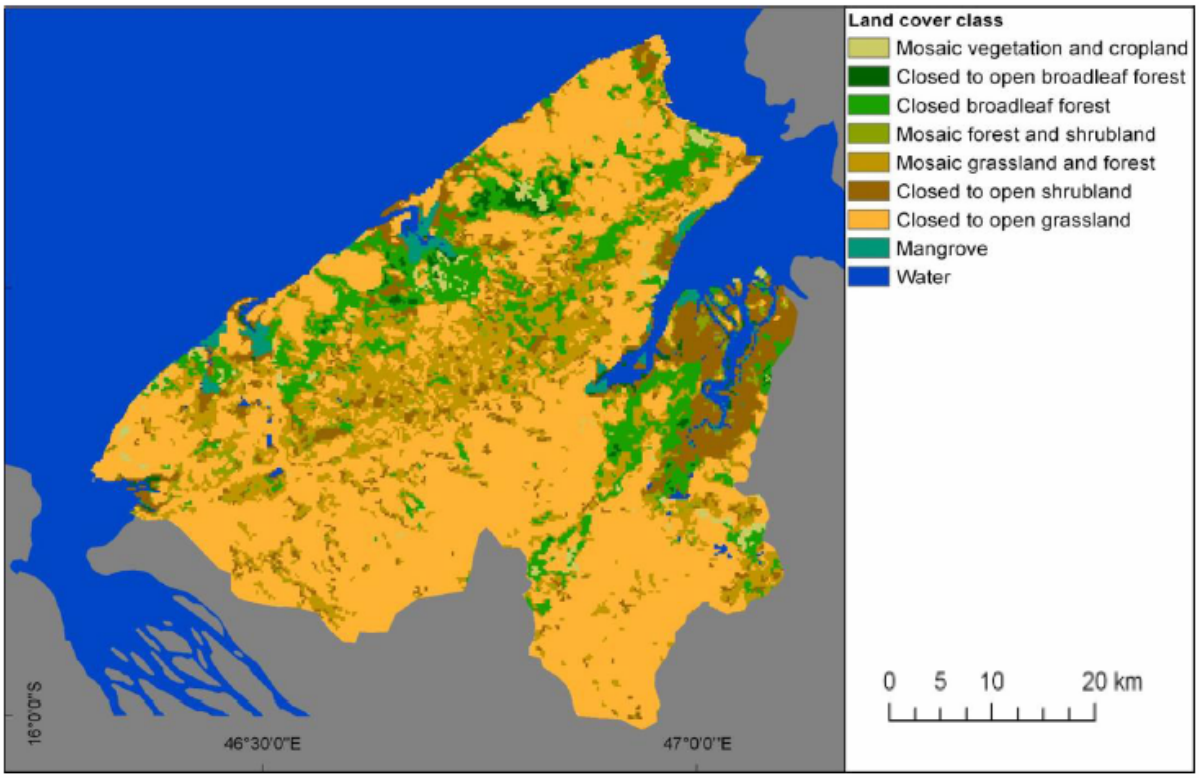
The Mahamavo region has received relatively little study, yet supports considerable biodiversity including globally threatened flowering plants, reptiles, birds and mammals. Flagship species for the area include Fish eagle, Coquerel's sifaka and Angel's and Oustalet's chameleons. Forests in this area are currently threatened by fires, charcoal production and agricultural expansion.

This project is a landscape-scale long-term monitoring programme of multiple taxonomic groups. The aims of the research project are to identify which species are present in the Mariarano and Matsedroy forests, to characterize spatial patterns and temporal trends in biodiversity, to monitor the condition of the forest habitat, and to contribute revenue to local villages and leverage further funding for environmental projects from the research results. Additionally, we aim to assimilate data from the biodiversity surveys in Mahamavo into global datasets and indicators including the Living Planet Index (LPI) and the Global Biodiversity Information Facility (GBIF).

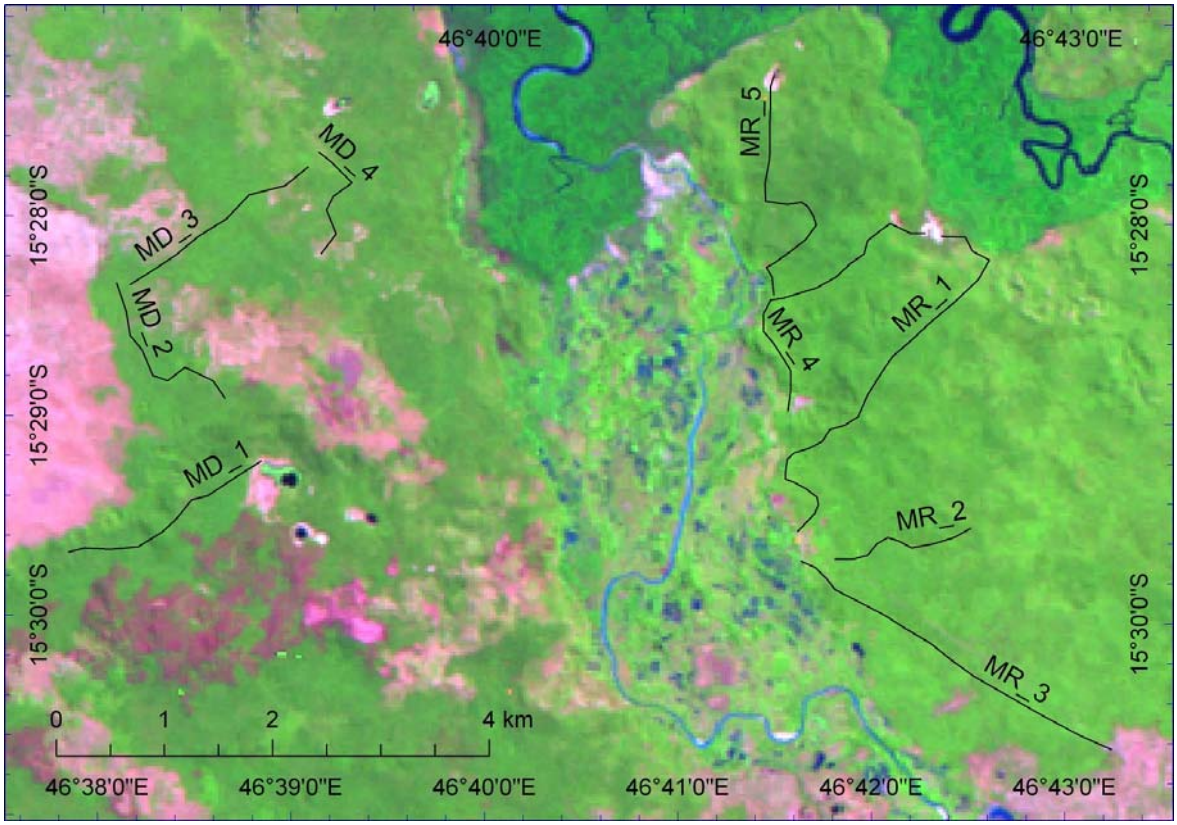
We believe that it is particularly important to undertake long-term biodiversity surveys in Mahamavo because this watershed is a large dynamic landscape which is experiencing changes in land cover and configuration. Climate change is also a potential threat to the persistence of biodiversity features in Mahamavo. Biogeographically, the Mahamavo region is a transition are between Northern and Western species pools, which means that potentially very large numbers of species may be found here, and there is great potential to document range extensions. The region does not contain any protected areas and has received relatively little scientific study.



