Muséum National d'Histoire Naturelle

our planet reviewed
Taking a closer look at biodiversity hotspots

Expedition MADANG–2012 Papua New Guinea

Estimating biodiversity in Papua New Guinea & on the planet : Biodiversity research sustaining conservation by indigenous communities

The project will take place in the northern part of Papua New Guinea:

- The terrestrial component of the project will be located in two areas: the Wanang area (1) and the Mt Finisterre area (2).
- The marine component will be based at Madang and the marine surveys will explore the coastal areas ca 20km N and S of Madang (3), and deeper environments at regional scale in the Bismarck Sea (4), both with the support of the R/V Alis.

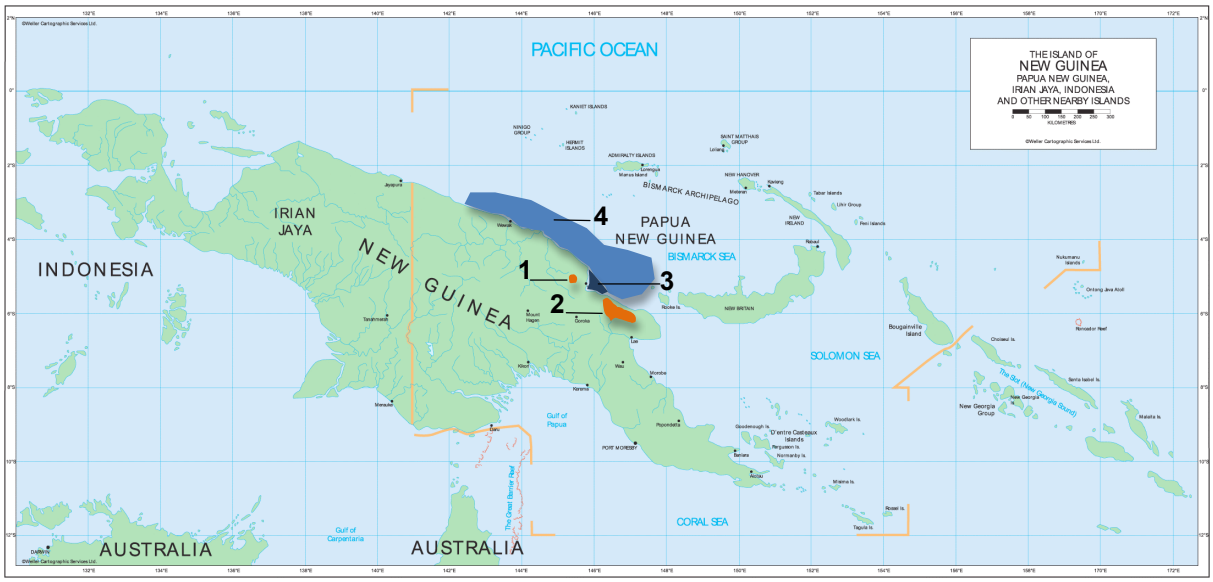

Fig. 1. Location of the study in New Guinea island

Background, the issues and challenges the project addresses

Papua New Guinea (PNG): an island of wilderness and one of the very few regions in the world where both terrestrial and marine biodiversity reach a maximum.

The island of New Guinea contains the third largest remaining area of tropical forest wilderness, after the Amazon and Congo basins. It is estimated that New Guinea supports five percent of global biodiversity whilst it covers less than 0.5% of earth's land area. Large enough to generate its own species diversity, New Guinea is regarded as a 'mini-continent' with a high proportion of endemic species not found outside the island. In plants for instance, the proportion of endemic species exceeds 70% of all species. PNG is also extremely rich from a cultural point of view, with over 850 indigeneous languages and traditional, rainforest dwelling societies.
It has been long acknowledged that maximum marine biodiversity, at least in shallow waters, can be found in the so-called "Coral Triangle" extending from the Philippines to Indonesia. In the last decade it was discovered that this zone of specific richness actually extends further to the East, to the Northern coast of PNG where Madang is located, and to the Solomon Islands. Due to local differences in the availability of experts and research resources we are far less familiar with this region than with the Philippines and Indonesian shallow waters. The Bay of Mandang was in fact declared a Priority Conservation Area in 2007 by the Australian WWF.

