Report of the Oxford University Expedition

A Herpetological Survey of the High Andes of Northern Ecuador

July to September 2000

By

Nora Schultz, Helen Forsey, Benjamin McCormick, Jessica Mather-Hillon and Larry Frolich

Summary

AndinoHerps 2000 completed herpetological surveys at four sites in the High Andes of Northern Ecuador. The study area is one of the largest remaining continuous patches of pristine high altitude Andean forest, yet its rich biodiversity is severely understudied, making the region's ecosystems an international conservation priority.

AndinoHerps 2000 aimed to provide information on the herpetological diversity of the region. The expedition found a minimum of three and up to seven new species, and overall greater amphibian diversity than previously reported or expected. Agricultural land supported the lowest diversity of all habitats studied.

Our results emphasise the conservation importance of High Andean ecosystems and the vital need to protect their forest and páramo habitats from destruction by agricultural expansion.

Table of Contents

Foreword 6
Acknowledgements 6
Introduction 7
Aims 7
Background to Ecuador & the Area 8
Background to Ecuador 8
Climate 8
Topography 8
Flora & Fauna 8
Conservation in Ecuador 11
Background to the Study Area 12
The Study Area 12
Study Habitats 12
Tropical cloud forest 12
Páramo 12
Agricultural land 13
Biodiversity in the Study Area 13
High Andean Frogs and Global Amphibian Declines 17
Why Study Andean Frogs? 17
Biological Interest 17
Environmental Indicators 17
Global Amphibian Declines 19
What is the Extent of the Declines? 19
Possible Reasons for Amphibian Declines 19
Research and Conservation Needs 20
Methods 21
Population Study at Nueva America and El Chamizo 21
Field Trips to Monte Olivo and El Playon 23
Processing of Animals 23
Results 24
Species Composition and Diversity 24
Diversity Patterns 28
Site differences 28
Habitat Differences 31
Ecological data 33
Habitat data 33
Nueva America 33
El Chamizo 37
Microhabitat Details 41
Discussion 44
Population & Habitat Study 44
New Species 45

Revision of Aims 46
Conclusion 47
APPENDIX 48
A) Administration and logistics 48
B) Finances 49
C) Expedition Log 51
D) Personnel 53
E) Justification and Limitations of Study Design and Methods 54
Drift fences & funnel traps 54
DNA samples 54
Bias in study design 54
F) Sample Data Sheets 55
Bibliography 58
Field Guide 66

Figures & Tables

MAP OF ECUADOR 10
MAP OF STUDY AREA 15
STUDY HABITATS 16
SUMMARY OF ANDINOHERPS 2000 FROGS 24
DIVERSITY INDICES FOR EL CHAMIZO 25
DIVERSITY INDICES FOR NUEVA AMERICA 25
DIVERSITY INDICES FOR MONTE OLIVO AND EL PLAYON 27
SPECIES SHARED BETWEEN SITES 29
NUMBER OF SPECIES SHARED ACROSS HABITATS 29
CONTRIBUTIONS OF SITES TO SPECIMENS FOUND 30
SPECIES CONTRIBUTION TO SITES 30
HABITAT DISTRIBUTION OF THE MOST COMMON SPECIES IN NUMBERS OF INDIVIDUALS FOUND 31
HABITATS FOR EACH SPECIES 32
SUMMARY OF HABITAT CHARACTERISTICS 33
HABITAT CHARACTERISTICS NUEVA AMERICA 33
TRANSECT LAYOUT PRIMARY FOREST NUEVA AMERICA 34
TRANSECT LAYOUT SECONDARY FOREST NUEVA AMERICA 35
TRANSECT LAYOUT PÁRAMO NUEVA AMERICA 36
TRANSECT LAYOUT AGRICULTURAL LAND NUEVA AMERICA 37
HABITAT CHARACTERISTICS EL CHAMIZO 37
TRANSECT LAYOUT PRIMARY FOREST EL CHAMIZO 38
TRANSECT LAYOUT SECONDARY FOREST EL CHAMIZO 39
TRANSECT LAYOUT PÁRAMO EL CHAMIZO 39
TRANSECT LAYOUT AGRICULTURAL LAND EL CHAMIZO 40

SUBSTRATE PREFERENCES OF COMMON SPECIES 41
MOST COMMON SUBSTRATE FOR EACH SPECIES 42
SUBSTRATE PROPORTIONS 42
DATA SHEET NUEVA AMERICA & EL CHAMIZO 55
DATA SHEET MONTE OLIVO & EL PLAYON 57

Foreword

Frogs are fascinating animals and may be globally endangered, with whole populations declining or disappearing around the world. The cloud forests and alpine páramo grasslands of the tropical Andes of northern Ecuador are amongst the most biologically rich ecosystems, still largely unexplored and yet already threatened by habitat loss.

These are only two of many good reasons to study the frogs of the northern Ecuadorian Andes. From July to September 2000, the AndinoHerps 2000 expedition set out to do just that, after over a year of intensive preparation and fundraising. With a biology student team from Oxford University, UK, and students from several Ecuadorian universities, as well as Ecuadorian scientists and local people, AndinoHerps 2000 surveyed high altitude forests, páramo grassland and agricultural habitats in Northern Ecuador and collected, described and identified the frogs found. This report presents the complete results of the expedition, including an integrated version of a field guide to the area, the complete version of which will be available as a separate document later in 2002.

As this report is intended as a summary of the expedition's findings as much as a resource for future similar expeditions and projects in the area, we have provided many details about the planning, logistics and background of the project at the end of this report. In addition to this, we tried to make it easier to put our findings into a context by including details about more general biodiversity and conservation issues in Ecuador and the study area, as well as a discussion of the amphibian decline problem. We would like to encourage all readers to contact us for further information if they do not find what they are looking for in this publication. The contact address is: nora.schultz@mac.com

Acknowledgements

AndinoHerps 2000 would like to thank: all our sponsors, for their generous support, and everybody who worked with us and helped us in Ecuador, for their enthusiasm and friendliness; Will Cresswell, for initiating the project; Richard Southwood and Fausto Sarmiento, our patrons; Stefan Lötters, for herpetological advice; Katharine Gotto & colleagues from the BP conservation programme, for the excellent training programme; the USFQ and FHGO, for letting us use their facilities; Luis Coloma & colleagues, for support, help and inspiration; Maria Elena Barragan, for introducing us to Ecuador's snakes; and David Warrell, for special medical advice.

Introduction

The High Andes of South America are on top of the list of global biodiversity hotspots (Conservation International website). They harbour some of the world's rarest and most threatened ecosystems (Hamilton et al. 1995): Tropical montane cloud forests (TMCF), at elevations typically between 2000 and 3500 meters, and the unique páramo: alpine grass- and scrubland landscapes. The tropical Andes are also at the epicentre of amphibian diversity and population decline issues. The heart of world-wide amphibian diversity is in the Neotropics with over half of all species found there (Duellman 1999, Mittermeier et al 1999). At the same time, habitat loss in mega-diverse amphibian areas has led Russel Mittermeier (1999) to rank four areas in Latin America as the top priorities or "hot spots" for amphibian conservation, with the tropical Andes as number one.

Recent work in regions adjacent to the study area has shown that the Andes, like other montane regions, are probably suffering serious amphibian declines (Coloma, pers. comm.). As discussed below, the reasons are still not well understood. Amphibians are thought to be particularly sensitive to environmental change and could thus serve as indicators for habitat quality. Knowing the status of the amphibians in our study area could be an important step towards monitoring the overall condition of these ecosystems.

AndinoHerps 2000 aimed to provide updated information on the herpetological diversity of the region. The last general surveys in the area were done in the late 1970s (Lynch & Duellman 1980, 1981), and the expedition study sites, except Monte Olivo, had never been sampled before.

Aims

The primary aim of the expedition was to collect baseline data on the poorly known herpetofauna of this region. AndinoHerps 2000 hoped to facilitate future research and conservation efforts by:

- contributing to the biological assessment of a conservation hotspot of international priority;
- laying the foundation for future monitoring of amphibian declines and habitat degradation;
- obtaining material for a field guide to the amphibians of the area;
- training students in field methods;
- providing equipment and resources for future work.

Background to Ecuador & the Area

Background to Ecuador

Ecuador is located on the northwestern coast of South America and is one of the smallest countries in the region, close to the size of New Zealand. It lies on the equator, between the coordinates of latitude 01 27' 06'' N and 05 00' 56'' S and longitude 75 11' 49''W to 81 00' 40''W, covering approximately 104,550 square kilometres - 270,670 km^2 - plus the Galapagos Islands (1,000 km off the coast of Ecuador). Its continental territory borders Peru to the south and the east (approx. 1,420 km), Colombia to the north (590 km) and the Pacific Ocean to the west (2,237 km of coastline).

Climate

Ecuador's weather patterns vary greatly between different geographical regions. The climate on the Highlands varies according to the altitude. During the year, a subtropical climate prevails on the Andean valleys; at higher altitudes it is spring like, with cold nights. The dry season, when AndinoHerps 2000 did fieldwork, is from June through to September. In Quito the temperature ranges from 7° C (55°F) at night, to 26° C (78° F) at noon, averaging 15° C (64° F).

Topography

The Andes Mountains, which cross the country from north to south, divide continental Ecuador into three distinct regions: *Costa* (Coastal Lowlands), *Sierra* (Highlands), and *Oriente* (Amazon Region). The *Galapagos* archipelago constitutes the fourth distinctive region. The Sierra lies between the western and eastern ranges of the Andes Mountains, each about 400km long - the Cordillera Occidental (Western Chain) and the Cordillera Oriental (the Eastern Chain). The Valley, named the Valley of the Volcanoes, has been populated and its land cultivated for many centuries. Nestled in the valley is Quito, the capital of Ecuador. Of the two mountain ranges, the Cordillera Oriental is wider and higher; however, Mount Chimborazo, the highest peak in Ecuador, is part of the Cordillera Occidental. The Sierra also contains volcanoes, of which six are still active, including the world's highest active volcano is Cotopaxi, which reaches 5,897 meters or 19,348 feet.

Flora & Fauna

Being a tropical country with an immense number of different habitats, Ecuador has a vast and extremely diverse biodiversity and is known as one of the world's 'megadiversity hotspots' for both flora and fauna, with a high level of regional endemism. Its biological richness is reflected in a variety of taxa, including amphibians. Approximately 3,800 vertebrate species, 1,550 bird species — more per area than any other country in Latin America, and 18% of the world's total species — 320 species of mammals, 350 reptile species, 375 amphibian species, 800 fresh water fish species and 450 marine fish species have been catalogued in the country.

Map of Ecuador

Also more than 20,000 varieties of plant have been recorded. 25,000 (10%) of the world's vascular plant species are located within an area that covers just 0.2% of the Earth's surface. The Andes support 1,050 species. In the Amazon basin and along the coast, around 800 species have been collected. The richness of the flora is largely due to the diverse ecological conditions created by the great altitudinal differences. The land rises from sea level to nearly 6,300m altitude. According to the Holdridge Life Zone system, (Holdridge, 1947) Ecuador is said to have 24 tropical life zones of a total of 116, each named according to forest type and altitude. The vegetation varies from xerophytic scrub to rain forest and high-Andean páramos. Major habitats include mangrove swamps, tropical dry forest, tropical cloud forest, páramo, and rainforest.

Conservation in Ecuador

The immense biodiversity of Ecuador is being threatened by increasing deforestation, which has led to soil erosion, and desertification.

Ecuadorian forests were relatively protected by their inaccessibility until the extension of roads to outlying regions in the early 1960s. Increases in human settlement, cultivated land, and firewood/charcoal gathering are major forces behind deforestation, which is occurring at the rate of 3,400 sq km per year. Forests in the Andes and Western lowlands have been largely destroyed, with only a few pockets remaining protected, mainly in private nature reserves. Soil erosion has increased as population pressures have forced farmers to cultivate steeper mountain slopes, and the loss of valuable topsoil is exacerbating river siltation.

After a process of consultations and national analysis, the seventeen basic environmental policies and principles of Ecuador were established on June 1, 1994. Included was the recognition of eleven top environmental problems of particular urgency in the country, and the establishment of nine geographic regions that necessarily require productive actions in order to avoid environmental degradation. Administrative and political weakness, however, continue to inhibit the effective monitoring of protected areas.

In 1996, the Government of Ecuador created the Ministry of Environment to systematize and support the enforcement of adequate environmental management, to reinforce the funds for conservation programs, to concentrate the institutional framework and legislation, and to exercise leadership in the political arena for the adoption of actions toward the protection of Ecuadorian natural resources.

Background to the Study Area

The Study Area

The northern Andes cloud forest area of Ecuador is a fascinating natural-cultural landscape that, on the one hand is unique, and on the other hand, gives a typical example of the problems in amphibian-diverse habitats worldwide. The study area is one of the largest continuous patches of pristine high altitude Andean habitat and extends over roughly 50 kilometres on the inter-Andean slopes of the Eastern cordillera in Ecuador's provinces Imbabura and Carchi. The localities visited by AndinoHerps 2000 represent a good geographic sample of the region: from Nueva America at the southernmost extent of the forest to El Playon at the northernmost, with Monte Olivo and El Chamizo evenly distributed between (see map below). The very rich and yet severely understudied biodiversity of these high Andean ecosystems makes them an international conservation priority.

Study Habitats

Three main adjacent habitats occur in the study area. Forests are bordered by páramo (high altitude grassland) at the top and by agricultural land at the bottom.

Tropical cloud forest

Found in remote valleys at high elevations (above 3000m), tropical cloud forests are one of the least known types of tropical forest, and comprise the primary habitat surveyed by AndinoHerps 2000. They trap and help create clouds that drench the forest in a fine mist allowing some particularly delicate forms of plant life to survive. Cloud forest trees are adapted to steep rocky soils and a harsh climate. They have a characteristic low gnarled growth and support plants such as orchids, ferns, bromeliads and epiphytes: aerial plants which gather their moisture and nutrients without ground roots and are often used as microhabitats by frogs. The forest of the region the expedition visited covers part of the inter-Andean slopes of the eastern cordillera and stretches between 0.25 and 0.75° North to the Columbian border. It lies partly in Imbabura and partly in Carchi province and ranges between 2800 and 3700 meters in altitude. Although a lot of forest in the area is pristine, much of it appears to be secondary, with many open or recently burned areas and a more prominent shrub layer. This 50 km stretch of inter-Andean cloud forest may be the very last significant and full-growth forest of this type in the northern Andes. Given the extreme rarity of inter-Andean cloud forest, the area holds a high priority for conservation and stewardship initiatives (Aldrich et al., 1997; Churchill et al., 1995; Mittermeier et al., 1998; Sarmiento, 1997).