Location of the Mahamavo watershed in Madagascar and major villages and roads in the study area.



Land cover classes in the Mahamavo watershed. Data derived from ESA Globcover.



Spatial sampling framework in Mariarano and Matsedroy forest in relation to a 2012 false colour composite of Landsat 7 data.

Mariarano's 2007 population was 2152. The majority of these people are subsistence level farmers, and almost all are involved in rice cultivation for their own consumption. Manioc and maize are also cultivated. Three-quarters of the population own zebu. Other activities include mat-weaving (75% of households) and Raphia sp. harvest. Around 60% of households are involved in charcoal production, and around 10% extract forest resources.

Biomass, mainly charcoal and wood, is the most commonly consumed fuel in Madagascar, comprising 84.9% of total energy consumption. Charcoal production is intensifying, with an increase in charcoal production from 0.65 to 1.03 Mt of charcoal between 2000-2008. This has contributed significantly to levels of deforestation across Madagascar.
In Mariarano, up to 60% of households take part in charcoal production (Ackermann, 2003). Some is consumed locally, but much is destined for sale in Mahajanga, transported either by collectors or by the producers themselves, often by sea to avoid additional charges. The rough price attained for sale to 'middle men' per sack is 1500ar (roughly $USD 0.70). These are reportedly sold on for 5000MGA

Charcoal pits were noticeably more numerous between 2010-2012, with several pits established within around the research camp at Matsedroy, where direct felling of live trees for charcoal pits was observed daily. Whilst forest fires are illegal, key informants expressed suspicion at a large forest fire in 2009 that has since allowed a large expanse of dry forest to be exploited for charcoal production. Villagers claim external exploitation is a big problem, and we witnessed a member of another village, clear felling for a large charcoal pit close to the research camp. However, with little official enforcement, and the potential for conflict, local people feel they have no power, or incentive to stop this.

Charcoal production is technically a licensed activity, under the control of the MEF. Despite this, people in the area were not aware of any permission needed to produce charcoal, and they noted very little MEF enforcement present in the area.

With no charcoal plantations in the area all charcoal produced locally comes directly from burnt forest or from the forest itself. As such, the current levels and potential growth of charcoal production are not sustainable in the area, especially given the slow regeneration of dry forests.

In the rainy season rice stocks typically fall, and local people turn to other food sources. One of the most important is Yam (Discorea spp.), of which an estimated 23,800 kg is consumed each year (between 123 households). As Discorea spp. grow best in areas with good light levels, they are often found in recently burnt forests, where it is also easy to harvest them.

Illegal timber extraction is a huge driver of ecosystem degradation and habitat loss, a driver that has been exaggerated since the political crisis of 2009, with weakened governance of natural resources in general.

In Mariarano, timber extraction is commonplace, with 20% of the local population listing timber extraction as a livelihood Dalbergi baroni, Foetidia asymmetrica, are the main targets, sold on in Mahajanga for furniture, along with local non-precious wood for construction. Ceriops tagal is also extracted from the mangroves (Washington et al., 2009). Much of the timber is transported to Mahajanga by boat, but we also observed trucks moving timber out of the area, often at night.

Livestock keeping is a livelihood a large majority of local people in Mariarano are reliant upon (80% of the population) Slash-and-burn to clear new zebu pastures, and subsequent burning to encourage nutritious new growth, is one of the major causes of habitat loss in the area, along side that to provide more areas to grow crops.

Hunting of lemur species is relatively common in the area, mostly of Common Brown Lemurs, *Eulemur fulvus* (NT). The Coquerel's Sifaka, *Propithecus coquereli*, (EN) are subject to a *fady* forbidding their hunting. However, recent immigrants into the area do not follow this *fady* and hunting of this species have been noted in the area.

The presence of charismatic threatened species such as the Madagascar Fish Eagle, Coquerel's Sifaka, Fosa, Uroplatus geckos provides an excellent opportunity to promote conservation of the region. However the presence of feral cats and dogs in these area is an issue that warrants further study, as they could be involved in competition with endemic carnivores, and over-predation of small mammal species.