Increasing deforestation pressure in PNG

The study of New Guinea biodiversity is gaining urgency as the rate of deforestation is increasing. A recent analysis by a team of geographers based at the University of Papua New Guinea (Shearman et al. 2009) revealed that logging intensity has been accelerating since 1990, with deforestation rates in commercially accessible forests varying from 1.1% to 3.4% per year. Papua New Guinea is exceptional in being one of the few countries in the world where traditional customary ownership of the land, originating in its tribal past, is recognized by the country's modern legislation.
Papua New Guineans are thus among the most empowered landowners in the world, owning 97% of the land in the country. This makes village communities important players in the preservation of the enormous biodiversity on their lands. Viable alternatives to logging are much needed for communities willing to protect their forests.

Global warming and species altitudinal shifts

Unsustainable extraction of forest resources is not the only threat faced by PNG biodiversity. The scenarios of future climate change predict important shifts in altitudinal distribution of biodiversity. In particular, global warming can facilitate the expansion of lowland species to higher altitudes, as well as the disappearance of cold adapted/ high altitude ecosystems from the tropics. The altitudinal shifts in species distribution have already been documented in the Temperate zone (Warren et al. 2001) and, more recently, also in the tropics, on the neighboring island of Borneo (Chen et al. 2009).

These changes in species distribution are particularly important in New Guinea, one of the few areas in humid tropics with a complete altitudinal range of natural and intact ecosystems, including a well developed alpine zone.

Global Warming in the Warm Pool

The marine region including Madang is known by oceanographers as the Pacific Warm Pool, being the area in the world where the average water surface temperature is the highest. Baseline data are needed to document faunal change in Coral reefs and at greater depths and to discriminate between the effect of warming and that of human activities.

Estimating global species richness: the need for new data sets

The number of named distinct species of eukaryotic species on Earth is thought to be around 1.9 million, with approximately half of these (c. 1.1 million) being arthropods, predominantly insects (Chapman 2009). Tropical arthropods make the largest contribution to global species richness through described species and species awaiting formal description but known from museum collections. Within the arthropods the beetles are a commonly used surrogate group because they are functionally diverse and are the most species-rich order, with about one quarter of all species on Earth thought to be beetles. This is the main reason why an empirical method proposed by Erwin (1982), in which the number of beetle species associated with an individual tropical rain forest tree species is used as the basis for extrapolating a tropical/global estimate has become popular.
Yet, all estimates of insect species richness so far have been based on samples from lowland rainforests. This limitation is causing uncertainty in the estimates on several levels: (i) it is possible that high altitude plant species differ in species richness and host specificity of their herbivores, the two key parameters for host specificity estimates; (ii) plant-herbivore trophic interactions can vary with altitude as a particular species of herbivore can have different hosts at different altitudes and vice versa, and a particular plant species different herbivore communities at different altitudes, (iii) the ratio of herbivore diversity to that of predators and parasitoids at higher trophic levels can also vary with altitude.

Data on benthic fauna

The first issue in marine biodiversity estimates is to assess the actual species richness of the most species-rich groups, the Molluscs and Crustacea (nearly half of known marine species).
A second issue is taking into account rarity: in our main sample group, the Molluscs, we have shown previously that most species are naturally rare and can be collected only through a huge sampling effort, and that this feature – rarity – produces a false picture of the local and regional structure of biodiversity.
This leads to the third issue, which is the scale of the geographic variation in tropical marine faunas: so far nobody can tell whether regional variation in global composition is a result of restricted species distribution or inadequate sampling. One of the parameters for evaluating global species richness is the relative predominance of commensal, parasites and specialized predators in relation to total number of species. Our hypothesis is that this proportion increases as a function of the total number of species, but we ignore whether or not there is a geographic structure of parasitic faunas in one same host species.