Páramo

Above the cloud forest lies the high-altitude grass- and scrubland known as the páramo. It covers about 10% of Ecuador's land area and is a highly specialised habitat unique to the neotropics, between 10°N and 10°S. It supports a fairly limited flora specialised for the harsh climate, high levels of UV light and the wet peat soils: most are small and compact with small, thick and often waxy leaves, and a fine hairy insulating down. Exceptions to this trend are the giant *Espletia* plants, colloquially known as frailejon, which are a feature of the Northern Ecuador páramo, in the region where the expedition's surveys took place (see photograph). Further south, the páramo becomes rather drier and bromeliads called puyas are found. The habitat, including those studied in the project, are also characterised by dense thickets of small trees, often of the genus *Polpylepis*. Fire and grazing have reduced their range into small pockets. Grasses are common, especially resistant tussock grass that grows in large clumps.

Over half a million Ecuadorians live on the páramo, although those studied were all uninhabited. It has been used for growing a large variety of potatoes and other tubers for centuries, while the increase in cattle grazing is a more recent phenomenon. Considerable threats are posed to this fragile habitat by erosion caused by overgrazing and burning to encourage the growth of young shoots for cattle. Like the forest at its borders, the páramo grassland is therefore considered an endangered ecosystem with high conservation priority (Balsler et al. 1992).

Agricultural land

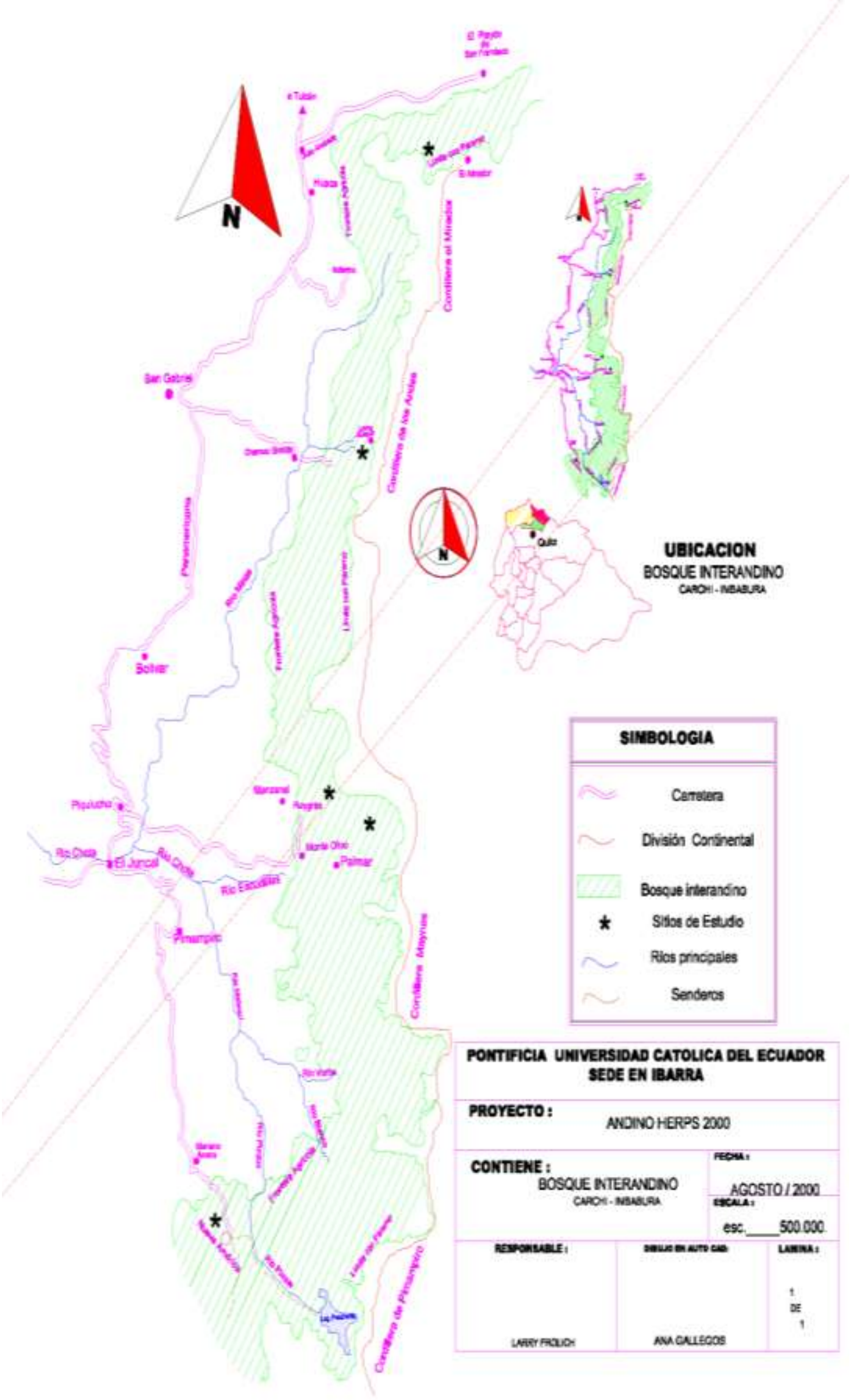
A considerable threat to the habitats studied by AndinoHerps 2000 is clearing of forests to make way for cultivation. Most forestland, including the study area, is in private hands and the agricultural frontier is constantly expanding as farmers cut forest to plant potatoes as a lucrative cash crop. (Cole et al., 1999; Frolich & Guevara, 1999; Frolich et al., 2000; Sarmiento & Frolich, In Press). Potatoes are the most universally grown crop in the region: these are grown in the local communities to sell at local markets. Potato farming has increased in recent times such that secondary or disturbed forest, which has grown up since the area was abandoned, is prevalent in many areas, especially on the lower slopes in close proximity to communities. Such regions are often characterised by bamboo growth and extensive ground cover. Over the last fifty years, agricultural techniques in the area have become more and more dependent on external inputs (mechanical traction, chemical fertilizers and pesticides) as a subsistence economy has gradually shifted to cash-cropping of potatoes for a national market (Cole et al., 1999; Frolich et al., 2000, Sulser et al., 2001). The issues of forest conservation, habitat loss, human quality of life, economic development and environmental degradation are very representative of amphibian habitats in the Neotropics and worldwide.

Biodiversity in the Study Area

Diversity and endemism in the forest and páramo are extremely high for any group of animals or plants that has been comprehensively surveyed, including birds (Cresswell et al., 1999a,b; Fjelsa, 1993) and herbaceous plants (Palacios & Tipaz, 1996; Poulsen & Krabbe, 1997). Amphibian field work has been sporadic in the region but nonetheless new species have frequently been found in the recent past, and most recently by this expedition (Guaysemin & Almeida 2002, Duellman & Altig, 1978; Duellman & Berger, 1982; Lynch, 1980; Marquez & Bosch, 1996; Miyata, 1980). Species composition also changes over very small geographic distances, suggesting that overall diversity might be quite high (Almeida et al., 2001;

Duellman, 1974; Duellman & Hillis, 1987; Frolich et al., 2001; Lynch, 1986; Lynch & Duellman, 1997; Miyata, 1982).

MAP OF STUDY AREA



STUDY HABITATS

Clokwise from bottom left: forest, páramo, searching for frogs in bromeliad, agricultural land

High Andean Frogs and Global Amphibian Declines

Why Study Andean Frogs[1]?

Biological Interest

Frogs are interesting animals that have evolved fascinating adaptations to their environment. The frogs of the study area mostly belong to a group called *Eleutherodactylus*. These species are noticeable because they do not have a tadpole stage but direct development: the froglets hatch directly from the eggs. The same is true of the frogs of the *Phrynopus* group of which this guide also describes two species. Perhaps most bizarre are the *Gastrotheca* frogs, also known as marsupial frogs: They carry their eggs in a pouch on their back until the tadpoles or froglets hatch. All these frogs are therefore more independent of water than other frogs with a completely free tadpole stage that must live in ponds or streams.

Environmental Indicators

Frogs might also be good indicators for what is happening to the environment. For example, this area should also contain frogs from the *Colosthetus* group that do have a free tadpole stage. But there have been no recent report of these animals and this expedition also did not find any. It could be the case that these frogs have already disappeared due to water pollution, but this remains to be discovered. And even though most frogs found in the area might not need good quality water for their tadpoles, they could still be more sensitive to detrimental changes in the environment than other animals or plants. This could be the case because with their moist, permeable skin, frogs take up more environmental poisons introduced by excessive agriculture and industry. Also because of their skin, frogs could be particularly sensitive to disease and parasites or UV rays. Their low mobility (unlike birds or many mammals, frogs cannot travel very far) could mean that frogs are more easily affected by habitat damage or loss than other species.

Although little of this has been proven, these are reasons to believe that frogs might be the first to show that something is wrong with the environment, because they are the first to suffer. This has become a worldwide phenomenon known as the amphibian population decline syndrome.

[1] Although AndinoHerps 2000's main interest was always in frogs, for reasons discussed in this chapter, we originally aimed to sample the reptile fauna as well as the amphibians. Both groups of animals can often be detected with the same methods. However, during the expedition, only two species of lizard were found, with only a few individuals each. Consequently, this report focusses almost exclusively on the amphibians, and the field guide does not include the reptiles at all.

Global Amphibian Declines

In many places all over the world, frogs are or have been declining, indicating that something is wrong. This might be happening in this area, too, but the frogs need to be watched for longer to find out about this and the possible reasons. Certainly, amphibian populations in various parts of the world seem to be declining, with many species apparently now extinct. Over the last two decades, researchers from various parts of the world have been reporting apparent declines and disappearances of their study populations (see Rabb 1990, 1997 for review; Heyer et al., 1988; Weygoldt, 1989). The vanishing of the amphibians was first heard of in a series of high-profile panels and publications in the early 1990's (Blaustein & Wake, 1990; Pechmann et al., 1991; Wake, 1991).

What is the Extent of the Declines?

Ten years on, there is still no certainty that amphibian declines are real. This is mainly due to the relatively short time and confined geographic range in which populations are being monitored (Blaustein et al., 1994). The longest detailed monitoring study, at the Savannah River Ecology Lab in South Carolina, began only 13 years ago. In over twenty-five years of study in Oklahoma, Arthur Bragg (1960) found that some species disappear only to return with equally high populations several years later. In Latin America and Australia, population declines appear to be focused at high elevations, making the northern Andes of Ecuador a potentially affected zone (Lips, 1998; Pounds et al., 1997; Laurance et al., 1996). Anecdotal, and in some cases documented, evidence shows species disappearances of ten years or more.

Possible Reasons for Amphibian Declines

The potential causes of amphibian population declines have been hotly debated. Environmental contamination, habitat degradation, global climate change, sensitivity to ultra-violet radiation, and increased susceptibility to illness due to environmental stress are among the proposed factors (Blaustein, 1994; Carey et al., 1999; see review by Waldman & Tocher, 1998). In the last few years, strong evidence for the role of fungal infections in many parts of the world has emerged (see review by Carey et al., 1999; Laurence et al., 1996; Lips, 1998). The fungi concerned decompose animal chitin and keratin. The particular species of fungus involved in amphibian deaths, *Batrachochytrium dendrobatidis*, appears to depend on a moist or aquatic environment to infect animals. Current thinking is that the fungus spreads among tadpoles (which have no keratin) and then attacks the keratin coating of adult frogs after metamorphosis. Although many scientists agree that the fungus may cause many frog deaths, the question remains as to whether this is really a novel disease or whether some other factor has made previously resistant frogs vulnerable to the fungus' attack on skin keratin (Carey et al., 1999). The fact that population declines and evidence of fungal infection are found even at very remote field sites suggests that global environmental effects, such as climate change or increases in radiation levels, are factors.

Research and Conservation Needs

The amphibian decline problem is fundamentally a multi-disciplinary one and joint efforts have been called for (Berger et al., 2000; Carey et al., 1999; Duellman, 1999). The input of herpetologists and ecologists, as well as environmental scientists and disease experts is required to solve the mystery of amphibian population declines. Paramount to this agenda is broad and unbiased population monitoring. Research scientists select their sites with certain goals in mind. Remote, undisturbed, mega-diverse, tropical areas are frequent targets for ecologists and taxonomic experts. At the same time, the abundance of specialists and resources in North America and Europe has given preference to those continents. Urban and agricultural sites, especially in the southern continents, have been largely neglected.

The area visited by AndinoHerps 2000 is just one example of such a neglected region. Here and elsewhere, future research and monitoring success will largely depend on the efforts and networking of small, independent volunteer groups consisting of students, local people and other interested individuals. In particular, we want this report and the included field guide to be a useful tool for local school and university projects and future student expeditions to the area. The expedition hoped to facilitate the efforts of such groups, both through easily understandable description of the frogs and through providing a valuable list of resources and contacts for anyone wishing to become involved in the study and conservation of these frogs and their habitats.

This is an exciting time to study frogs, not only because of the threats they face. Whist known populations may be declining, new species of amphibians are nonetheless being found and described at a higher rate than for any other vertebrate group (Hanken, 1999). In fact, the number of amphibian species now exceeds that of mammals (Glaw & Köhler, 1998). The area visited by AndinoHerps is no exception, as the findings of at least three new species by expedition show. There is still a lot to discover.

Methods

Population Study at Nueva America and El Chamizo

The aim of fieldwork at Nueva America and El Chamizo was to sample the amphibian and reptile fauna in the four major different habitat types of the area, páramo, primary forest, secondary forest and agricultural land. Initial site exploration consisted of collecting trips during the first nights at each site, which facilitated selection of appropriate sites for more precise searching with transects and quadrats. To allow both between and within-site comparison, the following methods were then used during the periods of systematic sampling at each site.

- <u>Diurnal Quadrats</u>:

Five 5x5 m quadrats were chosen in each habitat and sampled for ten minutes each by four people starting in opposite corners of the quadrat. Sampling involved intensive searching of the vegetation in the quadrat and raking of leaf litter where present. Care was taken to obtain a representative sample of each habitat by placing quadrats so that they would cover the full range of vegetation and microhabitat types. They were often in the vicinity of the transects though not directly on them, as the disturbance would bias that night's searching of the transect.