The area itself is at risk of further loss and reduction in quality of habitat, and to ensure it's maintenance as a key site for biodiversity, urgent action is needed.

Methods

The Mahamavo watershed lies between the larger Betsiboka and Sofia rivers. Within this large area, we have focused our research in Mariarano village. We have established a spatial sampling framework based around nine forest sample routes, each approximately 4km long, which are stratified with respect to forest condition and configuration. For some sampling activities the routes are sample units, whereas for others, the routes are paths used to access around 150 sample sites. Additionally, wetlands are sampled by boat along 6 standard routes and opportunistic observations of animals and plants are collected throughout the wider landscape.

In order to draw valid inferences about trends in relative abundances, all sample units are sampled on repeated occasions by each survey method during a field season. In the field, spatially-referenced observations are recorded on paper data sheets, which are then entered into a custom database. This permits the field data to be queried in multiple ways and combined with ancillary spatial data for further analysis.

Forest structural properties are measured in 150 plots each 20m by 20m. At each plot the circumference and height of all trees with diameter greater than 5cm are measured. Flowering plants are also sampled in plots. In plots, as many species as possible are identified and recorded together with co-ordinates.

Dragonflies are collected individually with a butterfly net. Specimens are killed in 70% ethanol, and preserved wet (in vials with 70% ethanol) or dry (in glassine envelops).

Zooplankton samples are collected by filtering water collected with a 10 liter bucket in a zooplankton net (33 micrometer mesh size). Water is collected from as many different places in the water column, by wading in the lake, aiming to include water from around different species of water plants.
Macro invertebrate and larger zooplankton samples are collected with a kick net (200 micrometer mesh size). Kick netting to collect larger aquatic Crustacea (e.g. Decapoda and Conchostraca) occurs. Aquatic Crustacea, zooplankton and macroinvertebrate samples are killed and preserved in 70% ethanol. Samples are stored in whirlpacs or 250ml plastic containers.

Spiders are collected quantitatively and opportunistic. The quantitative surveys are at night. Spiders are collected manually based on reflection of torchlight in the eyes. Surveys take 1 hour in a particular location. Spiders and scorpions are sampled opportunistically. Aranea are killed and preserved in 70% ethanol, stored in small vials or whirlpacs.

Butterflies are collected individually by net and killed by squeezing the thorax. Specimen are stored in glassine envelops and kept in Tupperware boxes with silica gel to keep it dry, and mothballs against invertebrate deterioration. Opportunistic encounters of two families of moths (Sphingidae and Saturnidae) are also collected.

Coleoptera are collected in opportunistic encounters, killed and preserved in 70% ethanol and preserved in small vials.

Reptiles and amphibians are sampled by walking sample routes on multiple occasions by day and night, as well as by opportunistic searches. When a reptile or amphibian is found, it is identified and recorded with its location. Crocodiles are surveyed opportunistically and by boat along 6 wetland sample routes.

Forest birds are surveyed using 10 minute early point counts in 150 sample sites on at least 3 occasions per year. When a cluster of birds is detected, the species, group size, distance to birds, method of observation (seen, heard) and site co-ordinates are recorded. Additionally terrestrial birds are recorded opportunistically. Wetland birds are also surveyed by boat along 6 wetland sample routes.

Mammals are sampled by walking sample routes on multiple occasions by day and night, as well as by opportunistic searches. When a mammal is found, it is identified and recorded with its location. Mammals are also recorded opportunistically, by boat surveys and by mist netting bats and pitfall trapping small mammals.

Main results

Species lists and new records

In the period 2010-2012 the biodiversity surveys have recorded 254 plant, 106 bird, 5 amphibian, 35 reptile and 20 mammal species.

