SANTO 2006
Expedition
Progress Report

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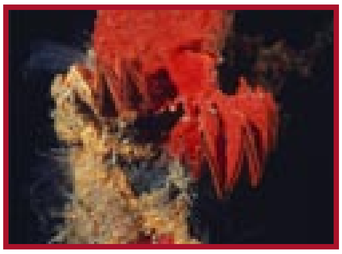


CONTENT

SANTO 2006 - SUMMARY REPORT

The SANTO 2006 expedition, the first biological survey of its kind, was designed to achieve a comprehensive assessment of the living organisms, both marine and non-marine, of a tropical oceanic island, Espiritu Santo (or Santo), in Vanuatu, located in the SW Pacific Ocean.
This global biodiversity assessment covered all the major environments (offshore deep-sea, reefs, caves, freshwater bodies, mountains, forest canopies) and also addressed issues regarding how indigenous biodiversity has been impacted by 3,000 years of human presence.

The SANTO 2006 Expedition was jointly coordinated by the Muséum national d'Histoire naturelle (MNHN), the Institut de Recherche pour le Développement (IRD), and Pro-Natura International. A total of 203 participants (of whom 153 scientists) from 25 countries were involved in 4 themes (Marine Biodiversity; Forests, Mountains & Rivers; Karst; Fallows and Aliens;) to document the fauna and flora of Santo.

This report summarizes the first findings of the expedition, and preliminary results are presented in Sections 1 to 4. There is still much work to be done, such as sorting samples and undertaking detailed studies of the materials and data collected in the field. A Scientific report is planned for publication later this year (September 2007) and numerous scientific papers will be published in the months and years to come.

An expedition such as SANTO 2006 requires considerable reactivity and flexibility in the management and distribution of funds, and would simply not have been possible without private funding. Supports from the private and public partners are gratefully acknowledged, not only by the Principal Investigators, but also by everyone in the international network of the expedition and the post-expedition scientists. The final balance sheet is still being prepared, but our initial interim reports indicate that expenses are in line with the budget. This has been achieved thanks to detailed and accurate provisional budget and a careful expenses auditing exercise that was carried out on a weekly basis by a specially designated person throughout the whole project.

All in all, the operating costs of the Santo 2006 expedition amounted to ca. 1,100,000 €, covered with supports from the following sources: the Stavros Niarchos Foundation (500,000 €), the Total Foundation (150,000 €), the Committee for Research and Exploration of the National Geographic Society (68,000 US$), the Sloan Foundation (45,000 US$), the Veolia Foundation (36,000 €), Triballat (25,000 €) and various public funds: the Fonds Pacifique of the French Ministry of Foreign Affairs (140,000 €), EDIT, a Network of Excellence of the European Commission (46,000 €), the French National Research Council (CNRS, 26,000 €), the French Embassy in Vanuatu (17,000 €), the European Union representation in Vanuatu (5,000 €). Universal Sodexho and Telecom Vanuatu Limited provided in kind contributions (valued to ca. 45,000 €). In addition, use of the *Alis* Research Vessel amounted to ca. 275,000 €, covered in kind by IRD.

Main findings

Preliminary scientific results are detailed for each of the four scientific components in Sections 1 to 4 below.
It should first be noted that each of the planned scientific projects and sub-projects was successfully completed in the projected time frame and according to the initial written scenario. Some logistical and meteorological problems naturally arose, but they did not cause any major disturbances to the scientific programme.

Overall, the general feeling of the Scientific Committee and the Principal Investigators responsible for each scientific component is that Santo 2006 represents a breaktrough in the approaches and methodologies used for biological inventories.

The main goal of the expedition, which was a comprehensive inventory of Santo's biodiversity, was achieved, within the constraints of a 4-month project. Some species were no doubt overlooked in our survey, but they are few in number and it would take years to sample all groups of organisms exhaustively. The most hidden parts of the island Biota have been however carefully checked. There is no question that we now have a much clearer and realistic figure of what is living in this isolated part of the world.

Well over 10 000 species of plants, animals and fungi were collected during the 4 months of the expedition. This outstanding yield of specimens and associated biological data is mostly the result of the dedicated and hard working participants involved in the expedition. But beyond that, as Pr. Roger Kitching states below in Section 2, integrative research is by far more efficient than the sum of individualities. In other words, Santo 2006 was more than just numbers: collective work almost always yields much more achievements than segragate research activities carried out without a master plan.

We have shown, perhaps for the first time ever, that the immense task of filling gaps in the biological inventories of the poorly known yet highly diverse groups of animals (invertebrates) and plants is possible provided the appropriate scale and size of operation are selected and the work is well designed and executed.

It should also be noted that the most exciting and striking results do not lay in the impressive list of species collected: most of the scientific teams have also gathered extremely interesting data on the spatial distribution of elements of Santo's biodiversity and on species assemblages. Some unexpected biodiversity patterns have already emerged and will require further analyses. This knowledge of biodiversity patterns will provide the essential foundation on which to build more sophisticated assessments of ecological and evolutionary processes.

Lessons learned and possible improvments

We have learned a lot from the Santo 2006 experience, but two main lessons of particular importance can be drawn:
The success of the project can, to a large extend, be attributed to the careful selection of enthusiastic and experienced participants, who acted as a superb professional group of experts. Mobilizing high quality senior scientists for this kind of operation is by no means an easy task. Forming such an effective team was a challenging issue, which Santo 2006 tackled sucessfully. In fact, the collective interest and commitment of the participants is a major 'product' of Santo 2006 and a very valuable resource for future endeavors.
However, keeping Scientists mobilized for future operations will be a challenge and we have to take

full advantage of contructive criticisms made by the participants. We have been repeatedly told that follow-up field studies should have been part of the Santo project from the start to ensure coverage throughout the year and the seasons. This is particularly true for groups of organisms that are highly sensitive to seasonality such as insects and some plants. While funding for such follow-up work may be difficult to secure, this suggestion has to be taken into account in a future operation design.

Expedition outreach has been fantastic (see the next chapter), thanks mainly to a group of dedicated people who worked as volunteers for the Santo 2006 project. It would, however, be unwise to rely on the good will of unpaid volunteers for the communication and educational aspects of future operations, and a specific budget line should therefore be included from the outset in the overall budget of future expeditions to ensure that these important activities are carried out successfully.

Expedition Outreach

Santo 2006 benefited from support provided by the media and communication departments of MNHN and IRD, as well as from the private company ATOM.
We present the expedition outreach as of January 2007, and there is much more to come, including a coffee-table book on the expedition, which will be published in November 2007, and a 110 minute documentary film that will be shown in June 2007 on one of France's public Channel (France 3).

Web

The site at *www.santo2006.org* reported on a daily basis, and has links to a French-English scientific blog at *http://www.ird.fr/recherche/santo2006/blog/* that specifically reported on the results of the Marine Biodiversity theme, and to a second site (French only) at *http://santo2006 ens-lyon fr/donnees/biodivmarine* which posted education material for teachers and schools.

As of February 20, 2007, a total of 52,000 visits have been registered at the Santo 2006 web site, which will be kept active and fed with news throughout 2007.

Press

The Santo 2006 expedition alos benefited from significant media coverage. More than 60 articles on the expedition were published in France and other countries between June 2006 and January 2007. A series of articles also appeared in *Libération*, a French newspaper, based on information fed weekly by journalists participating in the expedition.
Numerous radio interviews have likewise been given since the scientists have returned from Santo.

Sample press articles

Newspapers

AFP, 29/06/2006: “ Santo 2006 : une expédition qui se veut modèle sur le plan éthique ”.
Environnement-online.com, 30/06/2006: “ Santo 2006 : cap sur l'île-planète ”.
Euréka, n°6 juillet/août/septembre: “ les Aventuriers de la Biodiversité ”.
L'Humanité, 03/07/2006: “ Cap sur Santo, mine d'or de la biodiversité ”.
Le Monde, 04/07/2006: “ Une expédition internationale va explorer la biodiversité des Vanuatu ”.
Environnement & stratégies, 07/07/2006: “ Ne pas avoir de vision utilitariste de la biodiversité ”.
Le Figaro, 08/07/2006: “ Cap sur la biodiversité de l'île de Santo ”.
Vanuatu Daily News, 12/09/2006: “Marine scientific research targets survey from sea bottom to ridge crests”.

Weekly magazine

VSD, n° 1534, a weekly French magazine (17-23 January): “Santo: l’île témoin de la planète”

Monthly magazine

GEO, n°332 october 2006 : “ Santo: une île-échantillon exceptionnelle! ”
L’Express, Special Issue, December 2006: “ Santo : cap sur la biodiversité ”

2 large articles in high circulation monthly magazines are now in preparation:
Terre Sauvage (March 2007)
GEO (Avril 2007)

Focal point

A Santo 2006 focal point was established at the “ Palais de la Découverte ”, a French public exhibition center for science and education, based in Paris. This focal point was inaugurated on October 5, 2006 by the French Minister for Education and Research and the Director of the Muséum national d’Histoire naturelle. This focal point was linked to a dedicated web site: http://www.palais-decouverte.fr/index.php?id=accueil2

Education material

A series of 10 posters was designed and printed, thanks to the European Commission office in Vanuatu and the French Embassy. Five thousand posters have already been distributed in Vanuatu through the Vanuatu Ministry of Education.
This educational material is primarily directed towards schools and teachers in Vanuatu, providing a medium for communicating broad environmental messages in the three main languages currently used in Vanuatu (Bislama, English and French).

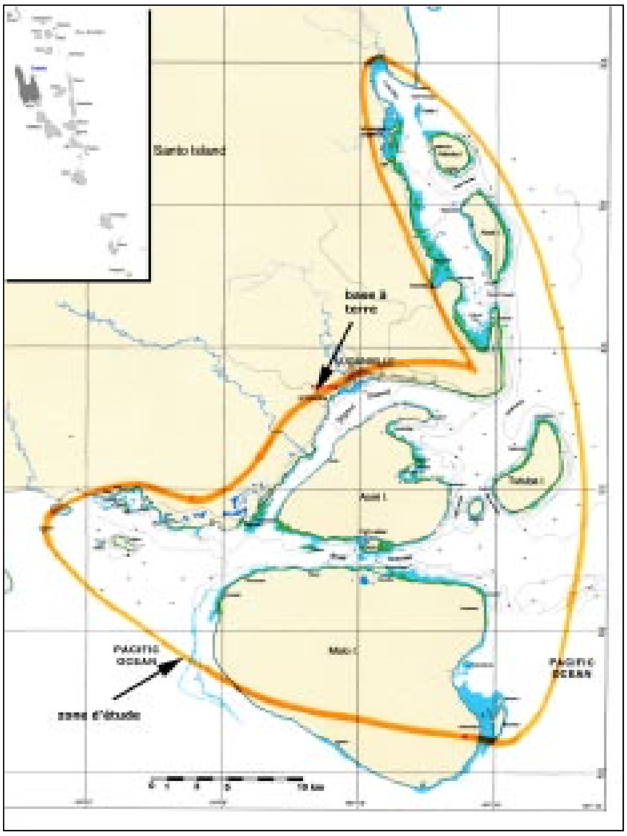
Santo 2006 - Section 1
Preliminary Report on the Marine Biodiversity component

Contex

The “Marine Biodiversity” theme of SANTO 2006 is a continuation, and an expansion, of similar efforts conducted earlier in New Caledonia (Lifou 2000), the Austral Islands (Rapa 2002) and the Philippines (Panglao 2004), and extending across the West Pacific biodiversity gradient from its species-rich center in the Philippines to a species-poor edge in the Austral Islands. Within SANTO 2006, the “Marine Biodiversity” theme took place between August 5 and October 22, with a total of 97 scientists, students, support staff and volunteers, from 18 countries. On average, the duration of individual stays was 30 days, and at any given time there was on average 55 persons on site.

Study location

Study area
Ca. 25,000 hectares between 0 and 100 meters deep.
Ca. 45,000 hectares to 200 meters.



The field programme

SANTO 2006 was very much inspired by the results and experience gained during the Panglao 2004 expedition, and the core group of participants was the same. However, SANTO 2006 was innovative in several ways.

1 Deep Reefs. The deep reefs, below 60 meters to ca. 150 meters, is a compartment of coral reefs usually neglected because of difficulty of access. During Santo they were sampled both by low tech (tangle nets) and high tech (divers using trimix gases with rebreathers) approaches. Our expeditions never had trimix divers before; this was a very successful addition and we have decided to continue our partnership beyond Santo 2006. The "deep reefs" part of Santo 2006 was specifically highlighted by the *Census of Marine Life* under their CReefs programme.

2 International Participants. Since 2004, participation in our projects is very international, and this was reflected again in Santo by having subsets of the programme placed under the responsability of Dr T. Gosliner (California Academy of Sciences; seaslugs), Dr Peter Ng (Singapore; decapod crustaceans), Dr Marco Oliverio (University of Roma; commensals, associates and parasites), and Dr Ellen Strong (Smithsonian Institution; barcoding sampling), all of them already present in Panglao.
However, several entirely new groups of participants joined Santo 2006 with new expertise. The group of Dr Bert Hoeksema (Naturalis, Leiden) has acquired considerable experience on coral reefs in Indonesia; the group of Dr Richard Pyle (Bishop Museum, Honolulu) is the authority on deep reefs exploration; the group of Dr John Gray (University of Oslo) is a leader on data analysis from quantitative sampling; and the group of Dr Claude Payri (IRD, Nouméa) specializes on algae.

3 Deep Offshore and Sunken Wood. The project was allocated 46 days of the research vessel *Alis*, a 27 meters, Nouméa-based trawler operated by IRD.
This has allowed sampling of the benthic fauna to 1,000 meters, with special emphasis on the fauna associated with sunken wood, and retrieval of organic substrates (whale bone, turtle carapaces, feathers, wood, etc.) that had been immersed one year before.

4 Comparing Methodologies. During Santo 2006, we deployed three approaches to "measuring" biodiversity: Rapid Assessment (RAP); all-species inventory; quantitative ecology sampling. These approaches had never been carried simultaneously on the same site, and their results could thus hardly be compared.