- <u>Nocturnal Transects</u>:

Four 50x2 m transects were laid out in each habitat, situated to cover the range of heterogeneous features within each habitat. Transects were set up by clearing the path, where necessary with machetes, and by marking transects every five meters with bright tape. They were then left to settle for at least one night before sampling started. Each transect was sampled by a different observer on three subsequent nights during each of the two visits to each site. Sampling consisted of slowly walking along the transect for 45 minutes and observing and catching every animal that could be found within one meter of either side of the transect.

- <u>Mapping & Habitat Assessment:</u>

Geographic Positioning System (GPS) data was taken at all sites visited and at all sampling localities in Nueva America and Monte Olivo. These data have been used to produce maps for the study area and will be made available for future work at the sites. Habitat characteristics were described for all collecting sites and quantitatively analysed along all transects in Nueva America and El Chamizo during the day. For every five metres of each transect we collected information on (i) predominant vegetation – identified to genus level where possible; (ii) diameter at breast height (DAB) – where trees were present; (iii) bushiness – measured on a scale from 1-10 for the 10 m^2 covered by each transect section; (iv) soil cover type; and (v) leaf litter depth.

Field Trips to Monte Olivo and El Playon

Work at Nueva America and El Chamizo had revealed a much greater amphibian diversity than expected and only very little species overlap between the sites. Instead of spending more time at those sites, it therefore seemed preferable to obtain a more complete picture of the study area by collecting from further localities.

Sampling at Monte Olivo and El Playon consisted of a total of 13 general collecting trips, spread out over two nights at each site. Transects and quadrats were not set up at these sites due to constraints on time in the field. However, detailed data sheets were used to document the time spent searching in each habitat and microhabitat details for each animal encounter[2]. Even though it will not be possible to fully compare the findings from these collecting trips with the more in-depth results from Nueva America and El Chamizo they complement the existing data in a more useful way than information we could have obtained from a third visit to the main sites.

Processing of Animals

All animals encountered during sampling were captured and the following data taken: date & time, substrate, height, observer, plot number. Animals were brought back to the base camp, where they were described, photographed, weighed and snout ventral length (SVL) measured. Where possible, sound recordings were taken. A significant number of animals per species were kept as voucher specimens and prepared in the field. All other animals were released at the end of each field visit in the same habitat where they had been found. Vouchers have been deposited with the PUCE and USFQ in Quito.

[2] Example datasheets have been included in the appendix.

Results

Species Composition and Diversity

Throughout the project, AndinoHerps 2000 found 14 species of identified frogs as well as three confirmed and up to four more putative new species. We also found two species of lizards (genus *Proctoporus*). Table 1 below summarises the findings.

<u>*Summary of AndinoHerps 2000 Frogs*</u>

Genus	Species	#s	NA				EC				MO				EP			
			P	A	1	2	P	A	1	2	P	A	1	2	P	A	1	2
Eleutherodactylus	buckleyi[3]	44	x		x		x				x		x		x			
Eleutherodactylus	chloronotus	58					x	x	x	x							x	x
Eleutherodactylus	gladiator	13										x	x	x				
Eleutherodactylus	glandulosus	1																x
Eleutherodactylus	leoni	43															x	x
Eleutherodactylus	ocreatus	18					x	x	x	x								
Eleutherodactylus	supernatis	21					x			x		x						
Eleutherodactylus	thymelensis	3	x															
Eleutherodactylus	trepidotus	20		X		x											x	x
Eleutherodactylus	unistrigatus	12				x	x						x	x				
Eleutherodactylus	sp. A	71	x	X	x	x	x	x	x	x								
Eleutherodactylus	sp. B	1						x										
Eleutherodactylus	sp. C	11													x			x
Eleutherodactylus	sp. D	8													x			x
Eleutherodactylus	sp. E	1																x
Eleutherodactylus	sp. F	2																x
Eleutherodactylus	sp. G	2											x					
Gastrotheca	orophylax	1						x										
Orsonophryne	bufoniformes	7					x		x	x			x					
Phrynopus	brunneus	1						x										
Phrynopus	peracci	7					x		x	x								
Proctoporus	simoterus	6														x		
Proctoporus	unicolor	2										x						

[3] There has been recent doubt about the identity of *E. buckleyi*. Re-examination of some specimens by Luis Coloma suggests that some or all of them might be *E. Glandulosus, E. curtipes* or *E. devillei* instead. However, at the time this report went to print, this had not yet received final confirmation. For practical purpose, we have stuck to the original identification of 44 frogs as *E. buckleyi*, but have included *E. Curtipes* and *E. devillei* in the field guide (*E. glandulosus* was already included). Interested individuals should contact the project leader for an update.

Details about the distribution of each clearly identified species can be found in the field guide section of this report, which is also available as a separate document with an added introduction. For the following analysis, but not in the field guide, the lizard species have been included and all putative new species have been treated as separate species. Evidence suggests they are all new species, but confirmation of this hypothesis could not be obtained at the time this report went to print due to lack of additional specimens.

The differences in amphibian diversity between habitats in Nueva America and El Chamizo, and between Monte Olivo and El Playon, respectively are summarised in the tables below which give a Shannon diversity index value for each habitat. A diversity index combines the number of species (species richness) with a comparison of the numbers found of each species (evenness)[4].

DIVERSITY INDICES FOR EL CHAMIZO

Habitat	Shannon Index	Interpretation
Páramo	1.6	Medium Diversity
Agricultural Land	1.1	Low Diversity
Primary Forest	1.5	Low Diversity
Secondary Forest	1.2	Low Diversity

DIVERSITY INDICES FOR NUEVA AMERICA

Habitat	Shannon Index	Interpretation
Páramo	2.93	Medium Diversity
Agricultural Land	1.08	Low Diversity
Primary Forest	1.21	Low Diversity
Secondary Forest	1.08	Low Diversity

[4] The formula for the Shannon diversity index is: $H = \sum_{i=1}^{s} p_i \ln p_i$,

P_I is the proportion in the population belonging to the ith of s species. It is usually estimated by $p_i = n_i/n$ (the proportion of that species in the sample; Heyer et al 1994)

DIVERSITY INDICES FOR MONTE OLIVO AND EL PLAYON

Site	Shannon Index	Interpretation
Monte Olivo	0.7	Low Diversity
El Playon	0.82	Low Diversity

Although AndinoHerps found a higher than expected species diversity, (see Lynch & Duellman 1980, 1981), this diversity is low compared with lowland rainforest sites. This is not a surprising result as species diversity decreases with increasing altitude. It is important to note that an evaluation of species diversity according to the Shannon index does not indicate habitat importance. Species found in highland areas are likely to be highly specialised and endemic. This makes them potentially more vulnerable than, for example, more widespread species from the diverse but more uniform lowland rainforests. We used these indices so we could compare how diversity in a finite geographical area changes with differing habitat type.

Diversity Patterns

A closer look at our results reveals surprisingly rich and complex diversity patterns for a small area. The most salient feature is the geographic and ecological restriction of many species. As shown in the figures overleaf, site overlap is rather low. Species' ranges appear more restricted than we would have expected given the fact that all work was carried out within the same altitudinal range in a continuous stretch of forest extending over only 50 kilometres. The majority of species (18 out of 23) were restricted to one site and only one species (*E. buckleyi*) was found at all four sites. Nine out of 23 species are also restricted to only one type of habitat, and a further five to only two habitats.

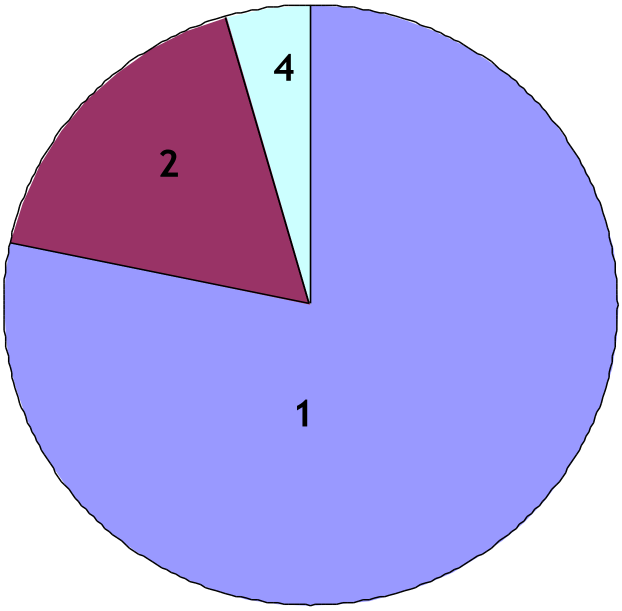
Given the low numbers of individuals found of most species, some of these restrictions may be artefacts. The species might be more widespread but may have remained undetected in other habitats or sites by AndinoHerps because they are so rare. Geographic, altitudinal and ecological restrictions of High Andean frogs are however common (Lynch & Duellman 1980) and we believe our data to reflect a true trend rather than a spurious pattern. Where further analysis was possible, this is mainly supported:

Site differences

Species distributions across sites are shown in the graph overleaf. Of the ten most common species (*E. species a, E. buckleyi, E. chloronotus, E. leoni, E. gladiator, E. ocreatus, E. supernatis, E. trepidotus, E. unistrigatus, E. species c*) only *E. buckleyi* was found at all four sites. *E. leoni* and *E. species c* were only found at El Playon, at the northern edge of the forest, *E. gladiator* and *E. unistrigatus* only at Monte Olivo, *E. ocreatus* and *E. supernatis* only at El Chamizo and the remaining three species were each found at two sites: *E. chloronotus* occurred at the two northern sites, El Chamizo and El Playon, *E. species a* at El Chamizo and Nueva America and *E. trepidotus* at Nueva America and El Playon. The latter two cases appear inconsistent with a geographically continuous restricted distribution; these species should have been found at the geographically intermediate sites, too. In the case of *E. species a,* failure to detect it at Monte Olivo might be explained with the very different habitat conditions there (see habitat section). Why AndinoHerps 2000 did not find *E. trepidotus* at the two intermediate sites remains a puzzle, especially as this species was found mainly in leaf litter and soil and should have been detected at El Chamizo with quadrat search methods, had it been present there. It is possible that there is some niche overlap and resulting competitive exclusion between *E. trepidotus* and *E. ocreatus*, as these species are very closely related but have never been found sympatrically. AndinoHerps 2000 found *E. ocreatus* at El Chamizo.

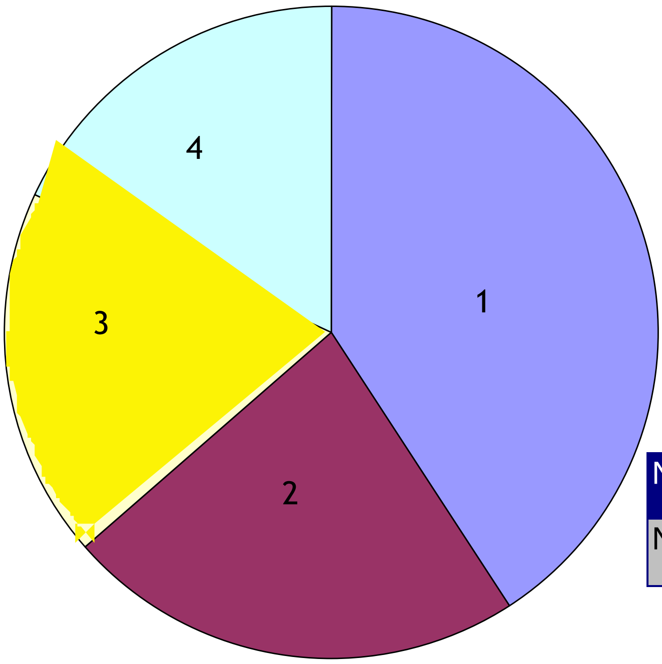
Looking at the sites themselves, as summarised in the graph overleaf, shows that the northern sites (El Chamizo and El Playon) both had more species and individuals than the southern sites (Nueva America and Monte Olivo). Given the low sampling effort at El Playon we probably even underestimated the diversity there. Future work in El Playon therefore has high priority.

SPECIES SHARED BETWEEN SITES



No. of Sites	No. of Species
1 site	18
2 sites	4
3 sites	0
4 sites	1

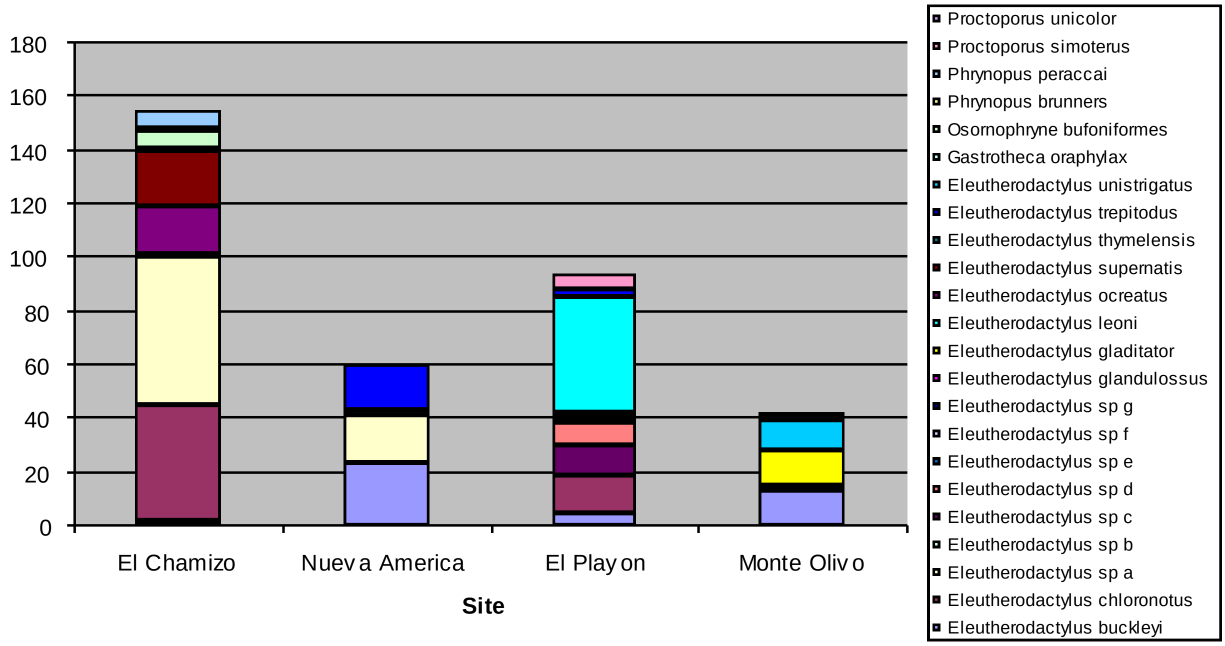
NUMBER OF SPECIES SHARED ACROSS HABITATS



No. of Habitats	1	2	3	4
No. species	9	5	5	4

<u>*Contributions of Sites to Specimens Found*</u>

<u>*Species Contribution to Sites*</u>



Habitat Differences

One expectation of AndinoHerps 2000 was that pristine habitats might support more diversity than disturbed habitats. If this was the case, we should have found fewer frogs in agricultural land and secondary forest than in primary forest and páramo habitats. Although we did find such a trend, it is not statistically significant (GLM, $F_{4,272}=1.56$, P=0.185[5]). A diversity difference between habitats might be demonstrated more convincingly in the future if larger comparison could be made within one site, using fewer observers, since unavoidable observer differences may have confounded part of the habitat differences.