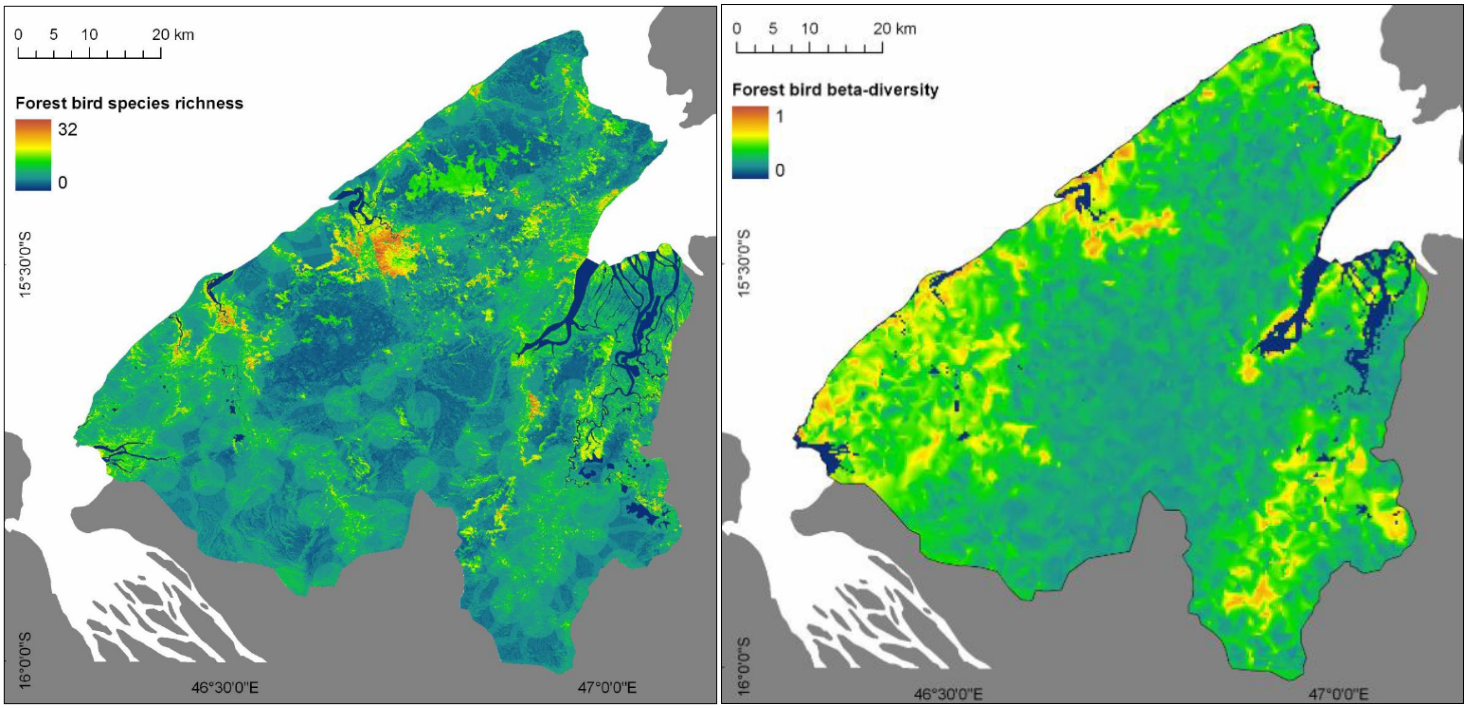
The science team have recorded new mammal record for the site including Macrotarsomys ingens and Phaner pallescens. . Five species of mammal were observed from the camera trap surveys, including the rarely observed Falanouc (Eupleres goudotti), and 4 species of introduced and invasive mammals including feral cats (Felis catus), dogs (Canis lupus familiaris) the Indian Civet (Vivvericula indica) and the Bush Pig (Potamochoerus larvatus). Although the endemic Fosa (Cryptoprocta ferox) was not directly observed, its tracks and scat were sighted on several occasions.

Reptile species, recorded in the Mahamavo forest for the first time during the DBCAM project include Ramphotyphlops braminus, Langaha pseudoalluaudi, Liophidium vaillanti, Voeltzkowia sp. aff. mira, Heteroliodon sp. aff. lava, and Ebenavia inguinis

Newly recorded birds in Mahamavo included Xenopirostris dammi and Eurystomus glaucurus. It is especially significant that A pair of Critically endangered Madagascar Fish Eagles and their nest site were recorded in the mangrove system. In the 2012 field season, at least one immature eagle was observed in the nest.

Patterns of biodiversity

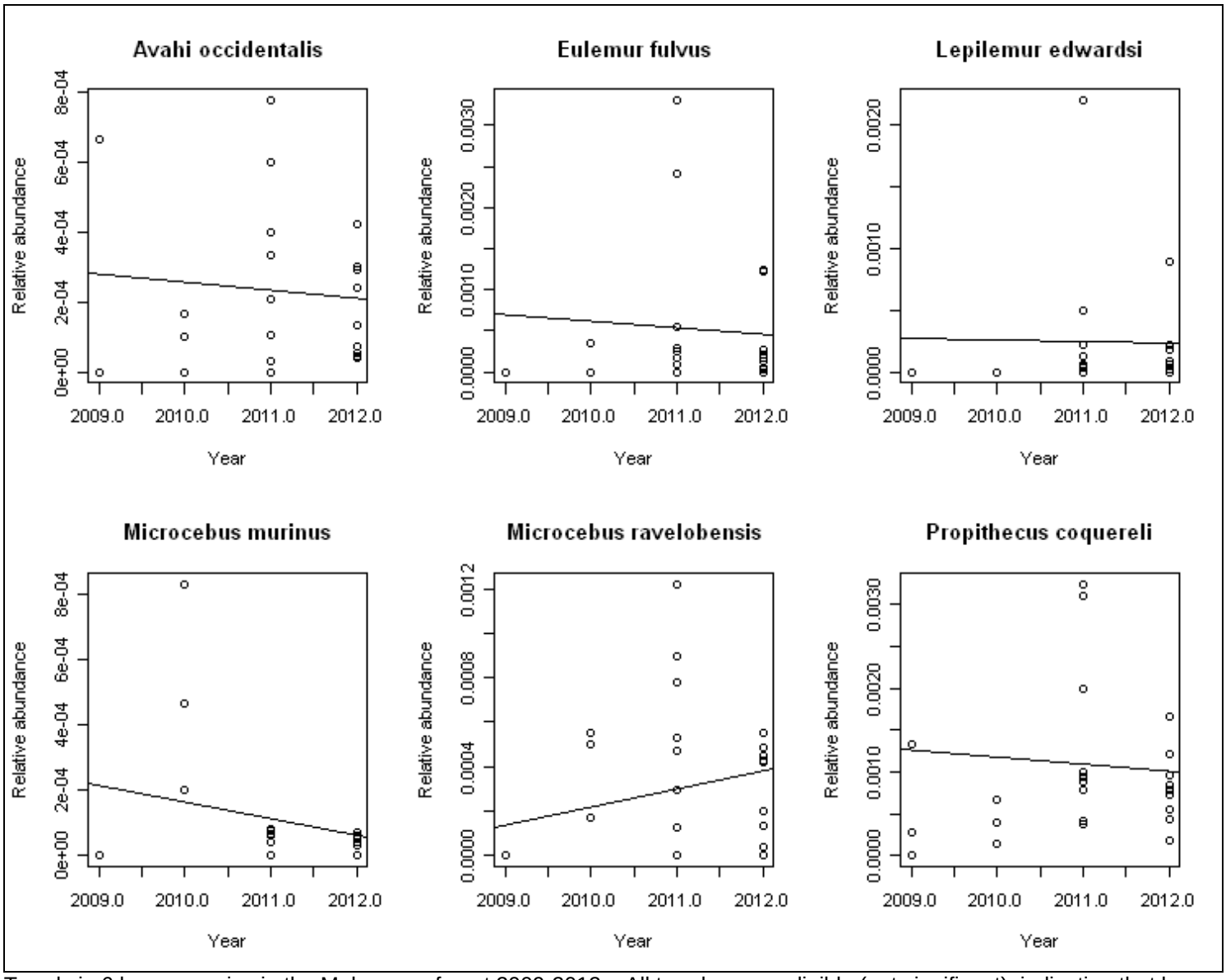
Species occurrence records have been integrated with maps of environmental covariates derived from remote sensing in order to understand patterns of biodiversity in the Mahamavo landscape. Analytical methods have included distribution models, generalised dissimilarity models, Mantel models of community dissimilarity and systematic conservation planning algorithms.