Ways in which the project addresses the insufficiently covered needs

The need for new and large biodiversity data sets

The main impediment to accurately estimating species richness and its distribution is the lack of sufficient sampling. Creating adequate sampling and data sets necessitates considerable expertise and a substantial workforce.
For terrestrial diversity, the PNG Binatang Research Center (BRC) and the paraecologist approach provide the necesary workforce to tackle the above mentionned issues in rainforests. Paraecologists and parataxonomists are local assistants trained by professional biologists. They collect the primary biodiversity information (collect samples and environmental data, rear specimens, conduct field experiments) and process the material collected (sort, prepare, pre-identify, image and database specimens). The knowledge of the local environment by the paraecologists is an additional benefit. The BRC, the in-country project counterpart for the terrestrial component, is one of the pioneers in this parataxonomist/paraecologist approach.
Projects relying on this approach are able to comparatively process more samples and more rapidly publish results. It is successfully combined with postgraduate student training, as there are many synergies between the team of 18 parataxonomists and 4 local MSc students based at BRC. The student training further contributes to the capacity building in PNG.
For marine diversity, there is no such organisation and no parataxonomist training in PNG. We will explore, in connection with the BRC and the University of Papua New Guinea (UNPG), the possibility to duplicate this approach in the marine sector.
Based on our former experience, there is no doubt that most marine invertebrate species which will be collected are unknwon to science, and that there are, worldwide, insufficient experts to tackle this. This is why we have introduced and aim to further develop DNA barcoding, at least in the most diverse groups which are the Molluscs and the Crustaceans.

Although less accurate than taxonomic expertise, DNA barcoding provides a first estimate of the number and taxonomic position of the species collected, which can be kept for further study and monitoring. This in turn allows comparision of faunal richness and composition at a regional scale, which is impossible at this time due to the lack of sufficient expertise. Even without species names, DNA barcoding can give us an estimate of the number of existing species and is therefore crucial to managing conservation in little known faunas such as those along the N coast of PNG.

Global warming

Our data set will be the first base-line quantitative data set for plant and insect distribution along an altitudinal gradient in New Guinea, and one of the first detailed data sets from the tropics regarding marine and terrestrial ecosystems.
We will use it to simulate effects of different climate scenarios on biodiversity, including upwards shifts in altitudinal distributions of 600 m estimated for a 3.2°C average temperature increase over a century. These simulations will assess how many species will have reduced altitudinal ranges, including those reduced to zero ant thus driven to extinction, or gaps between their present distribution and the one expected due to global warming. We will also include the effect of reduced land area available to each species as they shift to higher elevations. In collaboration with a team of geographers lead by P. Shearman (University of PNG) we have already obtained land area measurements for different altitudes in New Guinea. The effect of reduced area is important, yet unexplored in previous models. Finally, we will also include the effect of habitat destruction as some of the land areas are deforested and have to be discounted as potential refugia for rainforest species. We have state of the art habitat assessment for PNG based on satellite photos.

For research carried out in shallow marine ecosystems, Madang will be the fourth place in the South Pacific where our methods are implemented, the second in the Coral Triangle, and the first in the Pacific Warm Pool. We will then be able to provide the most comprehensive faunistic baseline existing so far, at least for Molluscs and Crustaceans, over most of the range of the West and South Pacific shallow water ecosystems and coral reefs, where models of change in surface water temperature could then be applied consistently. Our data include samples down to 1000 meters deep, including extreme and specialized environments such as caves, deep reefs and seeps, and will contribute to faunal change analysis and prediction when models for water circulation and temperature beyond sea surface are available.

Global species richness

The issues and challenges outlined above require further research, as montane rainforests have been seriously neglected in tropical research that - for historical reasons, including the location of most field research centres in the tropics - has focused on lowland ecosystems.
The combined expertise of the large number of scientists who will be working on this expedition should allow for the most comprehensive study of biodiversity distribution along an entire altitudinal gradient (from sea level to the tree line at around 4000 m) produced to this date. Relying on our extensive experience working in remote forest areas we aim to study a large set of groups of organisms (plants, amphibians, different groups of insects etc.) so as to truly demonstrate the richness of the local biodiversity. This will provide us with an extensive set of data that will enable to refine the present estimate of the global number of species.

At a regional scale, global marine species richness remains a mystery. This is due to insufficient sampling and an incomplete knowledge of the geographic distribution of species. However, we now know that in a large scale sample of Molluscs in a restricted area of a New Caledonian coral reef a minimum of 3000 species of Molluscs may be found, 90% of which are new species (Bouchet et al). This figure, when compared to to the figure believed to apply to the whole of the Pacific region, demonstrates how, at this scale, our present estimate of global species richness is inexact. Further estimates can be derived only by comparing species shared in different locations and performing the appropriate statistical tests. To this end the Madang area data will be crucial.