For some individual species, habitat differences are statistically significant. Chi square analysis of the habitat preferences of the four most common species (*E. species a, E. buckleyi, E. chloronotus, E. leoni*) shows definite correlations between species and habitat (DF=12, Chi square=166.396, p<0.0001). These are summarised in the table below.

HABITAT DISTRIBUTION OF THE MOST COMMON SPECIES IN NUMBERS OF INDIVIDUALS FOUND

Frog/Habitat	1° forest	2° forest	Páramo	Agriculture	Other forest[6]
E. buckleyi	10	2	26	6	0
E. chloronotus	8	27	4	7	11
E. species a	8	32	24	7	0
E. leoni	11	1	0	0	31

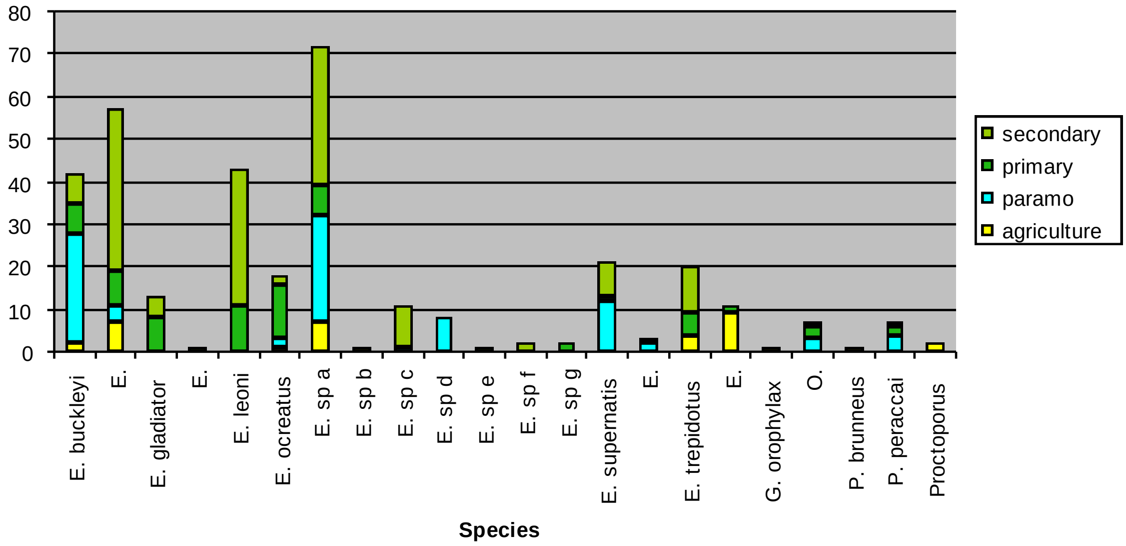
E. chloronotus is clearly forest frog, with 46 of 57 animals found in forest, as is *E. leoni*, which was exclusively found in forest. Note however, that *E. chloronotus* occurs mainly in secondary forest, whilst E. leoni was collected mainly in El Playon elfin forest and only once in secondary forest. In contrast to these clear preferences, *E. buckleyi* and *E. species a* show interesting ambivalences. This is most marked in *E. species a*, which is almost equally often found in forest (40) and open páramo and agricultural habitats (31). Whilst *E. buckleyi* shows a clear preference for páramo (26 animals), it is nevertheless remarkable that 12 animals were still found in forest. This species is also markedly absent from secondary forest.

The distributions of individual species across habitats are summarised in the figure overleaf.

[5] Statistical analysis was carried out using general linear models (GLM) and the programme Minitab. The model formula used tested the effect of habitat on the rate at which frogs were found per unit time, controlling for the variable that had been shown to be significant in preliminary tests (site, observer, sampling method used). The y variable (encounter rate) was logged to produce a better fitter model.

[6] "Other forest" here denotes a special type of elfin forest found at El Playon just below the páramo. For all other analyses, this forest was counted as primary forest, but in the case of this statistical test we tried to determine association of the commoner species with habitat as precisely as possible and made this finer distinction of forest types. The significance of the test would not decrease by lumping the forest types together again.

Habitats for Each Species



Ecological data

Habitat data

Although AndinoHerps 2000 did not aim to closely characterise the study habitats and sites, we believe that a brief description of site and plot layout and features will be useful to anyone who might plan future work in the study area or on the species studies and will also help future comparisons of our data with that of other studies. A summary of the habitat parameters recorded is given in the table below, averaged across Nueva America and El Chamizo, were transects were established. What follows is a description of the conditions of each habitat at each of these two sites.

SUMMARY OF HABITAT CHARACTERISTICS

Habitat	Average no. trees	Average tree Diameter at Breast Height (DAB) in cm	Average Bushi-ness	Leaf litter depth (average cm)
Primary forest	2.3	65.3	4.5	6.5
Secondary forest	1.9	47.5	3	3
Páramo	0.6	25.2	3	3
Agriculture	0.1	9.1	2	2

Nueva America

HABITAT CHARACTERISTICS NUEVA AMERICA

Habitat	No. trees	Average DAB	Bushiness	Leaf litter
PF	2.3	66.2	4.6	6.7
SF	1.8	46.5	3.4	3.0
Páramo	0.5	28.4	3.2	3.1
Agric.	0.1	8.0	2.7	2.0

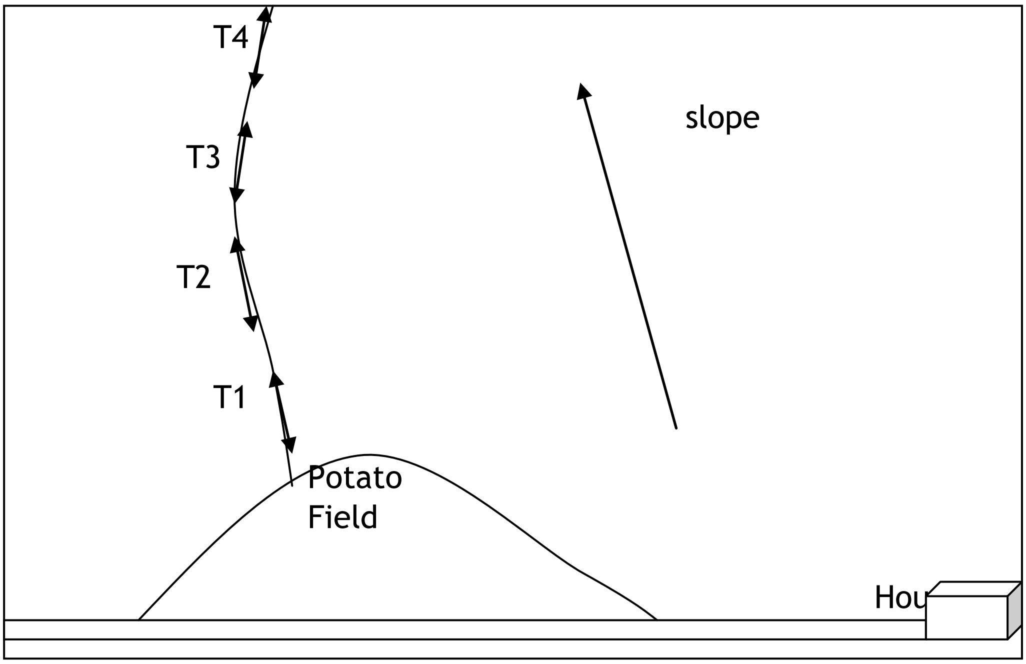
Primary Forest:

Altitude: 3400m
Coordinates: 16°78’00’’E
00°28’77’’N

Before reaching the primary forest a secondary forest composed mainly of bamboo has to be walked through. In the primary forest bamboo density decreases substantially.

The predominant plant groups are from the genera *Melastomataceae* and *Cunnoniaceae.* Many different vegetation heights present, most in the range of 15-20 m, and height decreased with increasing altitude. Many epiphytic Bromeliads present, also „lianas“ covered with moss hanging down from the branches, lichen and orchids. The main type of bushy plant amongst the trees remains bamboo, which makes movement through the forest relatively easy. Trees themselves are approximately 1-5 meters apart. The leaf litter is very dense and deep with numerous fallen decomposing logs. In transect three, starting at 30 m, the vegetation becomes drier and more open, with fewer herbaceous understory plants. In transect four the trees only reach a maximum height of about 12 meters, with many epiphytes. The slope in this part of the forest is about 60 %.

TRANSECT LAYOUT PRIMARY FOREST NUEVA AMERICA

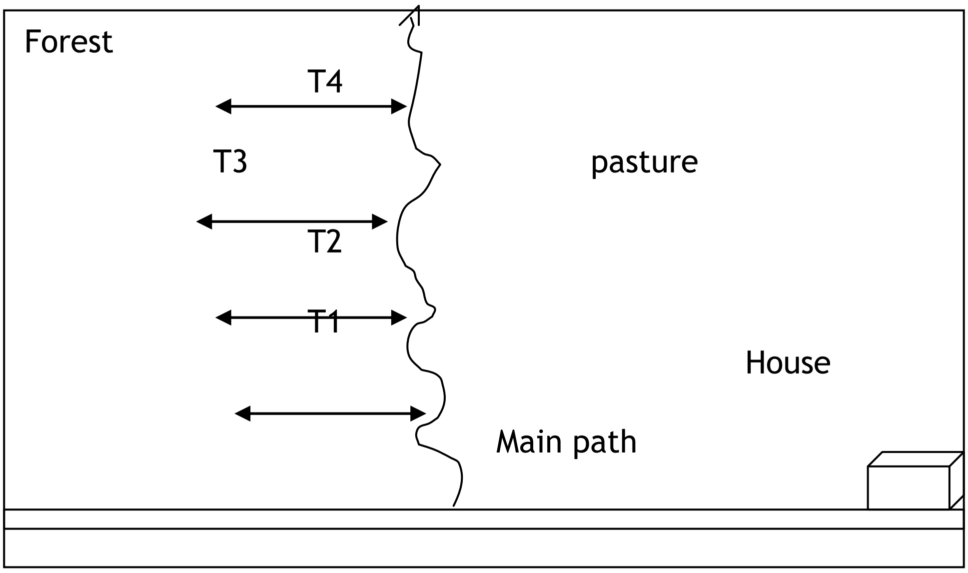


Secondary Forest:

Altitude: 3475m
Coordinates: 16°89’00’’E
00°28’65’’N

The forest goes up a steep slope (45-50%) and is bordered by dense grassland used for grazing by cows. This forest is less dense than the primary forest, with more clearings, and low growing bromeliads, a lot of regenerating forest, less dense understory and fewer overgrown big trees (fewer epiphytes). Mean tree height is approximately 10 meters, dead wood and cut off trunks of older trees remain, bamboo and grass plants present, dense leaf litter, a few green Bromeliads growing on the ground.

<u>Transect layout Secondary Forest Nueva America</u>



Páramo

Páramo Pucapamba, owner: Rafael Cayambe

Altitude: 3650 m
Co-ordinates: 16°71'70''E
00°28'65''N

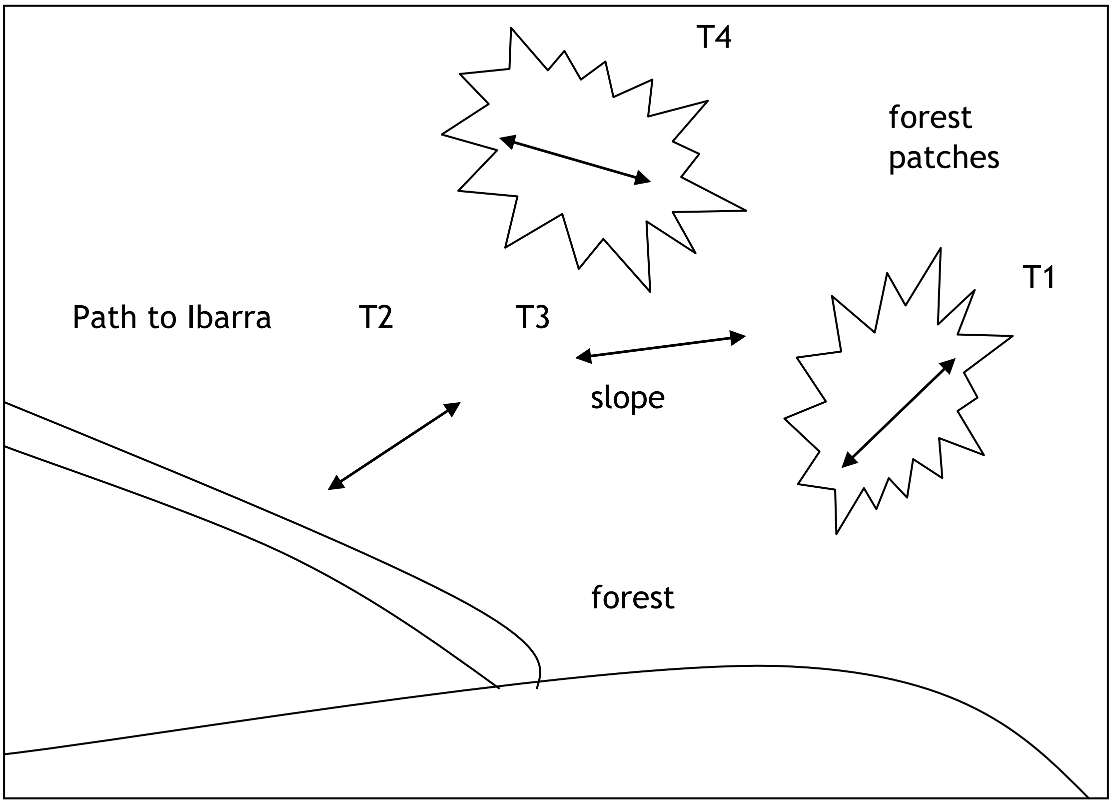
Strong wind and cold temperatures predominate. The warm air rising form the valley floor brings fine drizzle and rain. Vegetation is dominated by bunch grass. Small patches of elfin forest lie on the top of some ridges (transects two and four). The wood in these tree stands is often dead and strongly overgrown by moss, a smell of plant decay is in the air.