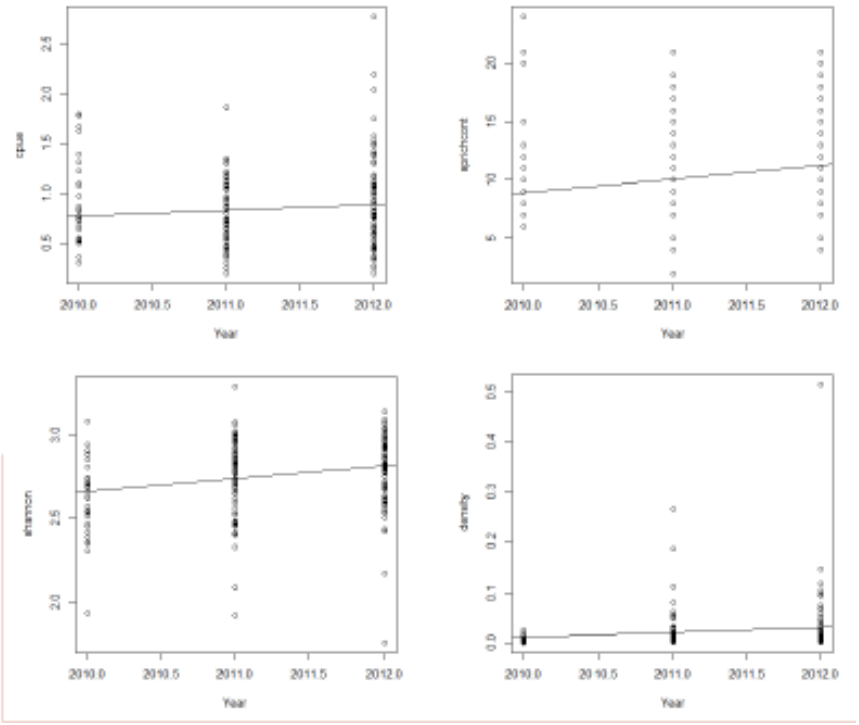
Patterns of bird alpha diversity and beta diversity in the Mahamavo watershed derived from species distribution models (Maxent) and generalized dissimilarity models (GDM).

Trends in biodiversity

Repeated sampling of multiple sample units, with careful recording of sampling effort has allowed us to use the records in the biodiversity monitoring database to monitor temporal trends in selected communities over time.



Trends in 6 lemur species in the Mahamavo forest 2009-2012. All trends are negligible (not significant), indicating that lemur relative abundances have not declined during the period of the monitoring programme.

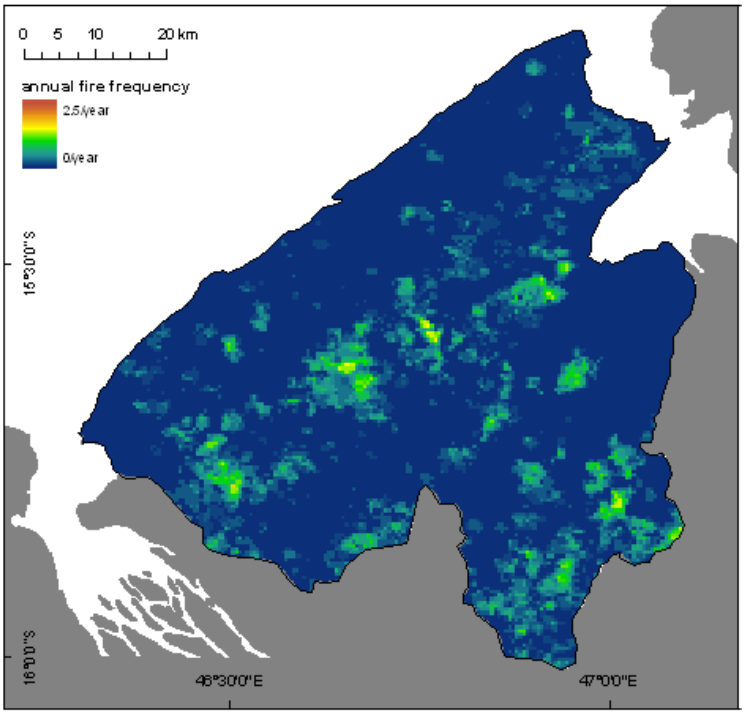


Trends in forest birds community attributes in Mahamavo during the monitoring programme in the period 2010-2012 i) relative abundance, ii) species richness, iii) Shannon-Wiener diversity, iv) Density. These slight increases are significant, indicating that the Mahamavo forest has remained in favourable condition for birds in recent years.