Conservation as an alternative to deforestation for local communities – the Wanang experience

The remote community of Wanang has decided to stay away from all large-scale logging projects offered to them by the PNG Forest Authority and have declared 10,000 ha of their forest as a Conservation Area. Our in-country project partner, the Binantang Research Center, is assisting with this conservation project, sponsoring the village elementary school and conducting biodiversity surveys in the community (details at www.entu.cas.cz/png/wanang_1.php). A permanent botanical plot of 50 ha, part of the global network of the SIGEO-CTFS (Smithsonian Global Earth Observatories – Center for Tropical Forest Science, 40 plots around the World, see www.ctfs.si.edu) is currently being established in the Wanang area. This is the first 50 ha permanent forest dynamic plot in the New Guinea/ Australia region. All free-standing trees with a diameter at breast height of at least 1 cm are tagged, measured, identified to species, and will be re-censused every five years. A selection of various arthropod groups (ants, termites, moths, butterflies, fruit flies) will also be monitored soon in this plot, and the present project will provide the base line studies for a set of these groups.

The altitudinal transect which will be used for biodiversity survey by the present project is situated in the 76,000-hectare community-based YUS[1] Conservation Area (gazetted on 9 January 2009).
It is the product of more than a decade of work by the Tree Kangaroo Conservation Program (TKCP, lead by L. Dabek) of Woodland Park Zoo, which is focusing on conserving Matschie's Tree Kangaroo (listed as *Endangered* on IUCN's Red List) through strict local management of a large forest reserve in the Huon Peninsula of Papua New Guinea. The TKCP has engaged local communities in a partnership to conserve forests and wildlife; in return the communities receive health and education benefits.
The altitudinal transect at TKCP has been established by Conservation International (project leader B. Beehler), primarily for the study of birds and plants. BRC has been collaborating with TKCP and CI, including on community-based surveys of food webs in the YUS Conservation Area.
The present project will support the YUS Conservation Area by bringing employment opportunities, training and biological information to the local communities, thus providing direct rewards for their decision to conserve their forests.

Assessing marine diversity for conservation: the need for an evaluation

For obvious practical reasons, in the marine ecosystems and especially in Coral reefs, rapid assessments are the most common tool for evaluation for conservation. Given the constraints on time and expertise when such complex ecosystems are addressed, this approach has been the only one available. However it necessarily relies on the group of larger (visible) animals and includes a relatively small number of common species, such as fish and corals.
We now know that these groups represent a very small fraction of the total animal diversity in coral reefs, where small (and less small) invertebrate species occurr by the thousands: we have previously shown that the median size of gastropod species is significantly lower than 1 cm, i.e. they are not even seen when a rapid assessment is performed. We propose to conduct rapid assessments in parallel with our collections and observations, in order to evaluate the representativity of rapid assessments when compared with figures closer to the actual local species richness, to start answering this question which is fundamental to the determination of adequate policies for conservation.

Terrestrial component

The project will comprise of surveys of selected groups of plants, invertebrates (ants, spiders, termites, butterflies, geometrid moths, parasitoids) and vertebrates (frogs) and their interactions along a complete rainforest altitudinal gradient from the lowland floodplains to the alpine zone in the Finisterre Mts., from 100 to 4000 m asl. Each group will be studied at 10 stations, from 100 m asl and at 400 – 450 m altitudinal increments up to 4000 m asl. These stations have already been established in the field.
Aditionally, a lowland site approximately 300 km from the transect will be included for comparison to investigate beta diversity within the lowland forest, which is the most extensive forest type in PNG. This is the site of Wanang Conservation Area, a 10,000 ha lowland rainforest protected by indigenous communities and surrounded by selective logging operations. Lab work will be conducted in the brand new, well equipped but low-impact biological research station located in the midst of pristine rainforest in the Wanang Conservation Area next to the CTFS-SIGEO plot where plant and arthropods will be monitored.
The Wanang site will also serve as a lowland anchor for a parallel altitudinal transect on the slopes of Mt Wilhelm, the highest peak of PNG (4509 m asl.), and a National Park. This transect is also a complete rainforest transect, but in a montane range with different geological history than the Finisterre Mts., thus providing an opportunity for comparison.

[1] Named for its three main rivers: the **Y**opno, **U**ruwa and **S**om of the Huon peninsula.