The lower plateaux of this Páramo tend to be covered in shorter vegetation as opposed to the tall paja (narrow leaves) and sigse (broad leaves) grass plants on the slopes. The soil on the low plateaus is very wet and soggy. Occasional higher shrubs (up to 1.50 m). The soil on the slopes is dryer.

Scattered around the site are *Achupalla* plants, many of which showed signs of consumption by the Andean spectacled bear: clear evidence that the rare mammal lives in the páramo of Nueva America.

Close to the lower forest tree line, where the Páramo begins, there are some deep cracks in the soil.

<u>*TRANSECT LAYOUT PÁRAMO NUEVA AMERICA*</u>

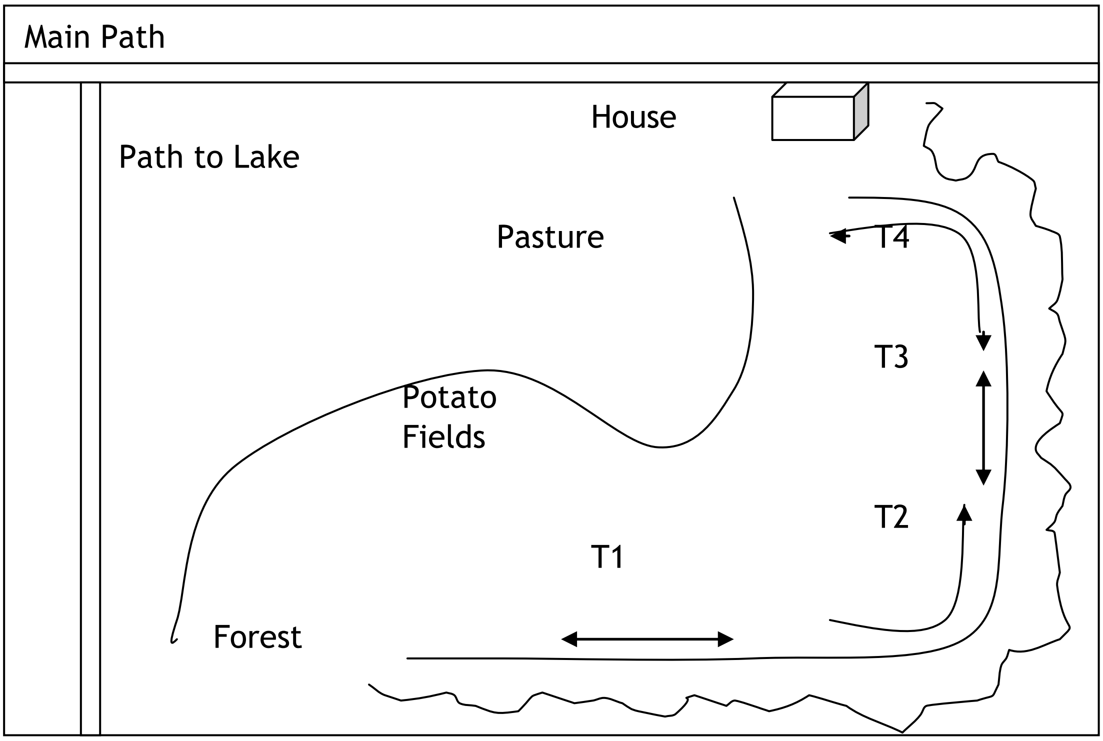


<u>*Agricultural Land:*</u>

Altitude: 3400m
Co-ordinates: 16°84’70’’E
00°28’70’’N

Sites to be surveyed lie between scrubby secondary forest vegetation on the one side and potato fields on the other side. Potato fields contain only few weeds due to intensive weeding and are well ploughed, pasture land nearby contains a diversity of herbaceous plants and often has very soggy soil. The scrubby vegetation at the tree line consists of bamboo, Bromeliads, bushes and a few trees. The transects slope gently down from one to four.

TRANSECT LAYOUT AGRICULTURAL LAND NUEVA AMERICA



El Chamizo

HABITAT CHARACTERISTICS EL CHAMIZO

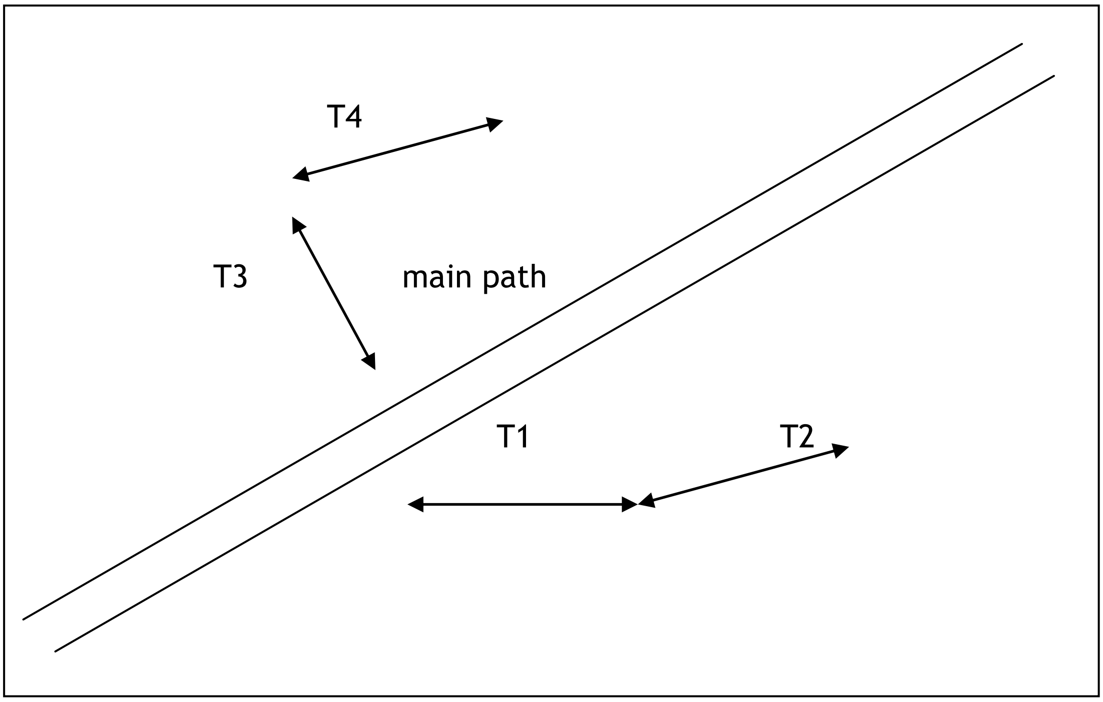
Habitat	No. trees	Average DAP	Bushiness	Leaf litter
PF	**2.0**	**76.8**	**4.0**	**8.7**
SF	**1.6**	**46.3**	**4.0**	**9.4**
Páramo	**0.08**	**2**	**4.3**	**1.4**
Agric.	**0.05**	**0.9**	**4.8**	**0.05**

Primary forest

Altitude: 3264m
Co-ordinates: 19°02'50''E
00°55'22''N

The forest here is dominated again by *Melastomataceae*, but also by *Cyclantaceae* and *Araceae*. This forest slopes at about 55-60%, the trees reach a height of 15-20 meters. The leaf litter is of similar quality as in Nueva América, but there is less herbaceous vegetation.

TRANSECT LAYOUT PRIMARY FOREST EL CHAMIZO



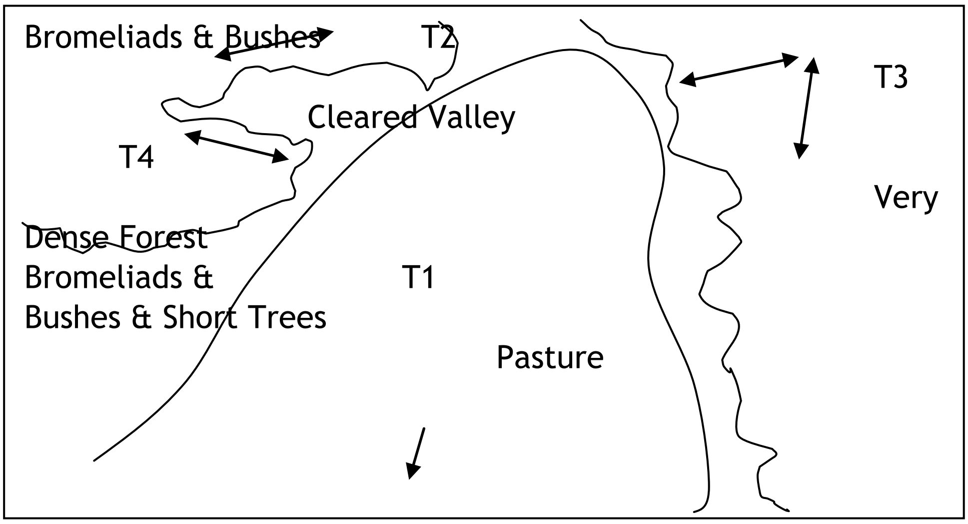
Secondary Forest

Altitude: 3150m
Co-ordinates: 19°04’00’’E
00°55’88’’N

This secondary forest borders the highest extension of the agricultural land and pasture. The transects are laid out in two very distinct forest patches (see layout map). One patch (T1&2) consists of very low and open vegetation (almost more bushland than forest), with many clearings, fallen and regenerating trees and very high densities of red bromeliads growing on the ground.

The other patch (T3&4) is very dense secondary forest with trees reaching up to 15 meters and dense understory. Bromeliads are numerous here, too, but they are of a different, green type. Frogs are very often found in red bromeliads, hardly ever in green ones.

TRANSECT LAYOUT SECONDARY FOREST EL CHAMIZO

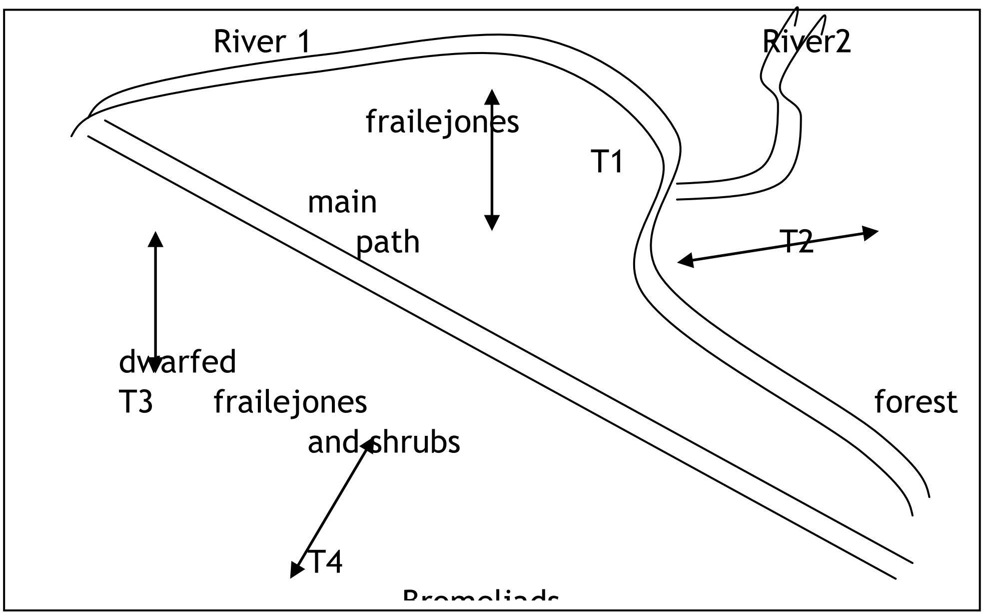


Páramo

Altitude: 3267 m
Co-odinates: 19°18'90''E
00°54'65''N

This Páramo is laid out in a high valley, with dwarfed primary forest flanking the ascending slopes. Two small rivers cut through the valley. The vegetation within the Páramo is diverse, with distinct vegetation type patches, including areas dominated by burnt tree trunks, or Bromeliads, or frailejones, or dense and diverse shrubby/herbaceous vegetation (see transect layout map).

TRANSECT LAYOUT PÁRAMO EL CHAMIZO

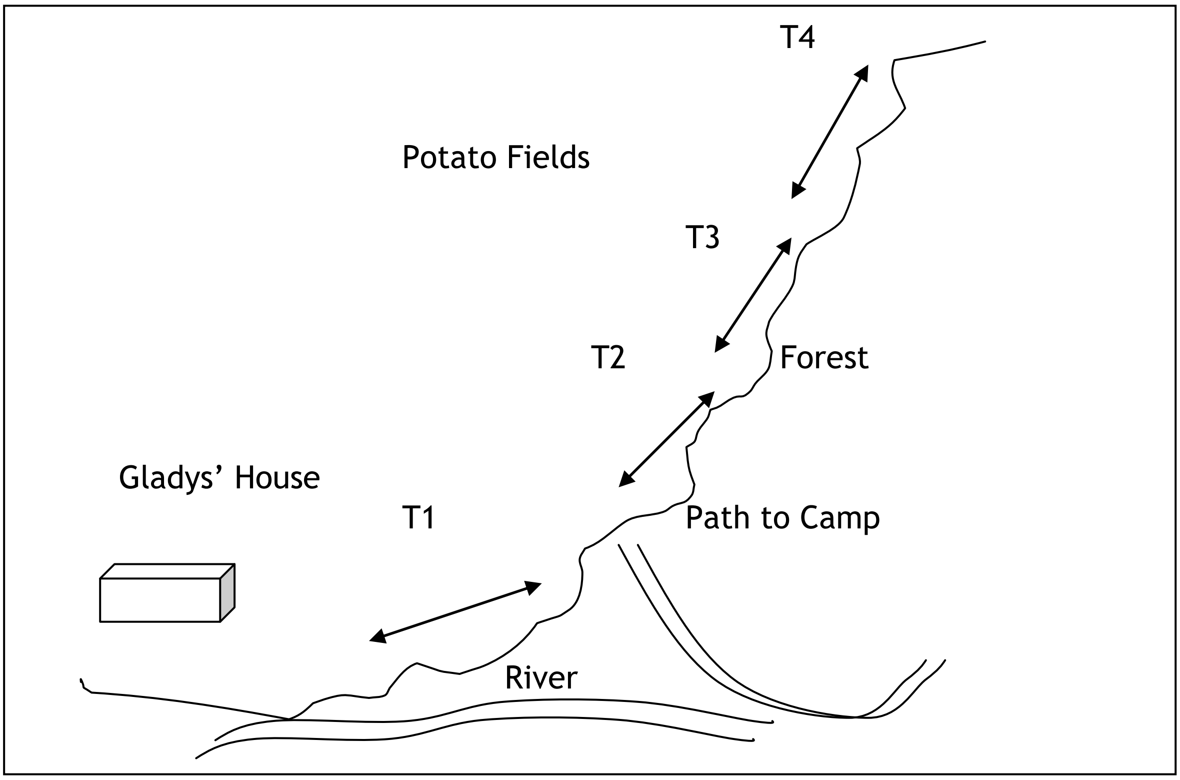


Agricultural Land:

Altitude: 3130m
Co-ordinates: 19°03'60''E
00°55'80''N

Potato fields slope up steeply (50-60%) bordered by secondary forest to the right and by pasture to the left and at the top. At the lower extension of the fields there runs a river inside the forest.