5 Molecular Barcoding and Digital Imaging

One of the significant outcome of our expedition is to reconcile traditional taxonomy, where most species have been named based on shell characters alone, and the modern approaches based on living animals. We have now optimized coordination of sampling and processing effort whereby bulk samples are sorted to morphospecies in the lab immediately after the catch, and specimens of each morphospecies are then photographed and selected specimen(s) are preserved for DNA sequencing. The Santo 2006 expedition has resulted in the single largest molluscan dataset now available worldwide for barcoding.

6 Training and Capacity Building.

With only 200,000 inhabitants, Vanuatu does not have academic biodiversity research institutions, and the administrations in charge of Fisheries or Environment have very limited staff. We proactively searched for local students, and 6 of them were involved in the field and laboratory work; one of them will remain closely involved in our reporting to the Government of Vanuatu. Five of the Santo 2006 participants were from the Philippines, 4 of whom had been involved in the Panglao project, demonstrating that our partnership with Filipino colleagues now extends well beyond their own country.

Indicative Results

Map of the recent hurricanes tracks that have hit Santo

The logistics and human resources deployed during the expedition were appropriate for our goals, and explain the quality of the results. We had learnt lessons from Panglao, and we probably worked better in Santo. In terms of species richness, the number of species inventoried goes even beyond our expectations : 1,100 species of decapods (crabs, shrimps and hermit crabs), in the order of 4,000 species of molluscs. The wealth of digital images resulting from the expedition will be a revelation to the scientific community as well as to the general public. Hundreds of new species - possibly over a thousand - have been discovered.Yet, our results are paradoxical. If species richness is used as a measure, it can be said that the marine biodiversity of Santo is “very rich”; in fact, **by the number of species of crustaceans worldwide, Santo is second only to Panglao.** However, we believe that this is the result of our large workforce, and we believe that if the same workforce had been deployed elsewhere in the South Pacific, including New Caledonia, the Solomon Islands, Papua New Guinea, and probably Fiji, we would have had similarly very high numbers. We even found that our study area glaringly lacked some habitat

types, such as seagrass beds, mineral sediments, etc. Many reefs were not in good shape, obviously not the result of overfishing as there is very little subsistance fishing going on in Santo, and no dynamite fishing. We believe that perhaps the hurricanes of the 1980s are to be blamed (see map of hurricane tracks).
We also found that most species were extremely scarce in the number of stations where they occured and in the individual numbers, more so than in many other sites known to the participants.
Thus, the paradox is: even if Santo is not a site of exceptionnal richness, as we have deployed an exceptionally complete workforce we came up with an exceptionally comprehensive species inventory rivalling with richest spots known in the world !

Few figures

Logistics

8 boats, ranging from R.V. *Alis* (27 meters long) to a 4 meters aluminium service boat.
Aldric (the only one of the small boats to be equipped with a log) alone covered 1,200 nautical miles.
Small boats (i.e. excluding Alis) and land vehicles together used 6,800 liters of fuel.
5,000 meals served, 3,000 dive tanks filled,1,000 liters of ethanol used for preservation of samples.

Sampling intensity

588 sampling events
- intertidal collects: 76
- hand picking and other targeted
- sampling (SCUBA): 188
- bulk brushings (SCUBA): 46
- bulk vacuum cleaner (SCUBA): 45
- tangle nets and “lumun lumun”: 37
- coastal dredging: 44
- coastal trawling: 2
- quantitative sampling (grabs): 40
- trap lines: 5
- offshore dredging and trawling: 105

Biodiversity

1103 species of decapod Crustacea
(603 species of crabs, 500 species of shrimps, hermit crabs and others), of which in the order of 100 new species; associated digital images of living animals for about 2/3 of the species.

3- 4000 species of mollusks,
including 380 species of nudibranchs (sea-slugs); in the order of 1,000 new species; associated digital images of 2,250 living animals representing about 1,500 species.

5,000 lots of mollusks preserved specifically for molecular barcoding.

486 fish species, of which 15 new species.

International recognition

The Marine Biodiversity expeditions conducted by our group have become the «gold standard» of marine invertebrates sampling and exploration, and have changed how we evaluate the global magnitude of tropical marine biodiversity.
The SANTO 2006 expedition was presented at a CReefs meeting in Honolulu in February 2006, and our sampling approach (vacuum cleaner, brushing baskets) was subsequently adopted by an NOAA cruise to Pearl & Hermes reefs in the NW Hawaiian chain.
The Panglao and Santo experiences were also presented to the Subsidiary Body for Scientific, Technical and Technological Advice (SBSTTA) of the Convention on Biological Diversity at their July 2006 meeting in Paris.

Some remarkable crustaceans found during Santo 2006.

1. *Calappa bicornis*
This two-horn Box crab (Calappidae) has two distinctively different claws one has a special tooth for cutting open shells (gastropods) and the other with long slender fingers to pull out the exposed gastropod. Interestingly, the cutting claw is almost always the claw on the right-hand side!

2. *Rhabdonotus xynon*
This crab is a deep-sea symbiont on crinoids (feather stars). This particular species was first described by scientists at the Raffles Museum of Biodiversity Research based on the material from the first French expedition to Vanuatu in 1994!

3. *Thor amboinensis*
About 350 species of shrimps were found in SANTO 2006, which is a rather high diversity for the region as compared to the nearly 450 species found in the PANGLAO 2004 at the Philippines. About half of the SANTO 2006 shrimp species have symbiotic lifes with other invertebrates and bearing striking colorations. *Thor amboinensis* is associated with corals and sea anemones.

4. *Lauriea gardineri*
Anomurans include hermit crabs, squat lobsters and porcellanid crabs, etc that with general appearance intermediate between shrimps and crabs. About 150 species of anomurans were found in SANTO 2006. Again this is a rather high diversity compared to the nearly 200 anomurans found in PANGLAO 2004. This squat lobster (family Galatheidae) is remarkable in being very hairy. It is associated with sponges, and it is possible that the dense hairs on the body are used to trap foods like the feeding mode of their host sponges.

5. *Synalpheus stimpsoni*
This alpheid shrimp has obligatory association with feather stars, or crinoids. Its color pattern varies according to the host feather stars and usually lives in pair.

6. *Xenocarcinus conicus*
The beautiful spider crab is an associate found on gorgonians (sea fan corals). Their beautiful colours are often the same as that of their coral hosts so as to camouflage themselves.

7. *Daldorfia horrida*
This crab looks like a piece of dead coral so as to camouflage itself. This is also one of several species of tropical marine crabs that were reported to be poisonous to humans.

8. *Discoplax longipes*
This long-legged land crab is an elusive and beautiful animal of limestone (karst) systems. Not only are they one of the largest land crabs, they are also edible!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Some remarkable molluscs found during Santo 2006

1. In Santo, the seaslug team alone spent some 130 day-persons in the field and other divers also had an eye for these colourful animals. As a result, no less than 380 species were inventoried and photographed.

2. Wentletraps (family Epitoniidae) are strictly associated with Anthozoa, in the present case corals of the family Dendrophylliidae from which they obtain food and derive their body colour. The small specimen is a male. Such cryptic associations are difficult to spot in the field, but thanks to the experience of Arjan Gittenberger we recognized in Santo 17 epitoniid species on their corals and sea anemones hosts.

3. This insignificant microgastropod (height 3-4 mm) is perhaps the most spectacular discovery of Santo 2006. Twenty years ago Anders Warén had noticed its empty shells in coral shell grit. These shells are suprisingly similar to fossils from the Carboniferous. Is this the result of convergence or have we discovered a "living fossil"? We will know once we have sectioned and sequenced the 6 specimens found alive by Richard Pyle during a deep dive in 120 meters.

4. Marginellid of the family Cystiscidae. The shell is transparent and the vivid colour are those of the mantle of the animal, visible by transparency.

5. Gastropod of the family Eulimidae. All eulimids are parasitic on echinoderms; this one parasitizes holothurians.

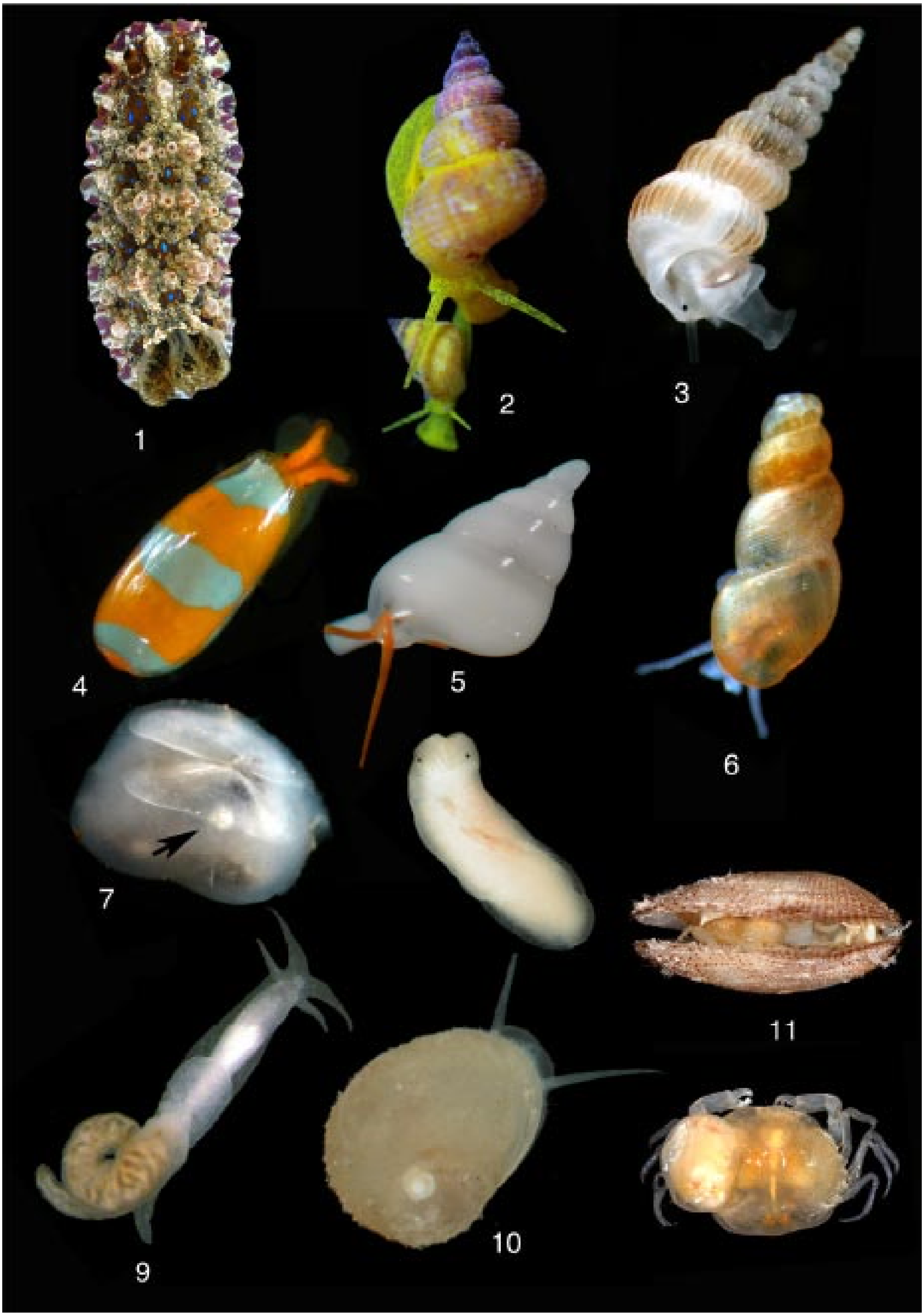
6. Microgastropod of the family Iravadiidae, a family still very little known by biologists, but widespread in many poorly oxygenated habitats (below deeply burried boulders, sunken wood, burrows, etc.).

7. Bivalves of the family Galeommatidae are probably the least "typical" of all bivalves : their shell is often concealed by the mantle, they live under stones and crawl like snails, they sometimes have dwarf males (arrow !), etc.

8. Another major discovery of Santo 2006: *Smeagol*. Found in Santo by Takuma Haba, this weird little seaslug was first noticed in New Zealand and the announcement of its discovery had been one of the highlights of the Sydney congress in 1979. Frank Climo had named it *Smeagol* because its naked body had reminded him of Tolkien's character from the Lord of the Rings. However, he had been mystified by its enigmatic appearance, and had classified it as a new order, until Simon Tillier unravelled its true phylogenetic position.

9-10. During the lowest tides we have investigated an intertidal platform that looked very "ordinary", just outside Luganville. This was nevertheless the site of a sensational discovery by our Japanese colleagues Yasunori Kano and Takuma Haba, who were intrigued by a karstic spring seeping right in the intertidal zone. They dug below some boulders burried deeply in the spring outlet, and discovered a community consisting entirely of new species, such as this Acochlidiacea (9) and a species of *Neritilia* (10).

11. "Russian dolls" interactions. While anesthetizing this arcid bivalve for taking tissue sample for barcoding, Ellen Strong noticed it hosted a peacrab (family Pinnotheridae), living commensally in the clam. When the crab was examined. We found that it was itself parasitized by a bopyrid isopod (the bulge on the left side of the crab).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Santo 2006 - Section 2
Preliminary Reports on the «Forests, Mountains & Rivers» component

Introduction

The "**Forest, Mountains & Rivers**" component (FMR) of the Santo 2006 expedition can be divided in two main categories of scientific activities: random sampling for a qualitative inventory in different parts of the island, and structured sampling for a quantitative inventory of a limited area.