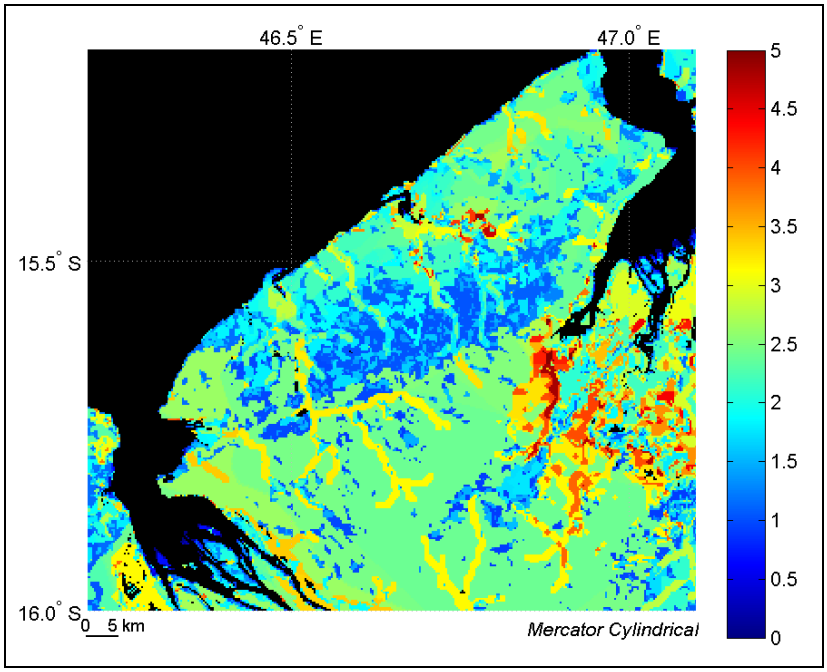
Power analysis of monitoring data using simulations has also confirmed that the monitoring methods do have the power to detect trends and that if further resources were to be available, the best ways to enhance the monitoring programme would be to add further sample units in preference to expending effort on sampling the existing units on further occasions.

Remote sensing and modeling of environmental change

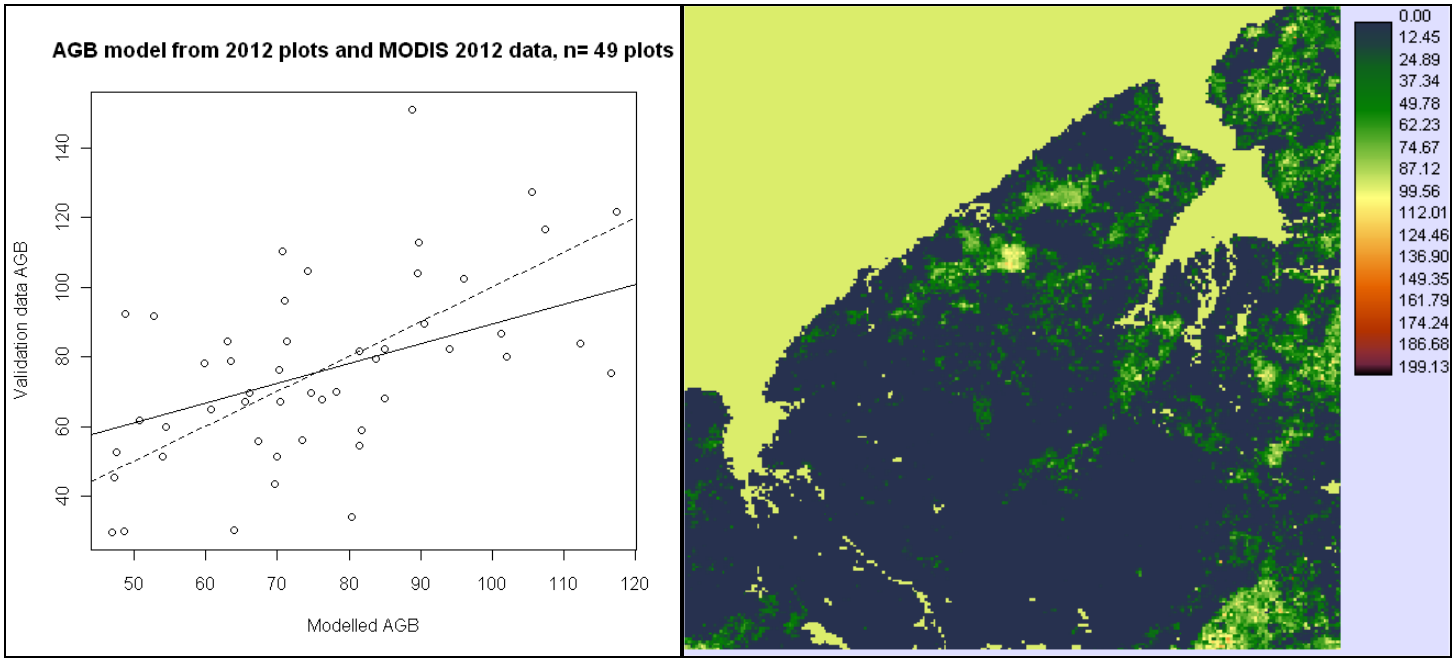
Satellite data has been particularly useful in monitoring the dynamics of the complex landscape in Mahamavo. Here we present some key findings from modeling based on earth observation data.



A 12 year time series of MOD45 monthly burned areas has allowed use to construct a “climatology” of burning and identify locations in the Mahamavo savanna landscape most frequently burned, and hence identify forest areas most at risk from fires from adjacent savanna.