TRANSECT LAYOUT AGRICULTURAL LAND EL CHAMIZO



Microhabitat Details

Microhabitat details collected for each animal included the substrate on which it was found, and the height above the ground at which it was encountered. For the four most common species (*E. buckleyi, E. chloronotus, E. species a* and *E. leoni*), statistical analysis of substrate preference was possible and revealed significant associations (Chi square test, DF=6, Chi square=67.953, p<0.001). The table below shows the substrate associations of these four species and also of *E. trepidotus* which could not be included in the analysis (due to too many low counts), but clearly shows a preference for leaf litter substrates.

SUBSTRATE PREFERENCES OF COMMON SPECIES

Species/Microhabitat	Ground[7]	Plant[8]	Bromeliad[9]	Leaf litter
E. buckleyi	**11**	**31**	**1**	**0**
E. chloronotus	**7**	**42**	**29**	**0**
E. species a	**5**	**27**	**39**	**0**
E. leoni	**0**	**41**	**2**	**0**
E. trepidotus	**1**	**3**	**2**	**15**

Of these microhabitat preferences it is perhaps most notable that *E. leoni* is hardly ever found in bromeliads. As these plants were not absent or particularly rare in the El Playon elfin forest, where this species was mostly found, there seems to be a real preference of *E. leoni* for other plants than bromeliads. In contrast to this, *E. chloronotus* and *E. species a* occur frequently on all types of registered plants, although the majority of *E. chloronotus* occurs in bromeliads and the majority of *E. species a* on other plants. However, this might well be explained by the comparative absence of bromeliads at Nueva America compared to El Chamizo. *E. buckleyi* is most often found on plants other than bromeliads; the latter are relatively rare or inaccessibly high in the primary forest and páramo where this species mostly occurs. The sparse and grass dominated páramo vegetation explains why so many individuals of the páramo frog *E. buckleyi* were found on the ground. *E. trepidotus* was almost exclusively found in leaf litter. Its plump form, with short limbs that lack digital pads it seems to adapted to a non-climbing lifestyle.

A summary of the substrate on which each species was found most often and on which substrates frogs were found most commonly is given in the table and pie chart overleaf.

---

[7] Ground substrates were moss, rocks, streams and unspecific ground substrate; we lumped these substrates for the purpose of statistical analysis.

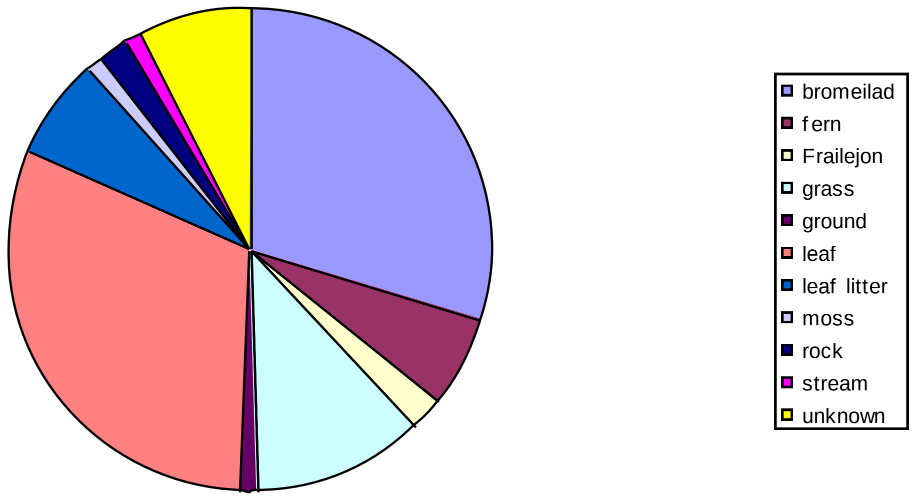
[8] This category consists of leaf, grass, fern and frailejone substrates, which were also lumped to make statistical analysis possible.

[9] Bromeliad and leaf litter substrates could be treated separately for the purpose of this analysis because they were conceptually different from other plant and ground substrates and were commonly enough by frogs to allow for putting them into a separate category.

Most Common Substrate For Each Species

Species/ Substrate	Leaf	Bromeliad	Grass	Leaf litter	Ground	Rock
E. buckleyi			X			
E. chloronotus		X				
E. species a		X				
E. species b			X			
E. species c		X				
E. species d			X			
E. species e		X				
E. species f	X					
E. species g	X					
E. gladiator	X					
E. glandulosus		X				
E. leoni	X					
E. ocreatus	X					
E. supernatis		X				
E. trepidotus				X		
E. thymelensis			X			
E. unistrigatus						X
G. orophylax		X				
O. bufoniformis				X		
P. brunneus					X	
P. perraccai			X			

Substrate Proportions


bromeilad
fern
Frailejon
grass
ground
leaf
leaf litter
moss
rock
stream
unknown

Discussion

Population & Habitat Study

The "Species Shared Between Sites" pie chart shows the proportion of species that were found at only 1 site, 2 sites, and 4 sites, respectively. No species was shared between three sites, although one species (*E. buckleyi*) was found at all 4 sites. It clearly shows that the majority of species encountered were found at only one site. Furthermore, the "Number of Species Shared Across Habitats" pie chart illustrates that most species were found only in 1 habitat, although this is a smaller majority than for site endemism. Approximately the same proportions were found in two, three and four habitats. As these two charts show, site and habitat overlap is rather low. Species range appears more restricted than we would have expected given the fact that all work was carried out within the same altitudinal range in a continuous stretch of forest extending over only 50 kilometres.

The "Contributions of Sites to Specimens Found" and "Species Contribution to Sites" figures complement the pattern shown in the "Species Shared Between Sites" pie chart by showing the proportions of species in each site and by the "Species Contribution to Sites", which shows the distribution of each species across the sites. A look at these figures allows a comparison of the species range and numbers found at each site: clearly searching at El Chamizo yielded the most individuals, and Monte Olivo the fewest. The range of different species encountered at El Chamizo and El Playon was the same, and both greater than those found at Monte Olivo and Nueva America.

Similarly, the "Habitats For Each Species" figure complements the pattern shown in the "Number of Species Shared Across Habitats" pie chart by showing how different species were distributed across the four habitats studied by AndinoHerps 2000. It is clear from this presentation of the data that many species are restricted to forest and/or páramo habitat, and that agricultural land supports both fewer species, and fewer individuals overall than the other habitats.

Interestingly, relatively few animals were found in primary forest, which appears to contradict the expectation that this habitat should support a high amphibian diversity. It is, however, possible that the high vegetation density in primary forest reduces detectability. Our data could therefore be an underestimate of abundance in primary forest. Conversely, detectability in agricultural land is much higher, and the fact that we found fewest animals there emphasises of how limited suitability this habitat is for the herpetofauna.

The diversity hinted at in these figures has been quantified with Shannon diversity indices, used so we could compare how diversity in a finite geographical area changes with differing habitat type. In El Chamizo and Nueva America páramo is interpreted as being the most diverse, with the other habitats classed as low diversity. El Playon has slightly higher diversity than Monte Olivo according to these indices. The searching methods used in these two sites do not allow for inter-habitat comparison. Although AndinoHerps found a higher than expected species diversity, (see Lynch & Duellman 1980, 1981), this diversity is low compared with lowland rainforest sites. This is not a surprising result as species diversity decreases with increasing altitude. It is important to note that an evaluation of species diversity according to the Shannon index does not indicate habitat importance. Species found in highland areas are likely to be highly specialised and endemic. This makes them potentially more vulnerable than, for example, more widespread species from the diverse but more uniform lowland rainforests.

Our interpretations of the data collected can be summarised in three important observations:

1) Variation between sites is high. This might indicate a larger extent of local endemism than previously thought.
2) The discovery of at least three new species indicates that the overall amphibian biodiversity of the study area is higher than expected.
3) Lowest amphibian diversity is found in agricultural land. This justifies efforts to protect and restore high Andean forest ecosystems.

New Species

The status of many frogs found by AndinoHerps 2000 remains uncertain. John D. Lynch, the world expert on the genus *Eleutherodactylus* confirmed three new species. Of these, one species (*E. huayacundo*, formerly "species c") has been described; the description will be published shortly[10]. The description of the new "Species a", the most common frog found in the study area, is still being completed by our Ecuadorian partners, the same applies to the third confirmed new species, "species d". The remaining putative news species need to be confirmed by comparison with more individuals. Despite efforts to collect these during a further field trip carried out by our Ecuadorian team members in 2001, this problem has not been resolved. Where available, we have included photos of all confirmed and putative new species in the field guide, to draw the attention of future researchers to similar looking frogs. Updated information about the new species will be available on the AndinoHerps website (www.andinoherps.org.uk) or upon request from the project leader (nora.schultz@mac.com).

[10] GUAYASAMIN, J.M. & ALMEIDA, D. (2002): A new species of frog (Anura: Leptodactylidae) from the highlands of Ecuador. in preparation

Revision of Aims

The aims set by AndinoHerps 2000 have mostly been fulfilled, with the exception of some technical changes to the original plan that had to be made early on in the project (see appendix: Justification and limitations of study design and methods). In particular, the expedition achieved the following:

- *Contributing to the biological assessment of a conservation hotspot of international priority*
  AndinoHerps 2000's findings clearly show a rich and previously unregistered amphibian biodiversity for the study area. This supports the assessment of the High Tropical Andes as an international conservation priority. Apart from in this report and the field guide, our results have been disseminated and their implications highlighted in a series of talks given in Ecuador and the UK, in scientific publications (Almeida et al 2001, Frolich et al 2001) and through reports in national and regional UK newspapers, on UK radio and in German newspapers. The expedition team gave two presentations whilst in Ecuador: one at the Consorcio Carchi in El Angel, a monthly assembly of local farmers, and one at the PUCE-I, our partner university in Ibarra. Similar presentations have been given by Ecuadorian team members at the PUCE Quito, during a conference in November, at the Universidad San Francisco Quito (USFQ) and at the Universidad Central, Quito. In Britain, talks were given at Oxford University and for the BP Conservation Programme in London.

- *Laying the foundation for future monitoring of amphibian declines and habitat degradation*;
  Through this report and the field guide, our results are accessible to anyone planning follow-up work. Our specimens have been deposited in Ecuador where they can be visited by future workers. Some follow-up work has already been carried out by Ecuadorian team members, and a monitoring programme is currently being planned by our field agent, Larry Frolich, and the participating herpetologists. This monitoring programme will be based largely on the data collected by AndinoHerps 2000. It will involve local high school students, thus continuing the successful cooperation with local people and building upon the great interest they showed in amphibian work and conservation issues during the expedition.

- *Obtaining material for a field guide to the amphibians of the area*
  Much of the information provided in the field guide has never been published before and is therefore a valuable addition to the public knowledge of the amphibians of the area. AndinoHerps 2000 managed to obtain photos of almost all the species of the area and took careful notes on appearance, habitat and behaviour of the animals. All this information has been integrated with previously published data in the field guide.

- *Training students in field methods*

The AndinoHerps 2000 team consisted of 2 experienced herpetologists and 8 university students who had never done any herpetological work before. Of these, one has since done a similar herpetological project in Bolivia and most continue an education or a career in science or conservation, including amphibian and habitat assessment work. During the expedition, the experienced members also gained insights into the requirements for training students which will be easily transferable to the training of high school students participating in the future monitoring programme. Some high school students and local young people already participated successfully in field methods and processing during the expedition.

- *Providing equipment and resources for future work*
  All equipment purchased by AndinoHerps 2000 was left in Ecuador with participating and cooperating institutions and individuals. Fieldwork equipment was mainly left with the PUCE-I to be made available to university students of the environmental and agricultural sciences. Some items were given to FHGO/USFQ herpetologists to facilitate follow-up work directly and indirectly related to the project. The PUCE in Quito received a set of sound recording equipment in exchange for their invaluable help with identifying the animals and supervising follow-up work. We have made a series of slide copies and photo CDs and deposited copies in Britain and Ecuador, to facilitate future comparison with new material and future presentations about the frogs in the area.

Conclusion

AndinoHerps 2000 had set out to gain a better understanding of the poorly known amphibians in an area of international conservation interest. The diversity and geographic variation discovered by this short study is much greater than we had expected. This, together with the discovery of several new amphibian species, strongly supports the classification of the High Andes as a biodiversity hotspot. Our data show that agricultural land supports the lowest amphibian diversity. As the Andean population continues to grow, it becomes more and more pressing to understand and protect the forest habitats. There is great scope for future work, both scientific studies and community-based conservation projects. The results of AndinoHerps 2000 will help to formulate priorities for such projects. A long-term monitoring programme for the area and beyond that relies heavily on our findings is already being planned. We aim to make our results and their implications as widely known as possible, and to encourage and find support for the work that is so crucially needed to conserve the unique ecosystems of the High Andes of Ecuador.