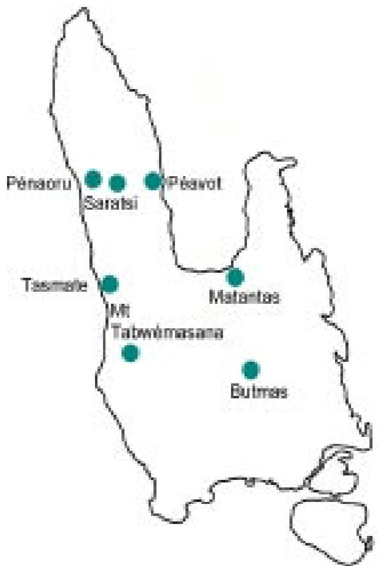
The first sub-component involved scientists around the Penaoru base camp for a deep qualitative and quantitative survey along an altitudinal transect from ca. 50 m above sea level (asl.) to 1,500 m asl. in the Penaoru river basin, on the west coast of Santo.
In this report, the preliminary results are put together in the chapter entitled "**Preliminary Report on the IBISCA project**", IBISCA (Investigating the BIodiversity of Soil and Canopy Arthropods) being both the name of an international program and a brand for a new and unifying way of surveying the arthropod life in forests.

The second sub-component was designed to get a broad picture of the island fauna and flora. Scientists did not traveled everywhere, but in pre-selected sites supposed to host intact ecosystems that are representatives of the island diversity of environments.
The preliminary results of individual group of researchers are put together in the chapter entitled "**Preliminary Reports on the Travelling Team Works**".

To a certain extend overlapping did exist between these two sub-components, as some of the travelling scientists surveyed the Penaoru Valley and some of the IBISCA representatives surveyed at random sites close to the altitudinal transect and at other locations as well.

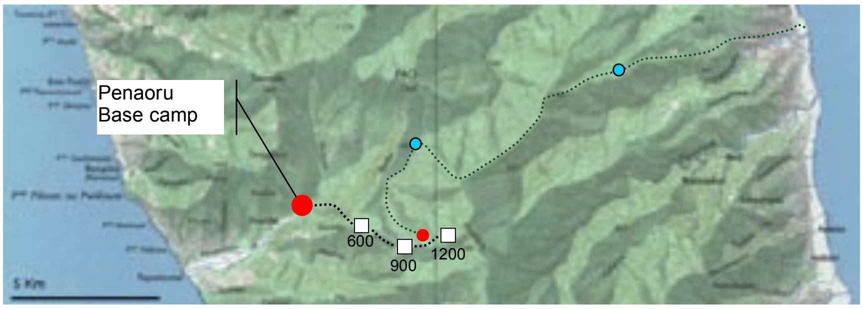
The chapter entitled "**Preliminary Report on the Botanical and Mycological Work**" exemplify these overlapping as it is grouping the results of the botanical studies conducted within the IBISCA program with the studies conducted elsewhere in the island by the traveling team.

The 'FMR' component has benefited from the strong logistical support offered by the Vanuatu Maritime College (VMC) which was of great help as most of the scientific activities took place in remote part of the island with no road access. Most of the scientists traveled by sea thanks to the Euphrosyne vessel, owned by the VMC, which was at the project disposal during October and November 06.
The FMR component has also



Study location

benefited from a strong support by the local communities. Penaoru villagers were of considerable help in building and running the Penaoru base camp. Every village visited either on the west coast or on the east coast of the Cumberland peninsula have to be warmly thanked for accommodating some of the scientists and for the numerous services they provided to each visiting team.



□ 20m x 20m reference quadrat main sites (at 600, 900, 1200m asl.)
Altitudinal transect (100m to 1200m asl.)
Temporary camps, used during the Cumberland Peninsula cross-over expedition
Itinerary of the Cumberland Peninsula cross-over expedition
Permanent camps

Cape Cumberland

Preliminary Report on the IBISCA project

Identifying significant patterns in forest biodiversity and erecting hypotheses about how these patterns have been generated is the key challenge for forest ecologists. Not only are such results of fundamental importance for the understanding of ecosystem dynamics but such understanding is the only viable key to management for sustainability and human use. And only by such proper management can the resources and services of natural forested ecosystems be harnessed for poverty alleviation and the long-term benefits to humanity.

By far the greatest fraction of terrestrial animal diversity is made up of the arthropods and the Insecta in particular. Inasmuch as a tradition of modern studies of arthropod biodiversity exists at all, it has been established that wresting high quality information from tropical and subtropical forests is a slow and painstaking business taking, optimistically decades of careful study if carried out by traditional, single-research group methodologies.

It was this apparent dilemma – the urgent need for high quality results contrasted with the essentially long-term nature of obtaining such results – that led to the development of the IBISCA-model. Conceived by Yves Basset, Bruno Corbara and Hector Barrios the first IBISCA Project was carried out in lowland rainforest in Panama in 2003-2004. They proposed, organised and executed a study which brought together a large international team of entomologists and botanists for two blocks of field work in 2003-04 to tackle the vexed question of the relative importance of the ground layer compared with the forest canopy as foci for arthropod biodiversity. About 40 scientists from 15 countries participated. Each brought their own expertise to bear but carried out against a centrally conceived and maintained experimental design in the field. This is will lead both to individual scientific results from various subsets of the participants and, of more importance, syntheses in which summaries of the results are combined to detect general patterns across different arthropod groups and sampling protocols. And results are likely to be generally available within a period of two to four years rather than requiring the much longer period that any individual research group would need to produce even a fraction of these results. The collegiality within this international group with a focussed mission has also led to collaborations and future activities which owe more to serendipity than to pre-planning – in the spirit of the best of scientific innovation.

As a meeting of the original IBISCA team held in Brussels in 2005 it was agreed that this collaborative, international model was of such potential power that it could and should be applied to other important questions of forest biodiversity elsewhere. It was from this decision that 'IBISCA' became a 'brand' identifier rather than an acronym and which led to the current activities in Santo Island, Vanuatu ('IBISCA-Santo') and Lamington National Park in south-east Queensland ('IBISCA-Queensland'). Other such IBISCA projects are currently at the conceptual stage.

IBISCA-Santo has been a project embedded within the "Forest, Mountains and Rivers" component of the Santo 2006 Global Biodiversity Survey.

In parallel with the IBISCA Queensland Project the Santo Project has examined the way in which the diversity of arthropods and plants (from mosses to angiosperms) varies along an altitudinal gradient from 100 to 1200m above sea level within the Saratsi Range above the village of Penaoru on the west coast of the Cumberland Peninsula of Santo Island, Vanuatu.

Aims and Context

The Penaoru valley, West Santo

This transect represents a transition from the narrow coastal strip which has experienced substantial human impact through shifting agriculture - up to altitudes with only occasional and patchy disturbance (ca. 300-500m asl) to higher elevations of more or less pristine rainforest (500-1200m asl).

The motivations for such study are several-fold:

- The results will generate primary inventory data from a region of the Pacific which has been little surveyed in the past. Such basic inventory data are essential to feed into the future conservation strategies of this environmentally-conscious nation.
- The way in which components of diversity differ (or do not differ, as the case may be) from altitudinal station to altitudinal station will represent a fundamental contribution to an understanding of ecosystem processes within these little studied forests. The results will have relevance to and resonate with those from other tropical and subtropical rainforests around the world. In particular the contrasts between patterns, and the implied underlying processes, among oceanic islands, continental islands and continents themselves will be of considerable biogeographical importance.
- Perhaps of most importance, identification of how assemblages of biodiversity differ along altitudinal gradients has a particular relevance to understanding the role of climate in determining the structure of ecological communities (or, conversely, the manifold ways in which ecological communities themselves are responding to changes in climate). Inasmuch as altitude recapitulates latitude in terms of spatial climate change, so studies of biodiversity change along altitudinal gradients are the most efficacious ways of getting useful data on these climate-driven responses. And, in a warming world, quantifying how biodiversity changes across adjacent climatic zones (altitudinal *or* latitudinal) will allow identification of how such monitoring can be done most effectively in the future. This will principally be because that group of taxa and sampling protocols which show clear altitude to altitude changes will be those of most use in rapid (and much less expensive) assessment techniques in the future. Only through the extensive baseline surveys such as IBISCA-Santo (and IBISCA-Queensland) can such 'predictor sets' for future monitoring be defined.

Santo- West Coast

Personnel

The participants in the IBISCA-Santo study essentially comprised two complimentary teams: those involved in botanical survey and those concerned with entomological endeavours. These participants, their institutional affiliations and primary areas of expertise were as follows.

The Entomological Team

Dr Bruno CORBARA (Project and Team Leader), Universite Blaise Pascal, Clermont-Ferrand, FRANCE. Social insects, ant biology and ethology.
Dr Yves ROISIN, Free University of Brussels, BELGIUM. Social Insects, termites.
Dr. Maurice LEPONCE, Royal Belgium Academy of Sciences, Brussels, BELGIUM. Social Insects, Ants,
Dr Jerome ORIVEL, University of Toulose, FRANCE. Social Insects, ants.
M. Thibaud DELSINNE, Free University of Brussels, BELGIUM. Social Insects, ants.
Dr Alexei TISHECHKIN, University of Louisiana, USA. Coleoptera, Histeridae, Interception Trap Programme..
Dr Claire VILLEMANT, MNHN, Paris, FRANCE. Hymenoptera, Malaise Trap programme.
Dr Juergen SCHMIDL, University of Erlangen-Nuremberg, GERMANY. Coleoptera, Special Habitats programme, Bark spraying.
Professor Roger KITCHING, Griffith University, Brisbane, AUSTRALIA. Lepidoptera, Light Trap programme.
Mr. Frederic DURAND, Societe d'Histoire Naturelle, Alcide d'Orbigny, Clermont-Ferrand, FRANCE. Hymenoptera, Pompilidae.
Mr. Emmanuel BOITIER, Societe d'Histoire Naturelle, Alcide d'Orbigny, Clermont-Ferrand *and* University of Limoges, FRANCE. Orthoptera, Beating Programme.
Mr Milton Barbosa DA SOUZA jnr, Federal University of Ouro Preto, BRAZIL. Canopy herbivory, Endophytic insects.

The Botanical Team

Dr Jérôme MUNZINGER (Team Leader), IRD, Noumea. Flora of New Caledonia.
Dr Marika TUIWAWA, Fiji Herbarium, FIJI. Flora of Fiji.
Dr Gordon MCPHERSON, Missouri Botanical Gardens, USA. Flora of New Caledonia.
Dr Elizabeth BROWN, Royal Botanical gardens, Sydney, AUSTRALIA. Bryophyta.
Mr. Frederic RIGAULT, IRD, Noumea, NEW CALEDONIA. Technical assistant.
Dr Pete LOWRY, Missouri Botanical Gardens, USA. Araliaceae.

Support Team

Mr. Jean-Baptiste GOASGLAS, Monitor Treeclimbing, Arboricole Association FRANCE.
Mr. Jean-Yves SEREIN, Independent Arborist, Sapogne, FRANCE, climber.
Mr. Frederic MATHIAS, Independent Arborist, Boult, FRANCE, climber.

The Field Programme

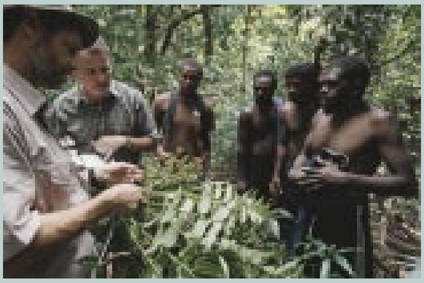
Field work - based at the Penaoru base-camp 4 km upstream of the village of Penaoru during the period from mid-October to early December 2006. Individual participants were in the field for periods varying from three to six weeks.

Two camps were established. The base-camp was about 4km upstream of the village of Penaoru on the Penaoru River at about 50m altitude. A subsidiary camp was located about 5km to the west along the Seratsi Range at 960m altitude.

Rainforest at 1200m asl.

Vegetation and Botanical Survey






Nine core and four additional sites were established. The core sites were established at 600m above sea level (asl) (3 sites), 900m asl (3 sites) and 1200m asl (3 sites), and the additional sites were established at 100m asl (1 site) and 300m asl (1 site).

At most of these sites the botanical team surveyed a 20m x 20m reference quadrat within which all plants greater than 5cm diameter at breast height (dbh) (1.2m height) were located, numbered and tagged, dbh measured and plant identified at least to the genus level where possible.

For each tagged plant, herbarium specimens were collected.
If the plant was sterile a single voucher was prepared and if fertile materials was present then enough materials was collected for at least five duplicates.

For each species collected a personal collection number assigned by one of the botanists was allocated to all specimens prepared from that species.

Other epiphytes, climbers, lianas shrubs and saplings <5cm dbh were also collected. General collection was then also carried out for all other plants outside the quadrat. Tree climbers were used to collected specimens from emergent and canopy trees and also of lianas and epiphytes high up in the very tall trees.

All materials collected were processed initially in the field and later dried at the base camp. Where appropriate DNA samples were collected and dried over silica gel. These were stored in coffee packets. Photographs were also taken of species that had flowers and or fruits.

TERRESTRIAL

Entomological Surveys

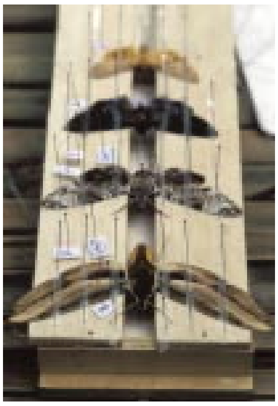
The IBISCA entomological team carried out complimentary sub-projects as follows:

The Social Insect Team (Corbara, Delsinne, Leponce, Orivel, Roisin)

Ants and termites were collected at all sites using a variety of complimentary methods. These included pitfall trapping, extraction of fauna from leaf litter using Winkler bag extractors, examination of dead wood and general collecting in both the field and canopy layers.The IBISCA entomological team carried out complimentary sub-projects as follows:

Light Trap Survey (Kitching)

In this programme, modified Pennsylvania-style light traps were used at all five locations for two nights at each. These traps rely use a neon tube attached to a 12v battery. The light emits significantly in the ultra-violet range and attracts night-flying insects. They are particularly effective for sampling moths and beetles. Moths belonging to the traditional 'macro-' families plus Hepialidae, Cossidae and Pyralidae were targeted. All specimens encountered were counted and substantial series of each were pinned in the field camps for transportation to France for future identification.



All other groups of insects were preserved in 70% ethanol for further sorting upon their return to Europe.