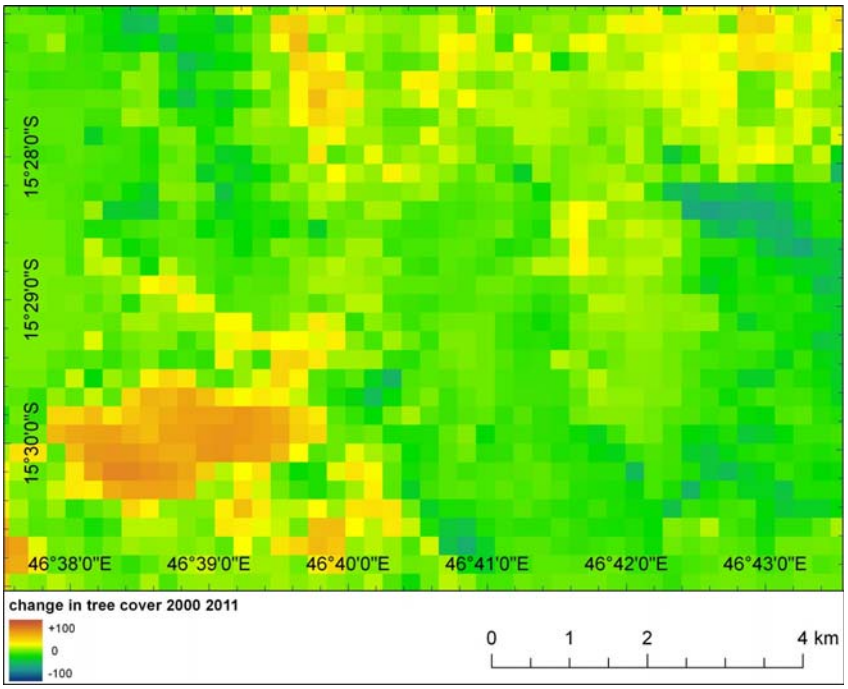


The long-term landscape scale multi-taxa monitoring in Mahamavo has been valuable in allowing validation of global models of ecosystems. This figure shows the resulting Summary Ecological Value of the Mahamavo landscape produced by a Local Ecological Footprinting Tool (LEFT) analysis.



i) Validation plot for an Above Ground Biomass (AGB) model using forest plot data and remote sensing covariates including reflectance and volumetric scattering from MODIS data ii) Map of modeled Above Ground Biomass in Mahamavo in 2012. Such data is very useful in planning carbon projects to enhance livelihoods and meet conservation goals.

To complement biophysical inversion methods for AGB, it is also possible to use linear spectral unmixing to detect changes in proportional cover of elements of land cover.



Change in MOD44B proportional tree cover in study area between 2000-2011. This figure has the same extent as the navigation map showing the sample routes. The main change is a significant regeneration of a forest block South of Matsedroy, which would be an interesting place to sample in future.

Potential Conservation Strategies

No conservation measures are currently present in the area, and no protection is afforded to it by the government. We suggest an array of possible strategies for long-term conservation in the area:

Projects to improve livelihoods, by several potential methods:
- Improvement of local educational facilities, with integrated sustainable natural resource and agricultural curricula.
- Training local people in sustainable agricultural methods to increase rice yields, for example improvements in irrigation management.
- Development of alternative livelihoods, such as sustainable charcoal production, an activity which could provide a stable income in times of food shortage, relieve pressure on the forest and, potentially, improve soil in severely degraded areas.
- Introduction of more fuel-efficient and cleaner cooking stoves, to reduce incidence of fuel-related disease and reduce consumption of charcoal, relieving pressure on the forest and lowering costs of living for households.
- Potential for new alternative energy source exploitation, e.g. solar panel plants.

Establishment of a research station in the area would allow maintenance of a long-term, holistic presence in the area. Through this, management efforts can be monitored to assess their effectiveness, in implementation and results. This can also allow for a very important degree of flexibility in the management strategies, as a year-round presence can allow consultation and adjustment, where necessary, at all stages of the process. Doing this side-by-side with a small, manageable and carefully controlled ecotourism venture could provide year-round employment (Our field season at the moment employs up to 30 local people during our 6-week visit.), whilst furthering the incentive for preserving local biodiversity to local people.

The Mariarano forest harbours considerable biodiversity, yet is unprotected and rapidly diminishing. As such, urgent, substantial integrated conservation and sustainable development action is necessary to preserve this refuge of dry forest diversity.

Research projects in Mahamavo in 2012

Reptile colour

Zoe Crookes, Derby University
Emma Roberts, Derby University
Chanel Draga, University of Southampton
Bradley Williams, University of Southampton
William Webb, Penn State University

This project is focused upon quantifying the colours and colour change abilities of the chameleons *Furcifer oustaleti* and *Furcifer angeli*, and the leaf-tailed geckos *Uroplatus ebenaui, Uroplatus henkeli and Uroplatus guntheri.* Chameleons can be both very brightly coloured and also very cryptic, they often exhibit very rapid colour changes, but this is almost exclusively used for communicating social status to nearby conspecific individuals. The Uroplatus geckos appear to use colour change for background matching. In this project, reflectance spectrophotometry will be used to accurately quantify the colours of reptiles and their substrates to test hypotheses concerning the circumstances in which colour changes occur.

Behavioural ecology of Coquerel's sifaka

Sinead Reynolds, University of Glasgow
Ruth Crawford, University of Gloucestershire
Shea O'Driscoll, University College Dublin
Emma Roberts, Derby University
Lauren Shinkwin, University College Dublin
Amy Edwards, University of Southampton

There are semi-habituated groups of Coquerel's sifaka *Propithecus coquereli* in the Mahamavo forest which can be readily observed . This species is active during the day and lives in small family groups. They appear to favour large fruiting trees. In this project, behavioural observations on multiple occasions will be used to test hypotheses concerning habitat selection and allocation of time budgets to activities such as feeding or vigilance at different times of day and in different habitat contingencies such as canopy height and distance from the forest edge.