APPENDIX

A) Administration and logistics

Research materials
Maps were obtained on arrival in Quito from the army headquarters. Several maps of the study sites and surrounding area were bought and used in construction of a more specific map for the sites, displayed in this report.

Permission and permits
Necessary permits were obtained well in advance from the Ministerio del Medio Ambiente and with the support of FHGO (Fundacion Herpetologica Orces). All voucher specimens and DNA samples were left with the research institutions in Ecuador: the collection was split between PUCE –I and PUCE –Q.

Travel and transport
Transport to the sites was organised via the PUCE-I, using university trucks and drivers. Taxis and public buses were also used to travel between Ibarra and Quito.

Food and accommodation
Food for periods in the field was purchased on the day of departure, in Ibarra and San Gabriel. Accommodation at the field sites and in Quito was arranged by Larry Frolich. In Quito, we stayed at a hostel; at the field sites, facilities ranged from a high school classroom to wood shacks provided by the land owner. On occasional trips away from basecamps, tents were used.

Risks and hazards
AndinoHerps 2000 was in Ecuador during a period of considerable social unrest, with frequent general strikes, dollarization underway and Ecuadorian-American relations deteriorating. The expedition suffered one hostile confrontation from local people in El Playon, who mistook us for Americans. An additional hazard was that posed by the continuous heavy rain that coincided with the second visits to the main sites. Travel was impeded by frequent mudslides entirely blocking crucial routes.

Medical arrangements
All members of the British team attended a first aid course organised by the Oxford University Exploration Club, in which we were taught basic first aid, as well as being given information which highlighted special aspects of safety on expeditions. The British team were inoculated appropriately before leaving for Ecuador. During the expedition there were no serious health problems. Most British expedition team members had minor stomach problems at some stage, and one member had minor dental work carried out. Precautions included having food prepared in the field by members of the local community and boiling all drinking

water. Medicine taken to Ecuador which was unused at the end of the expedition was donated to a local hospital under the care of Dr Alvaro Davalos.

Photography and sound recordings

Photographs were taken of every specimen caught, as well as of the sites and habitats. A cannon EOS 300 and EOS 500 was used with a 75 – 200mm zoom lens and macro setting. Sound recording equipment was borrowed from the National Sound Archive at the British Library and returned to them, along with our bird and frog recordings for editing and archiving.

B) Finances

Sponsors	Amount received (£ stirling)
Anderson Consulting	500
BP Conservation Programme	5000
Chester Zoo	500
Christ Church JCR	100
Christ Church Travel Grant	300
Duke of Edinburgh Trust No. 2	500
Gilchrist Educational Trust	1000
Henrietta Hutton Memorial Fund	200
Magdalen College Oxford	250
Malcolm Forster	500
Mike Soper and Jimmy Elliot Fund	400
Oxford Society	250
Oxford University Exploration Fund (OUEC)	1309
Personal Contributions of British Team Members	2000
Royal Geographic Society	2500
Shell Summer Travel Bursary	300
Studienstiftung des Deutschen Volkes	450
Stuart Lever	100
Timothy Bailey Memorial Scholarship	500
William Gurney Travel Prizes, Christ Church	2000
Albert Reckitt Charitable Trust	700
TOTAL	**19,259**

Allocation of Money[11]	**Expenditure (£ stirling)**
PRIOR TO EXPEDITION	
Administration	177
Equipment – Computer and Printer	1353
- Camping Equipment	670
- Literature	52
- Photographic Equipment	385
- Scientific Equipment	1080
Insurance	185
Medicines	485
Training	347
Transport	2283
DURING EXPEDITION	
Equipment (including e.g. flashlights, stove gas, field equipment, preservatives, museum materials and literature)	723
Expenses for field agent, herpetologists and students	1010
Living & Unclassified Expenses	4545
Salaries (for field agent, herpetologists, translator, guides, cooks)	1920
Transport	736
Vivarium FHGO (maintenance contribution)	143
POST EXPEDITION	
Administration	122
Field Guide and Report	1088
Follow-Up Work in Ecuador	567
Photographic Expenses	111
Recording Equipment	537
Contingency & OUEC bulletin (sum taken by OUEC upon expedition account closure)	740
TOTAL	**19259**

An expedition bank account was set up, into which all the contributions to the expedition were paid. Before leaving for Ecuador, the expedition money was divided between the bank accounts of the four British team members. This arrangement reduced the risks and problems of money withdrawal. Traveller's cheques in American dollars were also taken and mainly used for paying transport bills.

[11] Discrepancies between between this budget and the one in the preliminary report are explained by the more accurate revision of spendings in Ecuador and follow-up costs, based on receipts that only became availble after the preliminary report went to press. Figures in the preliminary report were rounded and partly estimated.

C) Expedition Log

Dates	Activities
1-7/7/00	Arrive Quito, meet herpetologists & visit FHGO, QCAZ and USFQ[12]; buy equipment; Spanish lessons.
8&9/7/00	Travel to Ibarra, meet PUCE-I students, buy field supplies.
10-16/7/00	Fieldwork at Nueva America: train group in techniques, sample herpetofauna in diurnal quadrats and nocturnal transects.
17-22/7/00	Fieldwork at El Chamizo (without PUCE-I students) using the same study design as in Nueva America.
23-29/7/00	Identification work in FHGO-USFQ labs, Spanish lessons.
29&30/7/00	Ibarra, buying supplies for next fieldtrip.
31/7-4/8/00	Fieldwork in Nueva America, repeating methods as previously.
4/8/00	Project presentation for Consorcio Carchi in El Angel.
5-9/8/00	Fieldwork in El Chamizo, repeating sampling as previously.
10-15/8/00	Identification work in FHGO-USFQ labs.
16-18/8/00	Identification work in QCAZ with Luis Coloma.
19-20/8/00	British team in Mindo (holiday).
21/8/00	Project presentation at PUCE-I, depart for Monte Olivo.
22-24/8/00	General collecting in Monte Olivo.
25-28/8/00	General collecting in El Playon.
29/8/00	Lunch in Ibarra with prorector of PUCE-I, travel to Quito.
30/8-6/9/00	Identification and data processing work in Quito at QCAZ.
6/9/00	Thank-you meal for all team members and helpers.

USFQ – Universidad San Francisco Quito; FHGO – Fundacion Herpetologia Gustavo Orces; PUCE-I - Pontificia Universidad Catolica del Ecuador – Sede Ibarra; QCAZ – Museo de Zoologia, PUCE Quito

D) Personnel

Core Team	Ecuadorian Students	Temporary Team Members
1/7/00 - 5/9/00 □ Nora Schultz □ Jess Mather-Hillon □ Ben McCormick □ Helen Forsey all Oxford University □ Fernando Nogales, □ Diego Almeida, both FHGO	**10-16/7/00, 23/7/00 – 13/8/00, 21/8/00 - 5/9/00:** □ Cecilia Tobar, □ Margarita Manceros, (not 21 - 24/08/00) □ Juan Carlos Monge, (not 21/08/00-05/09/00) all PUCE-I **24/7/00 – 25/8/00:** □ David Cotacachi, USFQ	**3/7/00 – 19/7/00:** □ Francisco Ubeda de Torres, Harvard University **16 – 29/08/00:** □ Daimark Bennett, Oxford University **17-21/07/00, 5-9/8/00:** □ Roberto, El Chamizo (local resident & guide) **21– 25/8/00:** □ Amanda Lomas, Natalia Velasco and Marcia Montenegro, Colegio (High School), Mariscal Sucre □ Lola, Monte Olivo(local resident)

A core team of six people (consisting of four Oxford University students and two Ecuadorian herpetologists) worked continuously throughout the expedition. Four Ecuadorian student team members participated during most of this, and visiting student and local residents joined AndinoHerps 2000 for shorter periods to help with the fieldwork.

Larry Frolich, the project's field agent, participated in some of the lab work and joined the team for a few days during each field trip. He has worked with AndinoHerps 2000 throughout the project duration, organising project logistics when he was not directly with the team. Additional visitors to the field included Ana Maria Lucero and Astrid Cotacachi (PUCE-I students). Finally, **Luis Coloma** and **Juan Guyasamin**, PUCE Quito, and **Diego Cisneros**, USFQ provided invaluable help with identification work in the lab.

E) Justification and Limitations of Study Design and Methods

When planning the expedition, several different methods were considered, however it was difficult to be know which would be the most suitable without knowledge of the particular sites. Consequently, in the course of the project, some modifications had to be made to the original plans as laid out or considered in the expedition proposal. They are listed for reference below.

Drift fences & funnel traps
Drift fences with funnel traps, and pitfall taps proved to be inappropriate for the study: the steepness and nature of the ground cover made them an impractical option, the length of our visits to the sites did not justify the effort involved in constructing the apparatus and for the same reason, they would not have time to settle before being sampled. Indeed no other traps or equipment were used at all, for example to capture arboreal species and lizard nooses, as was initially considered.

DNA samples
The duration of the study was also not long enough to warrant the use of mark-recapture experiments, but DNA samples were prepared from well-preserved specimens collected by the expedition, from reptile skin and amphibian toe clippings. These samples remain with the PUCE in Quito.

Bias in study design
Care was taken to reduce bias in all planning aspects, but elimination was not always completely possible. Firstly, we aimed to minimise inter-observer differences by allocating number and type of plots evenly to different observers, but since not all team members could participate equally at all stages of the project, it was impossible to achieve a totally balanced design and some observers inevitably searched more plots than others. Secondly, the nature of the habitats in which searching took place was such that invariably quadrats and transects were situated close to footpaths, edges of habitats and generally more accessible parts. Thus, the allocation of transects and quadrats was not strictly random. Positions were chosen by eye that represented the main features of the habitat. It would not have been practical to position them at random using a grid, as the terrain did not allow for such precision, and the areas studied were largely unmapped.

Bird work
Although bird work was planned initially, the time demands for herpetological work turned out to be greater than expected. Some bird surveying was still carried out on three days each at Nueva America and El Chamizo, and some notes and recordings were made, but the results obtained are negligible, since with the short duration of surveying and the inexperience of the observers, only few species were seen and identified correctly. The sound recordings have been handed to the National Sound Archive together with the frog recordings.

F) Sample Data Sheets

Data Sheet Nueva America & El Chamizo

HOJA DIARIA DE DATOS DE CAMPO

Nombre de Observador:			Fecha:	Hoja No.
Area:	Sitio	Muestreo No.	Transecto /Cuadrante No.	
Hora inicial			Hora final	

Trans/ Cuad.	Hora	Especie	No. de Campo/	Altura (m.s.n.m.)	Sustrato	Sexo (M,F)	Estadio (R,J,A)	Tamano (cm) (SVL, TL)	Peso (g)	Estado		
										Ca	Pr	Li

Data Sheet Monte Olivo & El Playon

HOJA DIARIA DE DATOS DE CAMPO

Nombre de Observador:	Fecha:	Hoja No.
Sitio:	Habitats (con hora):	
Hora inicial	Hora final	

Hora	Descripcion	Especie	No. de Campo	Altura	Sustrato	Plantas Predominantes	Cubierta de Suelo	Prof. de Hoja-rasca	D.A.P.	Otros Aspectos del Habitat	Sexo	Estadio (R,J,A)	Tamaño (mm)	Peso (g)	Estado (O, L, P)

Bibliography

Aldrich, M. Billington, C., Edwards, M. and Laidlaw, R. (1997). Tropical Montane Cloud Forests: an urgent priority for conservation. *World Conservation Monitoring Center: WCMC Biodiversity Bulletin No.2*

Almeida, D., F. Nogales, L. Frolich, L. & N. Schultz (2001) Diversidad de ranas en la cordillera oriental de la zona de la sierra norte del Ecuador. Merida, Venezuela [Frog divesity in the eastern range of the "Sierra Norte" region of Ecuador]: *Proc. 4o Simposia Internacional del Desarrollo Sostenible de las Montañas:* 244-248.

Balsler, Henrick, Luteyn, James, L. (1992) Páramo: An Andean Ecosystem Under Human Influence. Academic Press.

Beebee, T.J.C. (1996) Ecology and Conservation of Amphibians. Chapman and Hall.

Bennett, D. (1999) Expedition Field Techniques: Reptiles and Amphibians. Expedition Advisory Centre.

Beresford, M. & A. Phillips (2000). Protected landscapes: A conservation model for the 21st century. *George Wright Forum* 17(1): 15-26.

Berger, L., R. Speare & A. Hyat (2000). Chytrid fungi and amphibian declines: overview, implications and future directions. *Proceedings of National Threatened Frog Workshop, 1998.* Canberra: Australian Government Publications Office.

Blaustein, A.R. & D.B. Wake (1990). Declining amphibian populations: a global phenomenon. *Trends Ecol. Evolution* 5: 203-204.

Blaustein, A.R. (1994). Chicken Little or Nero's Fiddle? A perspective on declining amphibian populations. *Herpetologica* 50: 85-97.

Blaustein, A.R., D.B. Wake and W.P. Sousa (1994): Amphibian declines: judging stability, persistence, and susceptibility of populations to local and global extinctions. *Conservation Biology* 8:60-71

Bragg, A.N. (1960). Population fluctuation in the amphibian fauna of Cleveland County, Oklahoma during the past twenty-five years. *Southwest. Nat.* 5: 165-169.

Cannatella, D. C. (1981). A new Atelopus from Ecuador and Colombia. *Journal of Herpetology 15(2)* 1981: 133-138.

Carey, C., N. Cohen, & L. Rollins-Smith (1999). Amphibian declines: an immunological perspective. *Developmental and Comparative Immunology* 23: 459-472.

Churchill, S.P. , Balslev, H., Forero, E. and Luteyn, James, L. (1995). Biodiversity and Conservation of Neotropical Montane Forests. New York Botanical Garden.

Cole, D.C., Carpio, F, Julioan, J.A. & Leon, N. (1995). Health impacts of pesticide use in Carchi farm populations. Pp. 209-229. In: Crissman, C., J.M. Antle, and S. M. Capalbo. 1998. *Economic, environmental, and Health Tradeoffs in Agriculture: Pesticides and the sustainability of Andean potato production.* Kluwer Academic Publishers. 281 pp.

Coloma, L.A., and Quiguango, A. (2000) Anfibios de Ecuador: lista de especies y distribución altitudinal. [On line]. Ver. 1.2 (9 March 2000). Museo de Zoología, Pontificia Universidad Católica del Ecuador. Quito, Ecuador. http://www.puce.edu.ec/Zoologia/anfecua.htm [Inquiry: 15 July 2002].