Beating Programme (Boitier)

Sampling insects by beating involves holding a flat collecting surface underneath vegetation and 'beating' that vegetation with a stick. It is a simple but effective methods for sampling free-living, particularly herbivorous insects and the predators which exploit them. All altitudes were targeted and 2h of beating was carried out in each site targeting vegetation from ground level to about 2m. All material was preserved for further sorting in France.

Yellow Pan Trapping

Yellow pan traps are small trays of detergent-impregnated water placed on the ground. They target small flying insects which are part of the 'aerial plankton' present in all forests. They rely on passive interception and a measure of short-range attraction to the yellow colouration. They also accumulate some ground dwelling fauna. They are particularly effective in sampling Hymenoptera, Diptera and Collembola. A transect of such traps was established at the 600m site (only). Catches were examined for particular target groups (especially Pompilidae and Sphecidae). The general catches were preserved in ethanol to be returned to France for further sorting.

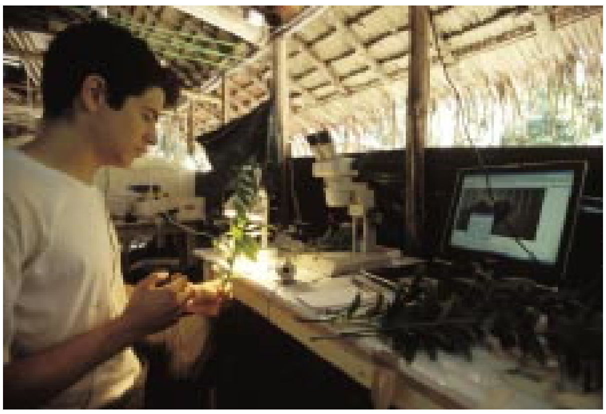
Durand also undertook general collecting at all sites in search, in particular, of selected families of Hymenoptera.

Endophytic Organisms from Ground to Canopy (Da Souza)

Leaves represent key resources for herbivorous insects. Many of these are free-living browsing or grazing of leaf surfaces and edges.

Others are more or less attached to the plant either as leaf-miners within the laminae of the leaves or in galls which they induce in the leaves. These are a little studied and important component of the herbivore fauna of the rain forest.

Da Souza established vertical transects from ground to upper canopy at all sites except the 1200m ones, using a standard, hand sampling protocol to collect representative leaves at all heights from the ground. In addition he established a horizontal transect at a single site at each elevation to contrast ground-zone processes with those occurring in the forest canopy.



Malaise Trap Programme
(Villemant, Durand)

Malaise traps are tent-like structures which intercept actively flying insects, directing them into a apical collector containing 70% ethanol.

The traps used in the IBSICA surveys were of the so-called Townes design. Sites at all altitudes were targeted with ground zone traps. In addition, in one site at each altitude, one trap was mounted in a frame and hauled into the canopy. Malaise traps catch a range of insects but are particularly effective in sampling Hymenoptera and Diptera. Specimens were preserved for further sorting in France.

Special Habitats and Bark Spraying Programme (Schmidl)

In any forest there are localized patchily distributed habitats which, potentially, contain specialized insect fauna. Schmidl targetted these habitats at all altitudes and sites. He hand collected from structures and resources such as dead wood, fungus fruiting bodies, phytotelmata (water-filled treeholes) and bark surfaces.

This sub-programme involved spraying bark surfaces with a pyrethrum-aerosol and collecting the resulting samples on sheets arranged beneath the spraying location. A range of arthropod groups may be encountered in this fashion.

TERRESTRIAL

All-taxa canopy programme using the canopy- glider

The IBISCA programme employs state-of-the-art methods of canopy access and sampling since the starting of field studies in Panama (2003).

IBISCA-SANTO represents the first attempt to combine single rope technique and the use of a new flying device, the Canopy-Glider for sampling in the upper-canopy.

The Canopy-Glider showed great promise as a research tool but, by the time it was up and running in Santo because of logistics constraints, it was essentially too late to use it for scientific work. However the demonstration flights helped to devise a dedicated research project for the glider within the overall goals of the IBISCA Project.

Indicative Results

We describe here first impressions and broad summaries of our findings. Numbers are indicative only and should NOT be quoted out-of-context. More precise quantitative results will be forthcoming following further laboratory-based processing of our samples.

The Vegetation

(account provided by Dr. Marika Tuiwawa, South Pacific Herbarium, Fiji)

More than 2000 specimens comprising ferns, gymnosperms and angiosperms were collected during the course of the survey. These represented around 300 species of plants and for the three botanists based at the Penarou camp more than 600 collection numbers were allocated to the 2000+ specimens collected.

Fruit of Myristica sp. One of the most common tree species in the forest between 600 and 1000m asl.

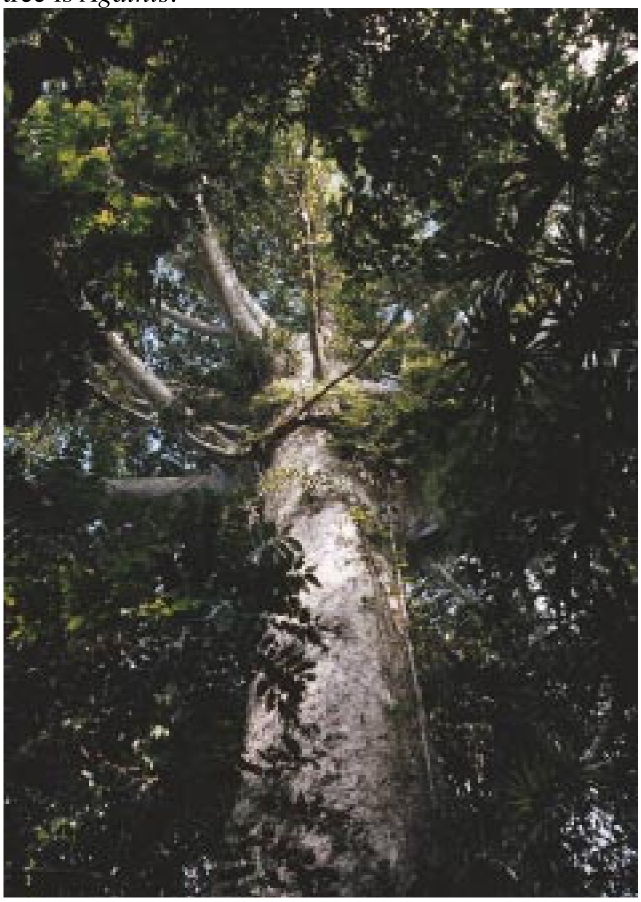
Overall the angiosperms dominate the sample with the families Orchidaceae and Myrtaceae being the most diverse and commonly collected taxa. The two most widespread taxa are *Calophyllum neo-ebudicum* and *Myristica* sp. and these are found in forests around the base camp (80m asl. to 1200m asl.).

In and around the **100m and 300m** plots the dominant and common emergent tree is *Castenosperma australe*. Other relatively common large emergent trees found here include *Dysoxylum* sp. and *Dracontomelon vitiensis*. Other trees that form the canopy layer included *Pterocarpus indica*, *Pongamia pinnata*, *Intsia bijuga*, *Macaranga* sp., and *Aleurites moluccana*. The most common sub canopy tree is an Annonaceae in the genus *Xylopia* which grows up to 4m tall. Other relatively common subcanopy trees include *Myristica* sp and *Garcinia* sp. The forest floor is mostly exposed with a layer of about 2-4cm of partially decomposed plant (mostly leaf) litter. Overall the tree density and diversity in forests with such exposed ground zones would be the lowest encountered along the whole transect.

The vegetation here can be best described as a seasonal or semi-deciduous forest with the presence of deciduous trees like *Terminalia catappa, Gyrocarpus americanus, Erythrina variegata, Pongamia pinnata* and *Albizia lebbeck*, an open under-storey and a general lack of ground cover. A relatively thin layer of debris on the forest-floor and the presence of a lot of lianas indicate drier elements but overall the forest is of a type typically found on the leeward side of large, high oceanic islands.

At **the 600m elevation** plots the dominant tree species is the Kaori tree (*Agathis sp.)* - trees with dbh of about 200cm are common. Other large trees that are relatively common in the area included *Dacrycarpus* sp., *Dysoxylum* sp., *Semecarpus* sp., *Elaeocarpus* sp., and *Syzygium* sp. These trees form both the emergent and canopy layer. Other common canopy trees include *Calophyllum neo- ebudicum*, *Garcinia* sp., *Tapeinosperma* sp., *Geissois* sp., and *Terminalia* sp. Some of the more common sub canopy trees include *Vavaea* sp., *Myristica* sp., *Psychotria* sp., *Cyathea* sp., *Dicksonia* sp., *Garcinia pseudoguttifera*, *Syzygium* sp. and *Eugenia* sp. The ground cover is mostly composed of *Selaginella* with a few low growing ferns.

At **the 900m plots** and their surroundings the dominant tree is *Agathis*.



A giant Kaori tree (Agathis sp.) - Penaoru Valley, ca. 1000m.

Calophyllum neo- ebudicum is very common especially as a subcanopy tree. Other large trees include *Dacrycarpus* sp., *Polyscias vanuatua*, *Turrillia* sp., *Melicope* sp., *Elaeocarpus* sp., *Metrosideros collina* and *Podocarpus neriifolius*.
Overall the forest-type encounterd between the 600 to 900m elevation could be best described as an ***Agathis–Calophyllum*** forest type where some emergent kauri can reach heights of up to 35m with diameters exceeding 2m.

At **the 1200m asl plots** the plant community changes quite dramatically where the dominant species is still *Agathis* but its occurrence is not as common as noticed at lower elevations. Other commonly occurring large trees included ***Metrosideros collina***. A subcanopy palm in the genus *Cyphosperma* commonly occurred here. A noticeable feature was the greater abundance of epiphytes and greater diversity in the plant community that formed the ground cover. The occurrence of some cryptic fern ally elements like *Tmesipteris* sp., and mosses and liverworts which covered a lot of stems indicates a montane cloud-forest type vegetation. The flora is more diverse here but tree density (>5cm dbh) may be less when compared with plots in the 900m elevation.

The Arthropod Fauna

Light Trap Survey (Kitching)

About 5500 moths were processed during the course of the survey. These comprised, at first estimate, about 350 species.
The families Noctuidae and Pyralidae s. l. (comprising both Crambidae and Pyralidae s. s.) dominated the samples. In contrast to other undisturbed rainforest samples Geometridae were relatively uncommon in the samples. Occasional influxes of very large sphingids (hawk moths) were a feature of the samples. Some at least of these belong to very widespread species occurring throughout the Asia-Pacific region. An overall comment is that the relatively modest number of species (in contrast with other tropical rainforests) is in line with the biogeographical expectations associated with an oceanic island fauna. Levels of endemism will be determined after further identification using the resources of European and other Museums.

Beating Programme (Boitier)

The beating programme actually produced relatively few species although spiders and crickets (Gryllidae) dominated many of the samples. Determinism of levels of endemism awaits critical identification later.
Overall Boitier encountered about 25 species of Orthoptera (grasshoppers, bush-crickets and true crickets). The dominance of Gryllidae was of particular note.

The Social Insect Team (Corbara, Delsinne, Leponce, Orivel, Roisin)

Samples are still in transit and will require further analysis before comments can be made on the patterns that are apparent.

TERRESTRIAL

Yellow Pan Trapping (Durand)

The yellow pan samples contained a rich mixture of material which awaits further sorting. In particular they were used to target families of predatory wasps. In this connection, Durand encountered two species of the wasp family Pompilidae, not previously recorded from Vanuatu (and a particular target of the surveys), 9 species of sphecid wasp and six others from a range of wasp families. The sphecids may well prey upon the abundant cricket fauna noted elsewhere.

Malaise Trap Programme (Villemant, Durand)

A quick first examination of the Malaise trap samples showed a relative scarcity of the parasitoid Hymenoptera. Such a species scarcity may be expected for an isolated Pacific island. Ichneumonidae accounted for twenty or so species whereas Braconidae seemed to be less diverse. Among microhymenoptera, Chalcidoidea appeared particularly poorly represented and Platygastroidea the most diverse. Other Hymenoptera were collected in small numbers. Vertical distribution of the fauna cannot be discussed before sorting and identifying the specimens. However, it was noted that, among Diptera, Empididae appeared to be more numerous at the 1200 metre level than elsewhere.

Endophytic Organisms from Ground to Canopy (Da Souza)

Samples are still in transit and will require further analysis before comment can be made on the patterns that are apparent.

Special Habitats and Bark Spraying Programme (Schmidl)

Dead wood at different successional stages was the most abundant "patchy", unevenly distributed resource for insects in the forest. Consequently, the special habitat collecting yielded numerous species of saproxylic insects, with highest species and individual numbers in the Coleoptera.

A first screening of the samples (which were already sorted in the camp) shows clear differences in the beetle assemblages along the altitudinal gradient. Mounting and morphospecies-sorting of the hand-collected samples is in progress in the laboratory, to extract information on species richness and patterns of distribution. The 40 bark spray samples from Santo show - on the basis of the first impressions in the field - very different results when compared with the 64 samples taken in Lamington NP, Queensland. The tree bark samples in Lamington NP have high species richness and consistent proportions of taxa like Carabidae, Lathridiidae, Acari, Pseudoscorpiones etc., indicating a habitat populated by a characteristic arthropod community. The tree bark samples in the geologically young Santo island reveal no clear patterns and many taxa (e.g. Carabidae, Lathridiidae) are missing in all the bark samples.

Further analysis will focus on biogeographical implications of the data as well as on altitudinal gradients.

Future Activities

Future work stemming from our surveys falls into three broad categories: the further processing and analysis of our samples; the comparative analyses of our results within the Santo surveys and beyond; and, finally, the development of future projects using the 'IBISCA-Model'.

Further processing and analysis

All material collected during the field expedition phase of the IBISCA-Santo Project requires substantial further work. This involves sorting major mixed samples to finer levels of taxonomic resolution and the identification, were possible, of these subsamples by appropriate specialists. Even where particular groups have already been extracted (as in the case of the moths, ants and termites) substantial further effort is required if even a proportion of the species encountered are to be identified. The absence of previous monographic works on the Vanuatu fauna makes this doubly difficult and identification will require direct comparisons with Museum collections in Paris, London and, probably, Honolulu. Such further identification will depend either on the goodwill of others (not easily found among the globally beleaguered taxonomic community!) or on the receipt of special funding for international museum visits.