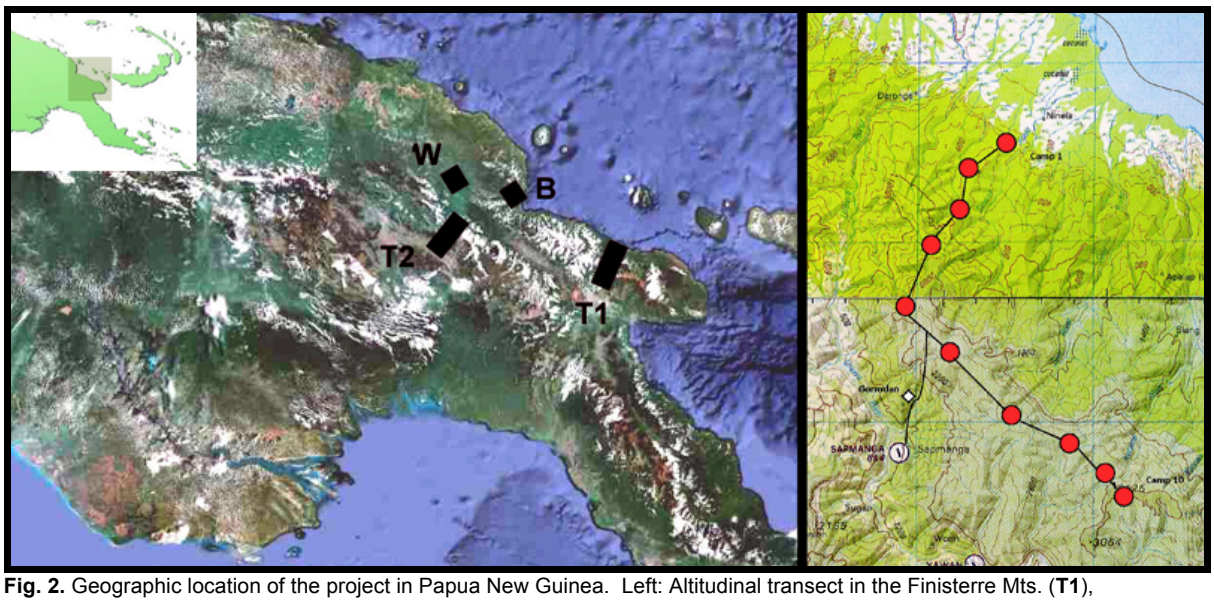

Fig. 2. Geographic location of the project in Papua New Guinea. Left: Altitudinal transect in the Finisterre Mts. (**T1**), lowland Wanang study site (**W**), altitudinal transect Mt. Wilhelm (**T2**) and the BRC campus, the logistical base of the project (**B**). Right: The Finisterre altitudinal transect with 10 research sites.

Marine component

The marine component will survey both shallow and deep sea waters in two different phases. The Reseach Vessel Alis from the French *Institut de recherche pour le développement* (IRD) will be used as a logistical base for each phase with different operational modalities:

(a) Shore / near shore phase
The study area covers about 10,000 hectares between the land area and 100 m isobath, and includes a lagoon dotted with islands, extending over 15-20 km north of Madang, a more open coast, with several islands in the South and the outlet of a small coastal river (Gogol River) 15 km south of Madang and of several other streams of lesser importance, especially at the end of the lagoon. During the shallow water phase, RV/Alis will be used as a marine station ship, with day trips, or even half a day, within 2 hours route around the port of Madang. A large laboratory will be installed on land with 35 work stations for sorting, photo, tissue sampling and preparation of samples. Specific habitats will be explored (sub-marine caves, deep reef (30 to 150 m) combining low tech approaches using tangle nets and dives to 60m, commensals, parasites and associated organisms, mangroves such as the Gogol River area).

(b) Offshore phase
The R/V Alis will be deployed in the Bismark Sea during 3 different legs. This phase of the expedition is conceived as a complement of the BIOPAPUA cruise, *Tropical Deep Sea Benthos* that took place in the area in 2010.
(The first leg will employ 6 persons on board and 4 ashore for 12 days. The second and third legs will employ 8 persons on board for 22 days).

General schedule of the project implementation phase

	2012						2013											
	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
Terrestrial component																		
Preparatory phase																		
Expedition (Lowland and montane forests)																		
Data collection (Lowland and montane forests)																		
Sample processing & analysis																		
Marine component																		
Preparatory phase																		
Expedition: Shore/near shore habitats																		
Expedition: Offshore habitats																		
Expedition: data collection & first-tier sample processing																		
Post-Expedition: second-tier sample processing & analysis																		