Cresswell, W., M.Hughes, R.Mellanby, S. Bright, P.Catry, J. Chaves, J. Freile, A.Gabela, H. Martineau, R. MacLeod, F. McPhee, N. Anderson, S. Holt, S.Barabas, C. Chapel & T. Sanchez (1999) Densities and habitat preferences of Andean cloud-forest birds in pristine and degraded habitats in northeastern Ecuador. *Bird Conservation International* 9:124-145.

Cresswell, W., M.Hughes, R.Mellanby, S. Bright, P.Catry, J. Chaves, J. Freile, A.Gabela, H. Martineau, R. MacLeod, F. McPhee, N. Anderson, S. Holt, S.Barabas, C. Chapel & T. Sanchez (1999)
Birds of the Guandera Reserve, Carchi province, northeastern Ecuador. *Cotinga* 11:55-63.

Duellman, W.E. (1974) A systematic review of the marsupial frogs of the Andes of Ecuador. *Occasional Papers of the Museum of Natural History, University of Kansas (22):1-27.*

Duellman, W.E. and Altig, R. (1978). New species of tree frogs (family Hylidae) from the Andes of Columbia and Ecuador. *Herpetologica. 34 (2):177-185*

Duellman, W.E. & Pyles (1980): A new marsupial frog. *Occasional Papers of the Museum of Natural History, University of Kansas (84):5-12.*

Duellman, W.E. Berger, T.J. (1982). A new species of Andean treefrog (Hylidae) *Herpetologica 38(4) 1982: 456-460.*

Duellman, W.E. Trueb, L. (1986). Biology of Amphibians. McGraw-Hill.

Duellman, W.E. and Hillis, D.M. (1987) Marsupial frogs (Anura: Hylidae: Gastrotheca) of the Ecuadorian Andes: Resolution of taxonomic problems and phylogenetic relationships. *Herpetologica. 43 141-173*

Duellman, W.E. (1993). *Amphibian Species of the World. Additions and Corrections.* Museum of Natural History, University of Kansas, Lawrence (Special Publication 21).

Duellman, W.E. (1999). Global distribution of amphibians: patterns, conservation and future challenges. In Duellman, W.E. (ed.*), Patterns and Distrubtion of Amphibians: A Global Perspective.* Baltimore, MD: Johns Hopkins University Press.

Fjeldsa, J. (1993) The avifauna of the *Polylepis* woodlands of the Andean highlands: the efficienc of basing conservation priorities on patterns of endemism. *Bird Conservation International* 3:37-55.

Flores, G. (1993) A new species of earless Eleutherodactylus (Anura: Leptodactylidae) from the Pacific slopes of the Ecuadorian Andes. *Herpetologica 1993; 49 (4) 427-434.*

Frolich, L.M. & E. Guevara (1999) The Role of Family-based Agricultural Innovation in Conserving Tropical Montane Cloud Forest: The Guandera Project in Northern Ecuador. pp 45-50. In: Sarmiento, F. & J. Hidalgo (eds). *Entendiendo las Interfaces Ecológicas para la Gestión de Paisajes Culturales en los Andes.* Memorias del Tercer Simposio Internacional sobre Desarrollo Sustentable en los Andes. Corporación Editora Nacional, Quito, Ecuador.

Frolich, L.M., S. Sherwood, A. Hemphill & E. Guevara (2000). "Eco-Papas": through potato conservation towards agro-ecology. *LEISA* 15(3/4): 44-45 (http://www.oneworld.org/ileia).

Frolich, L.M., F. Nogales, D. Almeida, B. McCormick, J. Mather-Hillon, H. Forsey, N. Schultz (2001). Unregistered Frog Biodiversity in the Tropical Andes of Northern Ecuador. *American Zoologist* 41(6): 1052.

Frost, D.R., ed. (1985). *Amphibian Species of the World: A Taxonomic and Geographic Reference.* Association of Systematics Collection, Lawrence, Kansas. (link with www.AmphibiaWeb.org).

Glaw, F. & J. Köhler (1998). Amphibian species diversity exceeds that of mammals. *Herpetol. Rev.* 29: 11-12.

Guayasamin, J.M. & Almeida, D. (2002): A new species of frog (Anura: Leptodactylidae) from the highlands of Ecuador. in preparation

Hamilton, L.S. et al (1995) Tropical Montane Cloud Forests. Springer-Verlag.

Hanken, J. (1999). Why are there so many new amphibian species when amphibians are declining? *Trends in Ecology and Evolution* 14(1): 7-8.

Heyer, W.R., A.R. Rand & C.A. Goncalvez Da Cruz & O.L. Peixoto (1988). Decimations, extinctions, and colonizations of frog populations in southeast Brazil and their evolutionary implications. *Biotropica* 20: 230-235.

Heyer,W.R. et al (1994) Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians. Smithsonian Institution Press.

Holdridge, L. R. (1947): Determination of world plant formations from simple climatic data. *Science*, 105:-368.

Kricher, J.C. (1989) A Neotropical Companion. Princeton University Press.

Laurance, W.F., K.R. McDonald & R. Speare (1997). In defense of epidemic disease hypothesis. *Conservation Biol.* 11; 1030-1034.

Lips, K.R. (1998). Decline of a tropical montane amphibian fauna. *Conservation Biol.* 21: 106-117.

Lips, K.R., J.K. Reaser & B.E. Young (1999). *El Monitoreo de Anfibios en América Latina (Borrador) [Amphibian Monitoring in Latin American (draft)]* The Nature Conservancy (available at www.amphibiaweb.org).

Lips, K.R. & M.A. Donnelly (2002). What the tropics can tell us about declining amphibian populations: current patterns and future prospects. In Lannoo, M.J. (ed*.), North American Amphibians: Status and Conservation.* Iowa State University Press.

Lötters, S. (1994). Mitteilung ueber das ploetzliche Verschwinden von Anurenpopulationen in den noerdlichen Andean Ecuadors. Pp.134-137. In Herrmann, H-J., and Zimmermann (eds.) Beitraege zur Biologie der Anuren [Contributions to the Biology of Anurans]. Tetra Verlag, Melle, Germany.

Lynch, J.D. (1975), The Andean Leptodactylid Frog Genus *Phrynopus. Occas. Pap. Mus. Nat. Hist. Univ. Kansas, 35: 1-51*

Lynch, J.D. (1976) A new high Andean slope species of *Eleutherodactylus* from Columbia and Ecuador. *Proceedings of the Biological Society of Washington. 88 (32): 351-354.*

Lynch, J.D. (1980) *Eleutherodactylus eremitus*, a new trans-Andean species of the lacrimosus assembly from Ecuador. *Breviora (462):1-7.*

Lynch, J.D. and Duellman, W.E. (1980) The Eleutherodactylus of the Amazonian Slopes of the Ecuadorian Andes (Anura: Leptodactylidae). University of Kansas Museum of Natural History. Miscellaneous Publication No. 69.

Lynch, J. D. (1986) Origins of the high Andean herpetological fauna. Pages 478-499 in High Altitude Tropical Biogeography, F. Vuilleumier and M. Monasterio (eds.), Oxford University Press

Lynch, J.D. and William E. Duellam (1997) Frogs of the Genus *Eleutherodactylus* in Western Ecuador. Systematics, Ecology and Biogeography. University of Kansas Natural History Museum, Special Publication No. 23.

Marquez, R. De-la-Riva, L. Bosch, J. (1996) Advertisement calls of three glass frogs from the Andean forests. *Herpetological Journal 6(3), July 1996: 97-99.*

Marsh, D. and Pearman, P. (1997) Effects of Habitat Fragmentation on the Abundance of Two Species of Leptodactylid Frogs in an Andean Montane Forest. *Conservation Biology, 11 (6): 1323-1328.*

Mittermeier, R.A., N. Myers & J.B. Thomsen (1998). Biodiversity hotspots and major tropical wilderness areas: approaches to setting conservation priorities. *Conservation Biology* 12(3): 516-520.

Mittermeier, R.A. et al. (1999). *Hotspots: Earth's biologically Richest and Most Endangered Terrestrial Ecoregions.* Mexico City: CEMEX, S.A.

Miyata, K. (1980) A new species of *Atelopus* from the cloud forests of northwestern Ecuador. *Breviora (458):1-10.*

Miyata, K. (1982) A check list of the amphibians and reptiles of Ecuador with a bibliography of Ecuadorian herpetology. *Smithsonian Herpetological Information Service No. 54, 1982: 1-70*

Palacios, W. & G. Tipaz (1996). Un bosque remanente de altura (Reserva Guandera): estructura y composición florística [a remnant high altitude forest: botanical structure and composition]. *Revista Geográfica* 37: 39-60.

Pearman, P.B. Velasco, A.M. Lopez, A. (1995). Tropical amphibian monitoring: a comparison of methods for detecting inter-site variation in species' composition. *Herpetologica 51 (3), September 1995:325-337.*

Pechmann, J.H:K:, D.E. Scott, R.D. semlitsch, J.P. Caldwell, L.J. Witt & J.W. Gibbons (1991). Declining amphibian populations: the problems of separating human impacts from natural fluctuations. *Science* 253: 892-895.

Perez-Santos, C. and Moreno, A.G. (1991). Serpientes de Ecuador. *Museo Regionale Di Scienze Naturali Cataloghi (Turin) 11 1991: 1-538.*

Perez-Santos, C. and Moreno, A.G. (1991). Distribucion y amplitud altitudinal de las serpientes en Ecuador. *Revista Espanola de Herpetologia 5 1990[1991]: 125-140.*

Peters, James A. (1967) The Lizards of Ecuador, A checklist and Key. *Proceedings of the United States National Museum. 119 (3545):1-49.*

Peters, James A. (1972). The snakes of Ecuador: A checklist and key. *Bulletin of the Museum of Comparative Zoology. 122 (9):491-541*

Poulsen, B.O.& Krabbe, N. (1997). The diversity of cloud forest birds on the eastern and western slopes of the Ecuadorian Andes: a latitudinal and comparative analysis with implications for conservation. *Ecography* 20:5: 475-482.

Pounds, J.A., M.P.L. Fogden, J.M. Savage & g.C. Gorman (1997). Tests of null models for amphibian declines on a tropical mountain. *Conservation Biol.* 11: 1307-1322.

Rabb, G.B. (1990). Declining amphibian populations. *Species* 14: 33-34.

Rabb, G.B. (1997). Declining amphibian populations: an update. *Species* 29: 14-15.

Redford, K. and Padoch, C. (1992) Conservation of Neotropical Forests. Columbia University Press.

Ron, S.R., Coloma, L.A., Merino, A., Guayasamín, J.M. and Bustamante, M. (2000) Información sobre declinaciones de anfibios en el Ecuador. [On line]. http://www.puce.edu.ec/Zoologia/infodecl.html [Inquiry: 15 July 2002].

Sarmiento, F.S. (1995) Restoration of Equatorial Andes: The Challenge for Conservation of Trop-Andean Landscapes in Ecuador. *Proceedings of the Neotropical Montane Forest Biodiversity and Conservation Symposium, 21-26 June 1993.*

Sarmiento, F. (1997). The mountains of Ecuador as a birth place of ecology and endangered landscape. *Environmental Conservation* 24(1): 3-4.

Sarmiento, F.O. (2000). Breaking mountain paradigms: ecological effects on human impacts in man-aged Tropandean landscapes. *Ambio* 29(7): 423-431.

Sarmiento, F.O., G. Rodríguez, M. Torres, Al Argumedo, M. Muñoz, & J. Rodríguez (2000). Andean Stewardship: Tradition linking nature and culture in protected landscapes of the andes. *George Wright Forum* 17(1): 55-69.

Sarmiento, F. & Frolich, L.M., in press. Cloud forest tree line dynamics: History, agriculture and the human dimension. *Mountain Research and Development*.

Sinsch, U. (1990) Migration and orientation in anuran amphibians. *Ethology, Ecology & Evolution* 2:65-79

Sulser, T.B., M.L. Duryea, L.M. Frolich & E. Guevara-Cuaspud (2001). A field practical approach for assessing biophysical sustainability of alternative agricultural systems. Agricultural Systems 68: 113-135.

Vasconez, P.M. (1995) Las Areas Protegias con Bosque Montano en el Ecuaqdor. *Proceedings of the Neotropical Montane Forest Biodiversity and Conservation Symposium, 21-26 June 1993.*

Wake, D.B. (1991) Declining amphibian populations. *Science* 253:860

Wege, D.C. and Long, A.J. (1995) Key areas for threathened birds in the Neotropics. Birdlife International, Cambridge, UK

Wiens, J. J. Coloma, L. A. (1992) New species of the Eleutherodactylus myersi (Anura: Leprodactylidae) assembly from Ecuador. *Journal of Herpetology. 1992; 26 (2) 196-207.*

Waldman, B. & M. Tocher (1998). Behavioral ecology, genetic diversity, and declining amphibian populations. Pp. 394-443. In Caro, T. (ed.) *Behavioral Ecology and Conservation Biology*. Oxford University Press.

Weygoldt, P. (1989). Changes in the composition of mountain stream frog communities in the Atlantic Mountains of Brazil: rogs as indicators of environmental deteriorations? *Stud. Neotropical Fauna and Environment* 243: 249-255.

Wyman, R.L. (1990) What's happening to the amphibians? *Conservation Biology* 4:350-352

ELECTRONIC RESOURCES

BACKGROUND ON ECUADOR

http://www.state.gov/www/background_notes/ecuador_1198_bgn.html

http://www.lonelyplanet.com/dest/sam/ecu.htm

GENERAL AMPHIBIAN SITES
AmphibiaWeb, www.amphibiaweb.org
Amphibians of Ecuador: http://www.puce.edu.ec/Zoologia/anfecua.htm

AMPHIBIAN DECLINE SITES

Declining Amphibian Populations Task Force (DAPTF):
http://www2.open.ac.uk/Ecology/J_Baker/JBtxt.htm
BC Frogwatch: wlapwww.gov.bc.ca/frogwatch
Global Amphibian Diversity Analysis Group (GADAG):
www.gadag.org
Maya Forest Anuran Monitoring Project (MAYAMON):
fwie.fw.vt.edu/mayamon
North American Reporting Center for Amphibian Malformations:
www.npwrc.usgs.gov/narcam
North American Amphibian Monitoring Program (NAAMP, USA-USGS):
www.mp2.pwrc.usgs.gov/naamp
Amphibian Declines in Ecuador:
http://www.puce.edu.ec/Zoologia/infodecl.html

Field Guide