For many of the sub-projects we envisage that scientific products will take the form of specialised ecological, faunistic and taxonomic papers. The first of these, based generally on multivariate analysis, do not depend on total identification of samples. Faunistic studies, of particular interest to biogeographers, do require further levels of identification than ecological studies. Finally the identification and description of new material (of which we anticipate there will be substantial amounts) requires the long-term efforts of specialist taxonomists.

Comparative Analyses

As mentioned at the outset of this report one of the great strengths of our multi-dimensional approach against a common experimental design is that results from individual sub-projects can be aligned and compared legitimately without any of the caveats usually present in such comparative analyses.

From such comparisons we will be able to identify particular taxa (species, genera, families, even orders) which show the most acute changes from altitude to altitude. It is these taxa that we can propose to managers and monitors as the most appropriate for detecting changes in climate – either from place to place or over long time frames. The coincidence of this Project with the IBISCA-Queensland Project which is using an essentially similar experimental design, is that such comparisons can be extended so that our Vanuatu results can be evaluated on a global basis.

These comparative analyses, to be effective, will require a number of drivers:

- Results from within the subprojects must be generated within reasonable time frames;
- Scientific leadership will be required to 'drive' the production of the comparative syntheses which are at the heart of our methodology;
- An appropriate Workshop must be convened within a reasonable time-frame (probably 12-18 months) so that the scientists who worked together in the field can be reunited and present the more digested results of their fieldwork as contributions to proposed syntheses;
- Post field work funding will be essential for these activities.

Future IBISCA's?

Finally the question arises as to whether or not the 'IBISCA-Model' should be further developed with new complimentary projects for the study of forest biodiversity. There is no shortage of candidate sites or ecological questions. It might, for example, be of particular interest to apply these essentially tropical and subtropical methods in a temperate setting. Further we have used these multi-dimensional methods hereto to examine the biodiversity of more or less undisturbed forest sites. Yet we know most forests have had substantial anthropogenic impact. Explicit study of the nature of the impacts of such human activities on biodiversity will be both useful and of great scientific interest.

Preliminary Report on the Botanical and Micological Components

More than a dozen experienced field botanists and two mycologists participated in the various components of the Santo 2006 expedition. Together made a total of nearly 1,200 vascular plant collections, increasing the number of gatherings from this botanically interesting island by at least a factor of three. Each collection made by the team comprised an average of about four duplicate specimens (for a total of nearly 5,000 specimens in all), sets of which will be deposited at the herbarium in Port Vila, and at the Museum in Paris, IRD in Nouméa (New Caledonia), the Missouri Botanical Garden (USA), and at the University of the South Pacific in Fiji. In addition, a small amount of leaf material was collected along with each herbarium specimen and preserved in silica gel; these will be of great value for analyses being conducted in research labs throughout the world to determine the evolutionary history of various plant groups and evaluate the relationships of species occurring on Santo.

The field team made preliminary identification of collections in the field, which indicate that about 700-800 species of vascular plants were recorded during the Santo 2006 expedition. Although we have not yet compiled comprehensive data on the total number of plants previously known from the island, our collections will almost surely double the documented flora. Hundreds of species were collected that were not previously recorded on Santo, and at least a dozen more appear to be completely new species, never before seen by scientists.

The most striking aspect of Santo's vegetation is the strong contrast between the spectacular, largely intact and well-structured forests that occur above 600m altitude and the widespread, highly secondary forests found at lower altitude in the west and along the eastern slope of the Cumberland Peninsula, and also throughout much of the rest of Santo, in which the structure has been significantly modified and an impressive number of lianas cover most of the canopy in many places. Two main types of intact forest were noted at higher altitudes. Kaori forests, found from about 600m to 900m altitude, including along ridges, are dominated by one (or possibly two) species of the conifer genus *Agathis*, which form massive trees that extend far above the surrounding canopy and provide a perfect habitat for dozens of epiphytic species that grow on its sprawling branches. Kaori forests have been recorded only on two other islands in Vanuatu, Anatom and Erromango, where they have come under heavy pressure from over-exploitation, making those on Santo perhaps the only remaining intact examples of this vegetation type within the archipelago. The second major forest type, found primarily above about 100m altitude, is characterized by a remarkable abundance and diversity of liverwort, and the presence of exceptionally large trees belonging to the genus *Metrosideros*, which like the kaoris at lower altitude, reach above the canopy and are covered with epiphytes.

TERRESTRIAL

Botanical Inventory

More than 200 collections of fern species were made mostly by Germinal Rouhan, a specialist on these interesting and important plants at several sites, including Butmas, Mt. Tabwemasana, Penaoru, and also during the Cumberland Peninsula cross-over expedition.

Ferns are especially abundant and diverse in humid, montane "cloud forests", where atmospheric humidity from clouds, fog, and mist is captured, adding significantly to precipitation from rainfall. These ecological conditions are particularly favorable for certain epiphytic fern species that were frequently observed in the forests that were visited, especially species of Hymenophyllaceae (Photo opposite), which are well diversified, and also several species of tree fern (Cyatheaceae), some of which can reach to more than 10m in height and have leaves (fronds) more than 5m long. Given how under-explored Santo was prior to the expedition, we are virtually certain that material of many new species of flowering plants were collected by the botanical team.

Based on our preliminary identifications, we have already found ten likely candidates (see below), and many more will no doubt be found as our collections are more carefully studied in the herbaria in Nouméa and Paris.

Cloud forest, at 1500m (Saratsi range)

New species

Terminalia (Combretaceae). We collected flowering material of a tall tree belonging to this genus in forest at 600 m elevation at Penaoru, and our initial examination indicates that it may be a new species.

Citronella (Icacinaceae). Two distinct species of the tree genus *Citronella* were collected on Santo. Since the genus had never been reported previously from Vanuatu, it is possible that one or both of the plants we found are new to science.

Geissois (Cunoniaceae). A very distinctive species belonging to the genus *Geissois* was collected in Butmas, which seems different from the only previously known species recorded in Vanuatu (*G.denhamii*). Yohan Pillon, who is preparing his Ph.D. on this family in theSouthwest Pacific,suspects that the plant from Santo may be a novelty for science.

G.denhamii

Gmelina (Verbenaceae). A tree belonging to this genus was collected in Penaoru valley, which was previously unknown from Vanuatu. Our material appears to resemble *Gmelina vitiensis* from Fiji, but differs in several characters, suggesting that it might also be a new species to science.

Xylosma (Salicaceae). Flowering material was collected in high altitude humid forest at 1300m of a plant that is likely a new species belonging to this genus.

Polyscias (Araliaceae). Several collections of a probable new species of this genus were made on Mt. Tabwemasana and at Penaoru, and a second member of the genus, *P. schmidtii*, was recorded for the first time ever on Santo.

Polyscias sp.

Weinnmania (Cunoniaceae). Vanuatu's second genus of Cunoniaceae, *Weinmannia*, is likewise represented by two previously recorded species in Vanuatu. One of these (*W. denhamii*) was collected during Santo 2006, but the other one was not seen. However, what appears to be a third species was found on both Mt. Tabwemasana and at Penaoru, and this is probably a new species as well.

Weinmannia sp.

Breynia (Euphorbiaceae). The botany team also collected a female plant of *Breynia* that is potentially an undescribed species.

Schefflera (Araliaceae). Several members of this genus occur on Santo, one of which clearly represents a new species, collected for the first time ever on Mt. Tabwemasana, that belongs to the *Dizygotheca* group, which centered in New Caledonia and has one other member in Vanuatu.

A second species, *Schefflera vanuatua*, previously known only from the southernmost island of Anatom, was also collected between 600 and 1000m on Santo, representing a disjunction of nearly 600km.

Schefflera vanuatu

Sciaphila (Triuridaceae). This distinctive parasitic genus, which entirely lacks chlorophyll, was not known from Santo until we made several collections, which appear to represent two distinct species. One member of the genus had previously been recorded from Vanuatu (*Sciaphila aneityensis*), suggesting that the second one may be a new species.

Coelogyne macdonaldii

Santo's humid forests abound in species of orchids, many of which are particularly beautiful. In addition to the numerous many terrestrial species that are easily collected, the botany team was able to obtain excellent material of many exclusively epiphytic species that are restricted to specialized habitats among the branches of large trees. This was made possible by the expert tree climbers who worked with the botanists, providing access to an important and very poorly-known portion of the flora that could not otherwise have been inventoried. The epiphytic orchids, which have never before been documented on Santo, almost surely contain several new species.

Plots Studies

In addition to conducting botanical inventory work on Santo, our team also established a series of plots at Penaoru in order to obtain quantitative data on forest structure and composition, which will contribute to a series of similar studies being conducted throughout the SW Pacific. The most notable finding from the plot work was that the vegetation below 600m is very disturbed, with very low tree densities and the presence of numerous widespread Pacific Island species along with other species that members of the team recognized from New Caledonia and/or Fiji, where this vegetation type would be called "Mixed Deciduous Lowland Forest". The much better-preserved forest types at higher altitudes were considerably more diverse in composition, and can be characterized as "Moist Lowland Forest" and "Montane Forest". Nearly all of the many interesting and exciting plants documented during the Santo 2006 expedition came from these forests.

A total of 12 plots were established at Penaoru, each comprising an area of 400m^2 (20 × 20m), for a total of area of 4,800 m^2. Within each plot, all trees with a DBH (diameter at breast height) equal or more than 5 cm were numbered with a permanent label, and a collection was made of each individual. A single specimen was taken from sterile plants for identification, where as five duplicate herbarium collections were made from fertile trees (with flowers and/or fruits), as well as from fertile shrubs and herbaceous species occurring within the plots. A total of 947 trees (at least 5 cm DBH) were recorded within the 12 plots.

Our preliminarily results indicate that these trees represent 233 species, although this is likely a slight over-estimate, especially for the plots at 1200 m, where the numbers appear to be particularly high (a more accurate figure will be available once all the sterile collections have been carefully analyzed). In addition to providing a basis for characterizing the forests on Santo, the plots also served as the inventory sites for the IBISCA study, ensuring a baseline of floristic and structural data that will be used by the entomologists. Several interesting plant specimens were collected by members of the IBISCA team, who also examined plant-insect relationships at several sites.

Altitude (no. of plots)	150 (1)	300 (1)	600 (3)	900 (3)	1200 (3)	Total
No. of individuals	23	33	208	367	316	947
No. of genera	9	14	42	53	54	172
No. of species	9	14	55	71	84	233

Mycology

Although several of the sites that were examined for fungi were too dry for the profuse fruiting of material, the mycological team collected ca. 400 specimens representing 300-350 different taxa, mainly Asco- and Basidiomycota (the larger mushrooms), but also some fifteen Myxomycetes of the genera *Physarum*, *Dictydium* and *Arcyria*. Because conditions were so dry, the large majority of fungi collected were saprophytes, growing generally on dead wood (including resupinate fungi, polypores, and various ascomycetes). The few other collections represent plant parasites (some polypores for instance), parasites of insects (Cordyceps sp.), or parasites of other fungi (e.g. Tremellales). Two potential symbionts were also collected that are possibly associated with trees of the legume genus *Intsia*. An interesting and spectacular phenomenon are the bioluminescent fungi of the genera *Mycena* (Photo below) and *Poromycena*, widely distributed on Santo and well-known by the local population.

TERRESTRIAL

Preliminary Reports for the travelling teams

River Team

Context

The River Team consisted of six persons of 5 different nationalities (New-Zealand, Australia, Vanuatu, Germany and France), assisted by local guides. Capacity building was made possible by the participation of Donna Kalfatak, a member of the Environment Unit of the Ministry of Lands of Vanuatu. The River Team work between Nov. 4 and 25 in the vicinity of three main sites: Tasmate and Penaorou, on the west coast of Santo, and Peavot, on the Big Bay side of Cape Cumberland.
The fish specialists in the Team had previously worked on the Jordan river and other drainages of east Santo, as well as other islands in Vanuatu.

By contrast, the aquatic insect fauna of Vanuatu was scarcely known. Regarding the insect orders with obligatory aquatic larval stages, a single species of mayflies and 25 species of dragonflies and damselflies were previously known from Vanuatu. There were no Plecoptera at all reported from Vanuatu. Likewise, there are also very few species of caddisflies described from Vanuatu. The purpose of the expedition was thus to investigate whether there is a broader diversity of Ephemeroptera, Odonata, Plecoptera, and Trichoptera than previously reported.

Sampling effort

The River Team has sampled over 1,100 fishing units in 12 catchments, corresponding to about 60 km of river course, and 150 km^2 of catchment area. Different collecting methods were combined to sample different life stages of aquatic insects: Mainly light trapping near rivers was used to gain imagines of caddisflies and mayflies. Additionally, imagines were collected from the adjacent vegetation of the rivers by using sweep nets and beating nets. Larval stages were caught by using drift nets and sturdy aquatic nets. Additionally, mature larvae of mayflies were kept in rearing cages in the rivers until they emerged. Specimens from other insect groups with aquatic life stages (Coleoptera, Lepidoptera, Heteroptera, Diptera) were also collected.

First results

In terms of fish and decapod Crustacea, Santo stands out as the richest island in Vanuatu: altogether, 47 fish and 28 decapod species are now recorded from Santo. This represents 70 % of the total fish species present in Vanuatu, as well as 90 % of all decapods. Placed in a regional perspective, Santo has more fish and decapod species than the whole of French Polynesia together. The combined fish and decapod freshwater fauna of Vanuatu now stands at ca. 100 species; this is the same as in New Caledonia, which is remarkable considering the ancient evolutionary history on that island.

The highlight of the findings was the discovery of the fish family Rhyacichthidae, now recorded for the first time from Vanuatu during Santo 2006. This is a primitive family, represented by 2 species worldwide, one in southern Asia and one in New Caledonia. The latter, (*Rhyacichthys sp.*), so far known only from 4 specimens, may be the same as that now found in Santo. In addition to being a new geographical record, the additional specimens collected in Santo will permit further studies to understand the evolutionary history of this fish sometimes refered to as the "River Coelacanth".