Niche partitioning in chameleons

Isabel Reid, University of Oxford
Robbie Martin, Bangor University
Alice Lett, University College Dublin
Craig Mathieson, Derby University

The Mahamavo dry forests support a diverse reptile assemblage. Competitive exclusion theory suggests that sympatric species must partition their niches in some way to persist. In Mahamavo there are two chameleon species, *Furcifer angeli* and *Furcifer oustaleti*. It is thought that *F. oustaleti* prefers more degraded habitat to *F. angeli*, but additionally these species may also be selecting different microhabitat niches in terms if height above ground selcted for feeding, branch thickness or substrate temperature. This project will test for competitive interaction and identify how niches are partitoned between these species.

Population ecology of crocodiles

Jamie Neaves, University of Southampton
Caroline Jablonicky, University of Southern California

In Madagascar the Nile crocodile *Crocodylus niloticus* have strongholds in isolated areas of the west coast including the Mahamavo wetlands. However crocodiles are threatened by egg collection for crocodile farms and by local people killing large crocodiles perceived to be a threat. For these reasons, crocodiles are currently listed on CITES Appendix II in Madagascar and international trade in crocodile products from Madagascar is banned. Since there is very little information bout the crocodile population in Mahamavo, this project will undertake a baseline boat survey and estimate population size.

Spatial behavioural ecology of colubrid snakes

Tom Williams, University of Oxford

Three of the species of colubrid snake in Mahamavo, *Mimophis mahfalensis, Leioheterodon madagascariensis* and *Madagascarophis colubrinus* are abundant and can be safely handled and marked. This sytem is being used to allow capture mark recapture analysis to estimate population sizes and, additionally the locations of repeated captures allow determination of territory size in relation to individual characteristics such as species, size and sex. The objective is to test hypotheses relating territory characteristics to characteristics of individuals to better understand the spatial aspects of behaviour in these species.

Landscape ecology of reptiles
Kate Munday, University of Nottingham

The Mahamavo landscape is a complex mosaic of patches which differ in their size, configuration and recent disturbance history. In this project, data on the relative abundance of all reptile species in landscape units will be joined with satellite derived data on the same units to investigate how reptile species respond to landscape configuration. In particular the goal is to identify if any reptile species are area sensitive, edge sensitive or isolation sensitive, and if so to test for any association between species characteristics such as mean body mass and dispersal capabilities. This research will potentially help predict species responses to future environmental change, especially land cover change.

Community ecology of reptiles
Joel Dixon, Northumbria University

Mahamavo supports a very large assemblage of reptiles. In any given location the assembled reptile community will have been shaped by the abiotic characteristics of the habitat, by the configuration of the landscape affecting how species may move, and by interactions between species. This research project will use a high quality time-series dataset to evaluate the relative important of habitat, landscape and biological factors in structuring both the entire reptile community and also individual guilds.

Species distribution models for lemurs
Lucy Thorp, Northumbria University
Hollie Poulter, University of Nottingham

Species distribution modeling is a technique for linking spatially referenced records of species occurrence – for example collected during appropriately designed field-based biodiversity monitoring programmes – with maps of environmental variables such as elevation, climate, vegetation or human disturbance, in order to create a statistical model of the relationship between a species and its environment, ie the species realised ecological niche. GIS can then be used to express the results of models as habitat suitability maps across a desired spatial extent. In this project, distribution models will b e built and validated for all lemur species observed in the Mahamavo dry forest.

Occupancy models for carnivores using camera traps
Lauren Cole, University of Hull

In the Mahamavo dry forest there have been a small number of sightings of carnivores including the Fossa *Cryptoprocta ferox,* Falanouc *Eupleres goudotti,* but not enough observations to infer their distributions or population sizes. The dry forests are also home to relatively large numbers of bush pigs *Potamochoreus larvatus*, feeding signs and droppings are often found, but the pigs are shy and very rarely encountered. We also have anecdotal evidence that there are feral domestic cats *Felis catus* in the forest, however since their density is unknown it is hard to evaluate if their presence is a significant threat to native biodiversity. For cryptic species such as these, we have deployed a network of camera traps to gain reliable data on distributions, densities and trends through time, without needing to trap animals.

Evaluating the efficacy of monitoring protocols for birds
Rachel Pickering, University of Oxford

It is only worthwhile to commit resources to a biodiversity monitoring programme if the methods being used would permit a significant trend of a certain magnitude in an indicator (say, 10% decline) over a specified period (say, over 3 years) to be detected with a desired level of confidence (eg 95%). This project will test whether our forest bird point counts satisfy these criteria by using power analysis. Performance of an indicator depends on the number of sample units, their spatial distribution, the number of sampling occasions on each unit each year, the prevalence in the landscape and detectability of the species of interest, the underlying variance in the state parameter estimated (ie. density, occupancy, relative abundance), and the level of disaggregation of the indicator (eg by individual species or by groups).

Systematic conservation planning
Russell Speight, Northumbria University

Given the scarce resources available for land management for biodiversity conservation, it is important to use resources in the most efficient possible way to maximize conservation benefits. In this project, species distribution models for flowering plants, amphibians, reptiles, birds and mammals will be used to produce inputs for a systematic conservation planning algorithm to map the relative irreplacability of land across the Mahamavo watershed which could inform future land use planning in this area.

Remote sensing of above ground biomass

Ross Hawton, University of Southampton

There is a critical need to develop and validate methods which could make use of the wide range of free satellite data available with global coverage, especially MODIS and LAndsat, to improve the estimation and monitoring of above ground biomass. Mahamavo offers an excellent case study site to address these issues since it is possible to access both tropical dry forest and savanna systems and because the environment has gradients of disturbance and degradation and is very dynamic such that validation sites which have experience a wide range of historical land cover change trajectories can be found.