The team was allowed to sample in sites protected by a "taboo", where fishing is forbidden, and found that species generally considered rare elsewhere are more frequent, that species reach a larger adult size and that population densities were also much higher. Overall, river species generally rare in the region are also more frequent in the Cumberland peninsula. As a result of these findings, the Environment Unit has decided to reinforce its decision to create a network of protected areas, working with the local populations.

Several hundred specimens of aquatic insects were collected, but the species richness turned out to be rather low, also compared to other Pacific islands such as New Caledonia: there were two species of mayflies, about 25 species of dragonflies, and few aquatic species of the remaining aquatic orders sampled. However, the collections will be complemented in due course by additional specimens collected by other members of the expedition, so the quantity and amount of species collected may still increase.
Among the species found for the first time on Santo (and Vanuatu in general) is the first record of the family Caenidae (Ephemeroptera), a probably new and parthogenetic species of *Caenis*.

Rhyacichthys sp.

Caenis n. sp., larva (Ephemeroptera: Caenidae)

Neurothemis sp. (Odonata: Libellulidae)

TERRESTRIAL

Crickets (ensiferan Orthoptera)

(account provided by Pr. Laure Desutter, MNHN, France)

Context

Within the Santo 2006 expedition, our aim was to sample the biodiversity of ensiferan Orthoptera, in order to document their phylogenetic systematics and the biological characters of the species (habitats, behaviours). This project represents the first inventory of Ensifera in the Vanuatu area, which was known up to now by few, fragmentary data only. Similarly, no data was up to now available on the biology of Vanuatu species.

This project is part of a wider research programme on the origin of endemism in New Caledonia, Oceania and Indomalaysia. The results will also be integrated in larger scale studies on the structure and the origin of communication modalities in Ensifera, especially for two model groups, the Eneopterinae and Phalangopsidae crickets.

Indicative results

During the field surveys, about 1500 specimens have been collected. Several tens of sound recordings of crickets and katydids have been performed. Most recorded specimens were collected, which significantly enhances the scientific value of the associated biological data. A new mode of acoustic communication in crickets has been discovered, based on an extensive use of ultrasounds (>30 kHz). The natural history of several species was documented (diurnal and nocturnal habitat types, male calling behaviour). Some of the collected specimens have been photographed and/or filmed.

The number of ensiferan species recorded from the island has been greatly enlarged. For example, only 2 katydid species were known from Santo: we collected 14 species, including 1 new genus (2 new species) of Gryllacrididae. 40 to 50 cricket species were collected, and at least half of them are new to science. These include 3 to 5 new eneopterine species, and 1 new genus and 4 new species of phalangopsid crickets.

Orthopteroïd insects have been extensively collected. This material will be studied by several colleagues, working or not at the Paris Museum, together with the specimens collected by other Santo teams in other areas of Santo.

Further data processing and analysis

We will first analyse the collected specimens, in order to give a list of all the Ensifera species found during the Santo expedition.

The data more specifically related to eneopterine crickets will be included in the phylogenetic analysis of the Lebinthini tribe. Acoustic data will be analysed both for themselves, documenting the unique use of ultrasounds we put in evidence, and second in the frame of the phylogenetic analysis of song evolution in the Lebinthini clade.

Phalangopsidae crickets will be studied at a regional scale, to compare our results with the data we already published about New Caledonia crickets.

Cardiodactylus sp. nov.

Lebinthus sp. nov.

TERRESTRIAL

Herpetofauna

(account provided by Dr. Ivan Ineich, MNHN, France)

The herpetological field trip to Santo was very fruitful: 549 specimens of reptiles and amphibians (frogs, lizards and snakes) were collected during a 3 weeks field trip around the island, including 1 frog, 507 lizards and 41 snakes. We collected 95 lizard eggs among which some hatched on Santo and most did so back in Paris. Most species occurring in the island were photographed and numerous tissue samples were taken.

Preliminary results

Amphibians

Only one amphibian species, *Litoria aurea*, occurs in Vanuatu. It was introduced in the archipelago around the 1970s, and is now widespread and can be seen in most irrigated taro fields in Santo.

Litoria aurea

Lizards

Vanuatu lizards belong to two families (Gekkonidae and Scincidae). A Fijian iguanid was recently introduced on Efate Island only.

The gekkonids (Gekkonidae)

We collected seven gekkonid species, including the uncommon Voracious Gecko (*Gehyra vorax*), a species considered as rare. Our results showed that the species is not as rare as expected, but its habits make sightings uncommon. We also obtained results (to be published) showing that a new sampling method allowing easier gecko inventories is possible on many tropical islands: this method will have an important impact on island gecko's conservation. We also collected nine specimens and several eggs (previously unknown) of the endemic Vanuatu gecko *Lepidodactylus vanuatuensis*. Some of these eggs hatched in Paris and we obtained the first data on egg size and hatching size for the species. We sampled the endemic *Nactus multicarinatus* at several localities and elevations in Santo. These data will allow an assessment of the intra-island variation of a widespread and common species, according to elevation and localization east or west of the Cape Cumberland mountain range. One Vanuatu endemic gecko (*Perochirus guentheri*), only known by few ancient specimens, was not found in Santo. We expected to collect that species during the trip but were unlucky.

Hemidactylus frenatus

The skinks (Scincidae)

This family is particularly diversified among Pacific Islands, with many endemic species all over the tropical Pacific. Two species known to be endemic from southern islands of the Vanuatu archipelago (Aneityum and Futuna) were not found in Santo. Several other species endemic from Vanuatu, widespread in many islands of the archipelago, were common and are well represented in our samples: *Cryptoblepharus novohebridicus*, *Emoia sanfordi* and *Emoia nigromarginata*.
The former is common but present mostly along the sea shore. The second species is common as well but its arboreal habits make sightings and collecting difficult. The latter species is less common but widespread on Santo. *Emoia sanfordi* and *E. nigromarginata* are forest species but they frequently occur on plantations around villages where they are easily seen, as foraging and laying sites are numerous. Several other skinks were also sampled, belonging to species which are widespread among tropical Pacific islands.


Emoia nigromarginata

Snakes

Only two species of terrestrial snakes occur in the archipelago, one considered as indigenous, the boid *Candoia bibroni* (Pacific Boa). The second, a small fossorial snake (*Ramphotyphlops braminus*), was recently introduced and is now widespread on many islands, but mostly found around plantations and human habitations.

Candoia bibroni is relatively common on Santo. We have taken tissues from several specimens around the island and most snakes were released afterward.

Ramphotyphops braminus is known by most inhabitants though they do not know it is a snake, as it looks like a worm.


Ramphotyphops braminus


Candoia bibroni (Pacific Boa)

Few species of sea snakes are reported from Vanuatu, but there are at least three known amphibious species (sea kraits of the genus *Laticauda*: *L. colubrina*, *L. frontalis* and *L. laticaudata*). Santo has few seashores providing a suitable habitat for amphibious snakes and we have collected only one specimen of *L. laticaudata* on the west coast (Tasmate). Other true sea snakes (which never come ashore) reported from Vanuatu are the Pelagic Sea Snake *Pelamis platura* and Cogger's Sea Snake *Hydrophis coggeri*. These two snakes, totally marine, were not seen during our terrestrial trip but we expect to obtain data from our colleagues working on marine faunas.

Further data processing and analysis

Our herpetological trip to Santo was fully positive. We collected an important material which will improve the knowledge on those vertebrates and their conservation status in the Pacific. Several scientific and popular publications can be expected from our results, among which the description of a new inventorying and sampling technique for geckos will have a significant and positive impact on their conservation in all tropical islands and even continental areas.

Widespread species, such as the skinks collected on Santo, are of high interest for the research we have undertaken for ca. 20 years. Further studies will be undertaken dealing with patterns of occurrence of ectodermic parasites for some skink species, since such parasites (mites) were not uniformly present in the populations found on Santo. We will try and find an explanation to these observed pattern variations. Such parasites can help to understand the colonisation routes taken by lizards when arriving to Pacific islands. We also have a wider project studying scale variations among some large range Pacific island lizards (ranging from New Guinea to Easter Island or Clipperton Atoll). First results showed that head scale variation patterns are species dependant; each species presents the same head scale variations independently from its geographical location. Material collected in Santo will be very useful in this broader study.

Land and freshwater molluscs

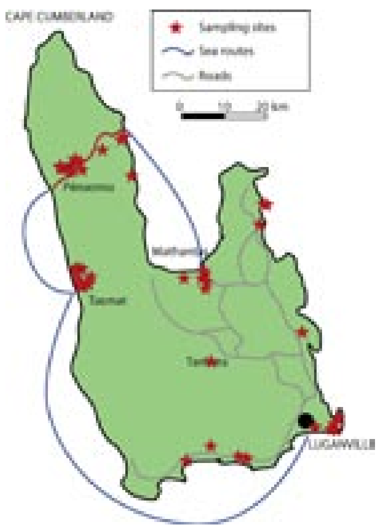
(account provided by Dr. Benoît Fontaine & Dr. Olivier Gargominy, MNHN)

Context

Papers published by Alan Solem in 1959-1962 represent the state of the art on the mollusc fauna of Vanuatu in general, and Santo in particular. These papers record 57 species from Santo, of which 41 are Vanuatu endemics. Most were collected in the southeastern part of the island, where man's impact is the most severe. Almost nothing was known regarding the forested and mountainous areas of the island before this expedition.

We collected at sites spread all over the island (see map) to inventory the terrestrial and freshwater mollusc (snails and slugs) fauna. Sampling was performed in various habitat types, from sea-level to 1500 m a.s.l., on calcareous as well as volcanic substrates. Natural vegetation was our priority, because this is where most indigenous/endemic species can be found, but we also collected in degraded habitats, particularly in the Luganville area. Freshwater habitats were also sampled.

Molluscs were collected by sight for the largest species, but because most species are less than 5 mm large when adult, litter-sieving was also carried out. Large fractions were sorted in the field, while small ones were packed to be sorted in the lab. All the material is now being shipped to the Museum and has not been examined yet, hence precise results cannot be given for the moment. Additional mollusc sampling was carried out by other people during Santo 2006, at sites we did not visit (Cape Cumberland, Philippe Bouchet; karstic areas, Vincent Prié). This material will be added to ours in due course.



Indicative results

Most of the species cited by Solem were found during our mission, and new species for the island (and most probably for science) were collected. Our material will give a good view of the introduced fauna, which now dominates the ecosystems in many areas (particularly in the eastern part of the island). Worth being noted, the alien predatory snail *Euglandina rosea*, introduced to Polynesia where it had a disastrous impact on native molluscs, was collected during our mission.

We consider it likely that the fauna almost reaches one hundred species, with a low level of turn over across the island. However, a rich sampling site will yield 12-15 species in Santo, whereas it would have 20-25 species in New Caledonia and 30-40 species in the Solomon Islands: the alpha-diversity of the mollusc fauna seems to be lower in Santo than in neighbouring islands. Some species are only found at higher altitudes, while others are restricted to calcareous substrates, but in general the fauna is quite uniform in the different regions of Santo. We were surprised by the low number of species found in altitude: in particular, the highest ridges we visited (1200m - 1500 m) were almost devoid of molluscs, despite being covered of native vegetation. However, litter sieving will most probably disclose many minute species, and we anticipate some surprises.

Most species collected in Santo were photographed alive for the first time ever.

Euconuladae

Coneuplecta sp.

Dendrotrochus sp.

Palaina sp.

TERRESTRIAL

Spiders

(account provided by Dr. Christine Rollard, MNHN, France)

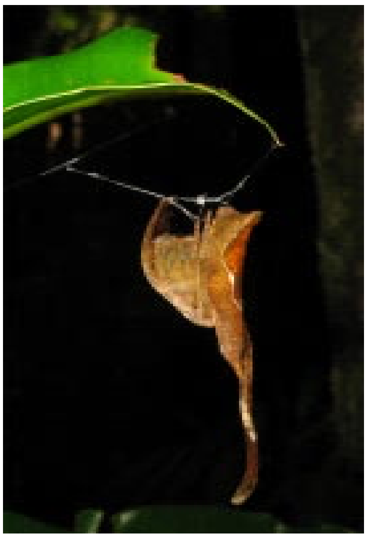
Context

Our knowledge of the group Arachnida, particularly of spiders, on the Vanuatu archipelago is old and sparse. Simon, in 1897, was the first to study material collected on Mallicolo and Vanikoro. From 1930, the situation improved as a result of fieldwork by several naturalists, such as Mr & Mrs Aubert de la Ruë. More than 100 species have now been described from the archipelago, a list of which was given by Berland (1938), including 12 cosmopolitan species and 40 present on more than one island.
On Santo, around 23 species have been identified, with only five restricted to this island of the archipelago, belonging to 10 families (including a small tarantula).

Indicative results

Specimens were collected over a period of one month, with itinerant prospecting at 4 main sites:
Tasmate and Pénaouru in the West, Matantas and surroundings of Luganville to Butmas and Port Olry (Northeast), as well as during travel across the island from West to East points.

The sampling was carried out in several types of terrestrial habitats, using combined methods of collecting in order to sample different levels of the vegetation: beating of high branches, sweeping of the herbaceous level and sorting of litter.



Arachnura sp.

The definitive number of specimens collected is not yet known because the counting could not be done locally and the material has yet to arrive in Paris. Nevertheless, several hundred specimens have been collected, representing between 100 to 200 species in about 25 families.

Among the species found for the first time on Santo can be mentioned 2 or 3 species of tarantulas and a greater number of orb-weaving spiders, including a single specimen of the genus *Arachnura* (also called scorpion-spider), with sizes of about 1 to 2 cm; the majority of the other spiders, including a number of interesting forms, are only 2-3 mm long.

Additional sampling was carried out for other groups of arachnids, such as scorpions, opiliones and pseudoscorpiones, orders for which very little information was available before.

These new data therefore represent a considerable increase in our knowledge of this group on Santo, with some species apparently having a wide distribution and others being much less common. The biodiversity appears to be high, but many species are represented by a very small number of individuals and sometimes only by immature individuals, so identifications may prove difficult.
The collections from the FMR component will be complemented by additional specimens collected by other members of the expedition, who have notably carried out sampling at the Penaoru site at different altitudes, providing quantitative as well as qualitative results concerning the specific diversity.

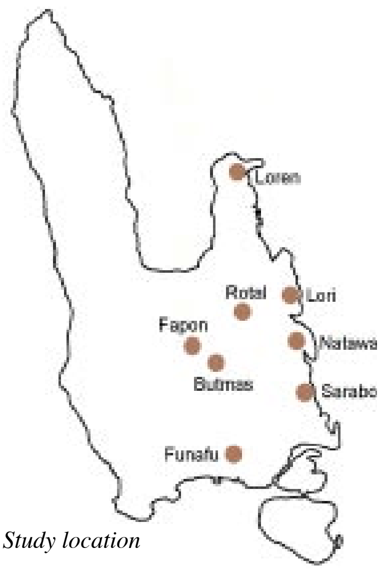
Tarentula

Santo 2006 - Section 3
Preliminary Reports on the "Karst" component

Limestone terrain made of Quaternary uplift coral reefs (the karst) occupies more than 1600 km2, i.e. nearly half of the total area of Santo. Most of this surface except in coastal areas is covered with secondary forest and is sparsely populated. Many typical karstic features are visible in the landscape, such as caves, avens, dolines, stream sinks, resurgences and blue holes. Many were mapped and sampled by the expedition. The team in charge of the scientific study of the karst of Santo included 20 people from Australia (1), France (12), New Caledonia (3), Indonesia (1), Spain (2), UK (1). Two Ni-vanuatu and Rufino Pineda provided invaluable assistance with the field work.

Three features of the Santo karst made it one of the most interesting in the Pacific. First, it was the largest extent of karstified limestone in the Pacific islands outside New Guinea. Second, it was the least well known of the large islands of the Pacific for its subterranean fauna. Third, basic sedimentological and archaeological studies were already available for the island.

To contribute to the global inventory of Santo biodiversity was our first objective. Understanding the present-day biodiversity patterns of the Santo karst was our second objective. This included reconstructing the recent geological and climatological history of the island, elucidating the geographical origin and the relationships of the fauna, searching for the factors determining local differentiation on the island, and exploring the structure and interconnections of subterranean, groundwater and soil communities.



Study location

We operated in the field as three core teams, having specific targets and investigation tools:

- a team of sedimentologists, palaeontologists and archaeologists;
- a team of hydrobiologists, with the support of divers;
- a team of terrestrial biologists, with the support of speleologists.

Field trips were targeted on either specific objectives ("survey of bats and guano of Sarabo cave" for instance), or were multi-purpose. The collected material, which in our case consisted of animals, and also of samples of sediments, water, and soil, was sorted at a gross level at the end of each trip.

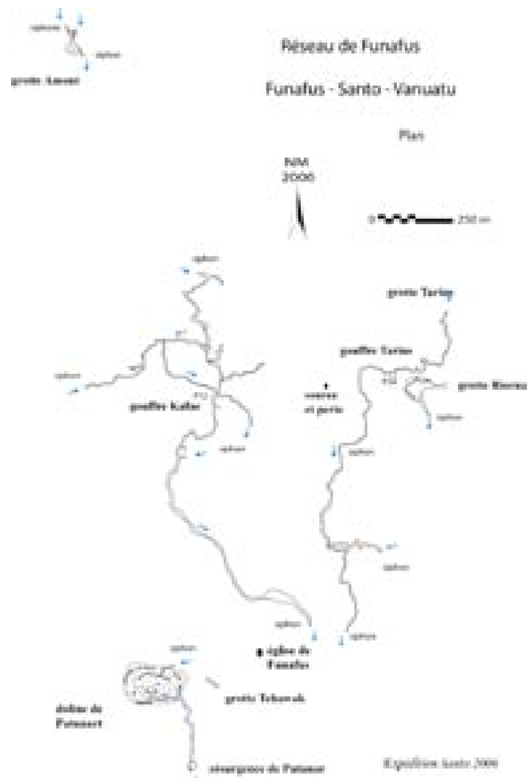
Thanks to favourable weather in September and uninterrupted activity, after a month of field work, more than 500 samples of cave, soil, terrestrial and aquatic fauna as well as sediment, palaeontological and archaeological samples were available for study.

The preliminary results and observations, are summarized below.

Indicative results

Huge caves and subterranean rivers discovered and explored

Many small caves were discovered during two preliminary reconnaissance trips undertaken in 2005. After further deep explorations and sump diving during the expedition itself, several of these caves subsequently turned out to be very large indeed. The longest of Santo, the Funafu system, develops several kilometers of underground passages, and exploration is far from being completed. Another surprise came at the end of our stay, when we discovered huge subterranean galleries with big underground river near Butmas. To-day, Santo has become the most promising karst in the Pacific islands outside New Guinea for the exploration of large underground systems.



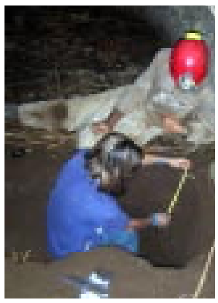
Map of Funafu system, the largest cave system of Santo

Widespread traces of human occupation, small vertebrate bones found

In the field, we sampled sediments by cuttings and coring, and we studied cave deposits for geological, palaeontological and archaeological analyses. The twenty rock shelters or caves sampled in the karstic zone of Cap Cumberland, Cap Queiros, east coast and Aoré Island provided plenty of archaeological and palaeontological rests. Megapod birds, thought to have possibly existed in Santo, as in New Caledonia, were searched for, but no remains were found. On the other hand, we found, at almost every site, layers with ceramics (more than 1000 years old), fire marks, sometimes tools and fossil remains (more than two species of *Rattus*, birds, bats, lizards…). Human bones were also discovered, sometimes associated with jaws and canines (tusks) of Suidae (pig family), indicating the importance of burial in these shelters.

The sediments taken from caves and swamps for palynological and sedimentological analysis are under study.

Human bones



Excavation in Lori cave

Many bats, guano everywhere

A bat colony of *Asellicus tricuspidatus*, Rotal caves

Miniopterus australis bearing large parasitic flies

Bats were represented by 5 species in caves and swiftlets, by 2 species. Bats were more widespread than in any other region of tropical Asia, with large colonies in most of the caves. The rate of parasitism by flies was also unusually high, especially on *Miniopterus australis*.
These large populations of bats and swiftlets produce huge amount of guano, inhabited by an abundant fauna that was intensively sampled. These guanobiont communities were highly diverse, in an unusual pattern, i.e. one or two species occurred in enormous numbers, but often differed from cave to cave and from guano pile to guano pile. Most of these dominant guanobionts, though devoid of adaptation to subterranean life, were never encountered outside caves.

Pullulation of *Hypocambala* millipeds on a guano pile

A group of *Yuukianura* Collembola on a guano pile

Few terrestrial cave-adapted species

Obligate terrestrial subterranean fauna (troglobites) was present, but poorly diversified in the interior of the island. The weak climatic differences between caves and soil habitats probably facilitates migrations of the fauna and may have prevented underground isolation of populations which would have led to speciation in this recent karst.

Cave terrestrial communities are rather dominated by non-obligate cave invertebrates. Most are carried in large numbers from soil into caves by percolating water and sinking streams, because of the many connections between soil and subterranean voids.

A female of a predatory Amblypygida (Charinus sp.) from Natawa Doline with nymphs on its abdomen

A very diversified soil fauna

Among soil fauna, microinvertebrates were always unexpectedly abundant and diversified. Point samples were on average 30% to 50 % richer in species than those of other regions of tropical Southeast Asia. At the same time, larger invertebrates (over 3 mm in length) were moderatly diversified. We are investigating some of the possible factors responsible for this peculiar community structure. Rarity of termites, which usually make available many soil microhabitats to other decomposers, might be a clue, but why are termites so rare in Santo remains to be understood.
Deep soil hosted a true eu-edaphic fauna, with Palpigradi and several minute Arthropod species devoid of eyes and pigment. Such a fauna suggests a long underground evolution, but it may have colonized the karst from neighbouring volcanoes, which are older geologically.

Contrasted richness in fresh and brackish waters

Collecting underwater traps in the anchialine waters of Loren cave

Two kinds of subterranean aquatic fauna were recognized : the fauna of freshwater caves above 50 m a.s.l., and the fauna of phreatic, freshwater caves and anchialine caves at lower altitude.
Subterranean freshwater above 50 m a.s.l . was colonized by surface shrimps and crabs, but not by fish (except large eels). None of the Crustacea collected there was cave-adapted : all had big eyes and, with rare exceptions, pigmented bodies. As a working hypothesis, the absence of fish might be linked to amphidromy and their mainly algal diet.

Conversely, subterranean waters from Blue hole and springs close to the coast, as well as phreatic water obtained by pumping, hosted a number of small blind or small-eyed and transparent Crustacea. This finding of a typically subterranean fauna raises questions of high biogeographical interest about their marine origin (where are their sister species in the sea?) and about the way they have been able to colonize freshwater.

A special effort was placed on anchialine waters, as one of the putative colonization pathways of subterranean freshwaters. Our divers explored, mapped and sampled the long and often narrow underwater passages of Loren cave. They caught in baited traps and by hand several species of troglomorphic shrimps and crabs, i.e. with no or reduced eyes, and no body pigment. This very peculiar fauna is under scrutinity by specialists.

Orcovita sp., a crab from the Loren cave

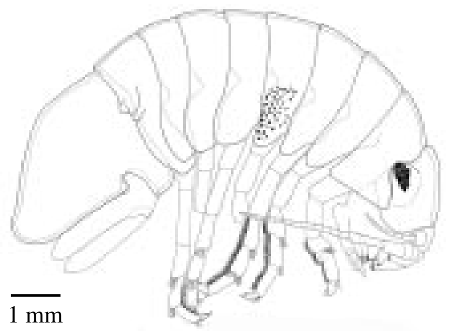
Two Atyidae shrimps, from surface river (left) and from cave stream (right)

New and remarkable taxa

The study of the fauna collected in the Santo karst has just begun, and it is not yet possible to estimate the proportion of taxa new to science in our biological material, but there are many. For Collembola alone, as a conservative estimate, at least 50 new taxa may be expected among the nearly 100 species collected. In any case, the number of soil and cave invertebrate species of Santo will at least double.

Among the collected species, a surprisingly high number are remarkable and unexpected taxa, such as terrestrial Polychaeta ; small, blind woodlice from deep soil ; a new freshwater genus of the mainly marine family Sphaeromatidae (Crustacea) ; Tanaidacea Crustacea, a group typically marine, in interstitial freshwater; or representatives of Zoraptera, a small order of rare tropical insects.

The forest soil was always rich even in relatively disturbed habitats, but biodiversity was not evenly distributed. In particular, the Fapon area emerged as an outstanding hot spot, with several animal groups that we found only here : terrestrial shrimps of the family Talitridae, terrestrial Polychaeta, and a new species of freshwater isopod crustacean.



A new species of freshwater Sphaeromatidae from the Fapon river (drawing Damia Jaume)

Conclusion

Information extracted from the Santo karst is exciting in several respects as we have shown. After a month of intensive sampling, Santo has become the best known island of the Pacific for cave and soil fauna. By the size of its karst, the easy access to its subterranean habitats, and the relatively low disturbance and high richness of its soils, Santo is a model island for testing key questions about the origin and evolution of biodiversity, well beyond its regional interest.

Perspectives are vast, and are broadening as the amount of study material increases. We have hardly sampled the deepest part of the Santo karst, discovered at the end of our trip. Sediments and archaeological remains to be dated, and will contribute invaluable information on the climatic fluctuations of the Quaternary. Most of the huge amount of collected biological and palaeontological material is still unidentified.

This will be done in the coming months, and we expect to be able to provide more detailed information on biodiversty of Santo, its magnitude, its structure and its origin before the end of 2007.

Santo 2006 - Section 4
Preliminary Reports on the «Fallows and aliens» component

Introduction

It may appear strange to find a theme specifically devoted to common and widely distributed alien included in an expedition devoted to biodiversity inventories mainly focused on finding new taxa. However, it is now clear that biological invasions induce major perturbations in ecosystem functioning and biodiversity, resulting in the disappearance of numerous indigenous populations and in species extinction, especially in insular ecosystems.

Human impact on Espiritu Santo's ecosystems was greatest during the Second World War, but since then this island has remained outside the major trade routes that have induced many species introductions. Moreover, while not unique in this regard among the eastern Pacific Islands, Espiritu Santo is of special interest in having its land divided among two very contrasted parts. The southeastern portion of the island, calcareous and more or less flat, is subjected to variable level of pressure from European settlers, while the western, volcanic and mountainous part hosts small traditional Melanesian villages. This situation offered the opportunity to combine alien species inventories and an assessment of alien invasion along human perturbation gradients.

Study location

Goals

The goals of the "Fallows and aliens" Theme, initially set during a meeting on April 20th 2005 in Nouméa and clarified during 2005 in a series of meetings in Paris, are as follows:

1) to conduct an inventory as exhaustive as possible of Espiritu Santo's alien species belonging to a selected set of taxa;
2) to assess the current proportion of alien species among selected taxa by drawing on expertise from scientists participating in the various component of Santo06 focusing on less impacted parts of the island;
3) to assess trends among alien species and taxa that have disappeared from the island or gone extinct, evaluating changes in their representation among the selected taxa since Man colonised the Island through collaboration with archaeologists and palaeontologists;
4) to assess distribution of the alien species within human perturbed ecosystems and how far they penetrate into less impacted ecosystems;
5) to assess how alien species are perceived by the native Melanesian population;
6) to produce a report for Vanuatu authorities providing a set of coherent and pertinent data on alien species;
7) to contribute to the collections of the Museum in Paris and to publish scientific papers during the two years following the end of the expedition.

Strategy

As the "Fallows and aliens" Theme was not simply restricted to inventories but also needed to take into consideration a spatial and temporal ecological approach, we had to develop an adapted sampling strategy that allowed for comparison among data gathered by all the team members, each a specialist on very different taxa. In an attempt to reduce biases among our results due to seasonal variations, all the team members worked together in the field at the same time, throughout October 2006. Four sites were chosen based on the hypotheses that they were arranged along a decreasing gradient of pressure from human disturbance:
1) The town of Luganville and its harbour, where most of Santo's trade activity has taken place for a long time;
2) The CTRAV agronomic station, located near Saraoutou village, where several alien species of interest for agronomy and breeding were introduced along with associated adventives and parasites more than 50 years ago;
3) The Melanesian village of Butmas long isolated until it was connected to the island's road network by a bad track in 2000;
4) The Vathé Conservation area, close to the Melanesian village of Matantas which is presumed to have fewer invasives than our other sites because of its protected status, a hypothesis that we set out to test.

Moreover, three habitats arranged along an hypothesised gradient of decreasing human disturbance were sampled simultaneously at each site:
1) The town of Luganville and its harbour along with a set of cultivated plots, which are presumed to harbour the highest number of alien species;
2) The "ecotone" that forms the boundary between cultivated plots and the "surrounding habitat", and is presumed to harbour the highest local species diversity;
3) The "surrounding habitat", which is a more or less secondary rain forest, and is presumed to be the least perturbed by human activities and the least invaded by alien species locally.

Because the taxa studied by the team members vary considerably with regard to their mobility and life history, various sampling tools were used. Harmonisation and standardisation of sampling protocols were set during meetings that took place during the first week of the expedition.

The "Fallows and aliens" team and their areas of competence

The "Fallows and aliens" team included 11 scientists with the following areas of competence: micromammals, ungulates, carnivores, birds, herpethology, parasites, hymenoptera social, solitary and Chalcidoidea, Coleoptera (Tenebrionidea, Agaonidea), self-propagating plants and epiphytes, geography, sociology and anthropology.

Sampling effort and methods

Vertebrates - Micromammals were sampled with 20 to 30 trapping posts that were set along 17 line transects representing a total effort of 2280 trap-nights. Ungulates and carnivores were sampled by sightings along 60 standardised tracks representing 61.7 km; their faeces and tracks were checked on 50 standardised 50 m linear transects. Birds were checked using sightings and songs at 128 checkpoints that were distributed along 27 tracks representing a total of 58 km. No quantitative approach was used for the herpetofauna, but 162 specimens were hand captured and photographed during diurnal and nocturnal investigations, 160 of which were identified as belonging to 17 species, the two last needing further investigations.

Entomofauna - Social Hymenoptera from each habitat at each of the study sites were sampled with standardised protocols using simultaneously pitfalls, 400 cm^2 litter samples, and dishes baited with peanut butter, each distributed along line transects.
Four days were devoted to two intensive prospecting campaigns that took place along eastern coast of the island, from Luganville to Shark Bay, to encompass the area that has been invaded by the electric ant, *Wasmannia auropunctata*, recently arrived from the Banks Archipelago. This operation was performed with the collaboration of Espiritu Santo Phytosanitary Service. Coleoptera (mainly Tenebrionidea) and solitary Hymenoptera were sampled by hand or using a malaise trap system or light (UV) during day and night at the site scale.
Agaonidea (Hymenoptera, Chalcidoidea) were obtained from fruits of several *Ficus* species, that had been placed in vivariums. Insects belonging to other families or orders (Coleoptera- Cetonidae, Chrysomellidae- Hemiptera...) were also collected.

Mammal parasites - Tick presence on cattle was checked using binoculars and several specimens were collected from trapped rodents, slaughtered breeding cattle and two feral pigs hunted by Nivanuatu. Fleas (Siphonaptera) were collected on alien rodents, and parasitic worms were collected from slaughtered breeding cattle.

Terrestrial Malacofauna - While terrestrial molluscs were not specifically taken into consideration by the "Fallows and aliens" team, an index of abundance assessment was performed for two introduced snails, *Achatina fulica* and *Euglandina rosea*, using the standardised 50 meter transects that were established for assessing ungulates and carnivore abundance.

Flora - Excepted in the Luganville area, semi-quantitative flora sampling of the three sites was performed and additional samples were collected during exploratory treks devoted to an assessment of ungulate and carnivore, and during inquiries on alien species' perception by locals. Moreover, an index of abundance assessment was performed for two lianas, *Merremia peltata* and *Mikania micrantha*, using the same standardised 50 meter transects.

Sociology & Anthropology - The "Fallows and aliens" team anthropologists drew up one-to-one lists of species in Latin, Bichlama (the national lingua franca) and other local languages using samples and pictures collected by team members. The time at which several introduced species arrived at various sites on Santo was determined based on the collective memory of local residents, who ranked them as native or alien based on their perceptions.

An inquiry using a pre-established, unordered list was performed at three of the four sites. The aim of this inquiry was to establish an alien species inventory and a hierarchy of their impacts as perceived by natives. Forty-four interviews of adult men between 20 and 75 years old were conducted. Several plants and invertebrates (mollusc shells, insects) were collected with the interviewed persons for later identifications.

First results

Mammalian fauna – Among the 86 micromammals that were collected, all but one could be identified as follows : 25 as *Rattus* cf. *exulans*, 18 as *R.* cf. *rattus*, 20 as *R.* cf. *norvegicus* and 22 as *Mus* cf. *musculus*. Three other rodent species may be present in the wild on Espiritu Santo: *Mus musculus castaneus* (the Asian house Mouse), *Rattus tanezumi* (the Asian house Rat), and *Rattus praetor (*the big spiny rat of New-Guinea) sub fossils remains of which are known from Vanuatu. Future analysis may reveal the presence of one or more of these other alien species in ours samples.

Trapped Rattus cf. norvegicus – Vathé Conservation Area

The breeding pig, *Sus scrofa*, was observed at all the sites except Luganville and the CTRAV agronomical station at Saraoutou. Feral populations were sighted in the Vathé and Butmas areas, where they locally reached high-densities, especially in the Butmas area, where natives complained about crop damage.
Breeding cattle, *Bos primigenus*, were sighted near houses or cultivated plots at all sites except the Luganville urban zone. They reached high densities around the Saraoutou CTRAV agronomic station. Feral populations were sighted at Butmas and Vathé, and reached high densities in the meadow area located in the central part of the Vathé Conservation area.

Interviews with authorities and native peoples from Butmas and Vathé showed that feral pigs and feral cattle were under hunting pressure, which varied from one site to another and along the annual cycle. A rapid examination of two feral pigs and one feral cow hunted by Ni-vanuatu suggested that these animals were in good health and did not exhibit evident pathology.

Breeding cattle at the CTRAV agronomic station - Saraoutou

Some goats (*Capra hircus*) and sheep (*Ovis orientalis*) were sighted in the Luganville urban area and some goats also near Vathé village. All these animals were domesticated and no information was collected supporting the hypothesis that feral individuals of theses species occur today in the wild on Espiritu Santo.

Dogs (*Canis lupus*) were sighted near human settlements at the four study sites. Sighting, tracks and faeces of this species were also checked at localities several km away from these human settlements, although each time associated with hunters or human tracks. We did not find any evidence of feral dog populations at the study sites, and native people confirmed this conclusion.

The cat (*Felis sylvestris*) was sighted near human settlements at the four study sites. Sightings of two cats were made that exhibited long distance behavioural shyness, and collections were made of faeces several km from human settlements supporting the hypothesis that feral cats roam Butmas and Vathé areas to day. Native guides strengthened this hypothesis.

Back from a Nivanuatu feral pig hunting party – Butmas village

Avifauna - Sightings and song checkpoints documented a total of 35 native bird species and four introduced ones. These records can be compared with the 50 species listed for Espiritu Santo, five being alien, the feral jungle Fowl (*Gallus gallus*), the Indian Mynah (*Acridotheres tristis*), the Black-headed Mannikin (*Lonchura malacca*), the Chestnut-breasted Mannikin (*Lonchura castaneithorax*) and the House Sparrow (*Passer domesticus*). While the two last species are presently absent from the island, we added a new one, the feral Rock Dove (*Columba livia*). The alien bird species previously noted were sighted at all study sites excepted the feral Rock Dove, which is restricted to Luganville, and the feral jungle Fowl, which is absent from this site.

The presence of the two major alien species is probably better explained by the occurrence of open habitats than of urban areas. The granivorous Black-headed Mannikin is associated with alien grasses that were introduced as pasture species and the Indian Mynah is associated with cattle, which are themselves associated with alien grasses. The impacts of these two alien birds on native birds, if any, might thus be expected in such open habitats. However, impacts on native birds seems to be negligible because there are no native granivorous birds on Santo and because the non granivorous native birds that use open habitats took advantage of the modifications of pristine habitats that produced open ones.

Forest habitats hosted the highest number of native bird species and were the least invaded by aliens although the feral jungle Fowl, introduced by Melanesians long ago, cohabits with the Incubator bird (*Megapodius freycinet*) without apparent negative impacts on this endemic species.

Herpetofauna - A synthesis of the available references covering 164 works in all, suggests that Espiritu Santo hosts a total of 19 terrestrial or freshwater species (one amphibian and 18 reptiles). Of the 17 species we observed, all had been cited previously from Espiritu Santo. Two unidentified specimens remain.

Among the 19 species mentioned from Espiritu Santo, three are aliens, all of which observed during our stay. There are a frog (*Litoria aurea*) sited in Luganville and Vathé, a gecko (*Hemidactylus frenatus*) observed in Luganville, CTRAV and Vathé and a snake (*Ramphotyphlops braminus*) seen at CTRAV.

Entomofauna - Among the 50 ant taxa collected, 36 were previously known from Vanuatu and the others were sighted for the first time; 15 of these species were clearly alien. Among these alien species, we established that the recently arrived electric ant (*Wasmannia auropunctata*) has to date invaded a restricted one-hectare area on the east coast of Espiritu Santo. With the collaboration of the Espiritu Santo Island Phytosanitary Service, we attempted to eradicate this highly undesirable species.
More than 25 Tenebrionidae Coleoptera species were collected, all of which are new species to Vanuatu and one may be new to Science. A synthesis of the taxonomy, systematics and biogeography of Tenebrionidae of the far western Pacific area now underway will help to know which of the species on Espiritu Santo species are alien *vs*. native.

Mammal parasites - The eight Siphonaptera collected on individuals of *Rattus* cf *norvegicus* belong to the species *Xenopsylla vexabilis* Jordan, 1925, which has been introduced by Man to nearly all Pacific Islands, although our record is the first for Vanuatu. Two tick species were collected, *Amblyomma cyprinus* on feral pigs and one rodent and *Haemaphysalis longicornis* (adult) on domestic cattle. Moreover, several *Haemonchus* cf *placei* were present in the rennet stomach and larvae of *Oesophagostomum* sp. in the wall of the large intestine of breeding cattle.

The tick Amblyomma cyprinus, collected on feral pigs – Butmas village

Malacaufauna - Two widespread common snail species, *Achatina fulica* and *Euglandina rosea* were never observed on the 50 meter line transects established in the various habitats of the Butmas area. On the other hand, shells of *A. fulica* were seen in all the habitats at Vathé and Saraoutou except in meadows and pastures. *Euglandine rosea*, less frequent than *A. fulica*, was sighted only in secondary forest at Saraoutou and Vathé and in cultivated plots at Vathé.

Flora - Approximately 250 plant collections were made, representing about 200 species, near 50 % of which are aliens. Moreover, almost 110 plants, the large majority being alien, were collected during the enquiry using the pre-established, unordered list and along the tracks used to assess ungulate and carnivore abundance.
Observations were made on 3 particular common invasive alien liana species, *Merremia peltata*, *Mikania micrantha* and *Lamiaceae* sp. The first of these is especially abundant and its 'alien' status is problematical. *Merremia peltata* has a local name in

The liana Merremia peltata killing the trees and preventing the forest regeneration - Saraoutou

the Butmas language, which is not the case for recently introduced alien species, and Espiritu Santo is located within the natural distribution area of this species, which is regarded as native in the Solomon Islands, Fiji and Samoa Islands and also in Australia, *inter alia*. Nevertheless, this species which is dominant in human perturbed habitats on Santo, exhibits a particularly aggressive behaviour that is not characteristic of a native species.
This liana is present throughout undergrowth and spreads by the way of creeping stems on the ground, producing vertical stems where ever a shaft of light appears, that reach and then cover the canopy, killing adult trees and preventing regeneration. If this plant were native or introduced long ago, its aggressive behaviour would surely have destroyed all the island's forest by now. This is however not the case, which suggests that this species has been introduced. Alternatively, it could be that its aggressive behaviour recently evolved or was increased by human perturbation of the local forest ecosystem. Analyses of pollen from old sediments might make it possible to determine which explanation is the more likely.

Sociology & Anthropology - The inquiry based on the pre-established, unordered list revealed about 30 animal taxa and as many plant taxa regarded by the persons interviewed at the three sites as introduced and invasive. The relation between the local name used in Bichlama and the Latin binomial was established for about 40 species of animals and plants.

The animal species most frequently mentioned by local people who were interviewed and were ranked highly in the list as introduced and problematic were: the *Acridotheres tristis* (the Indian Minah), *Lonchura Malacca* (the Black-headed Mannikin), *Achatina fulica* (an African snail), *Sus scrofa* àthe feral pig) and *Bos primigenius* (feral cattle), respectively. The plants that were cited the most frequently were *Solanum torvum, Mikania micrantha, Mimosa pudica, Merremia peltata, Cassia torra* and *Mimosa invisa*, respectively.

HUMAN IMPACT

SANTO 2006 - Participant list

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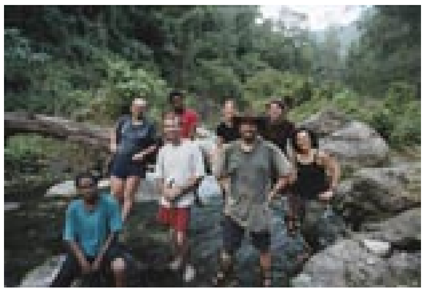

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