University of Bristol
Río Paute Headwaters Expedition
Ecuador 1991

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Patrons

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Report edited and compiled by Toby Maitland

Contents

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Scientific acknowledgements follow the individual project reports.

Preface

At these elevations between 2,500 and 3,500 metres above sea level, the traveller finds himself constantly surrounded by a dense fog. This precipitation (or this mysterious formation of water?) that could be the result of a strong electrical tension, gives the vegetation a verdant colour which is continuously renewed.

Alexander von Humbolt in 1807
about high mountain vegetation
in Columbia and Ecuador

The montane cloud forest of southern Ecuador represents a remarkably rich, but fast disappearing ecosystem. Designated by the IUCN as top priority for ecological study, the remaining pockets of cloud forest provide ideally moist, temperate conditions for the growth of an abundance of epiphytes, especially mosses, bromeliads and orchids with the presence of peculiar and beautiful arthropods, amphibians and birds.

In 1991 the Río Paute Headwaters Expedition involved six British and five Ecuadorian students in seven weeks of fieldwork within cloud forest of the Púlpito valley in southern Ecuador. The Púlpito valley is found within the Paute Basin and in Bosque Protector 15 (BP 15), a forest protected by the Ministry of Agriculture and Cattle (MAG), The National Electricity Company (INECEL) and La Unidad de Manejo de la Cuenca del Río Paute (UMACPA), the institution set up by INECEL to manage the Paute basin.

Selected aspects of the ecology and hydrology of the forest were studied, in an effort to provide the first steps towards a better understanding of the effects of deforestation in this complex and threatened area. The project was developed at Bristol University in close co-ordination with The Universidad del Azuay in Ecuador and the University of East Anglia Ecuador Cloud Forest Expedition which enabled the whole to exceed the sum of the parts.

This report is designed not only to give an account of the achievements and workings of the 1991 Río Paute Headwaters Expedition but also to put the work into perspective. Part 1 briefly sets the stage, exploring and explaining the geography, ecology and sociology of the Ecuadorian cloud forest. Part 2 details the scientific work, the discoveries and the conclusions. Part 3 introduces the team members and covers the logistics, the nuts and bolts of expedition, its organisation and management. This section details how the accepted protocol provided by the RGS Expedition Planners Handbook was applied to the cloud forests of Ecuador. Much of this reiterates what can be found elsewhere but it is hoped that future expeditions will be able to learn from both the positive and negative aspects specific to this expedition. Part 4 summarises the findings and points to the future.

It is hoped that this is a readable up-to-date source of information. Wherever necessary, references are cited and further reading suggested.

Toby Maitland
March 1994

1.1 Cloud forest, the basics

"Cloud forest" is neither a scientific term, nor does it serve as a definition within the disciplines of ecology, geography or meteorology. It is, however, a term frequently used to describe the forests of the humid tropics which predominate in the zone of maximum cloud condensation, i.e. those which are found within, and affected by, the cloud layer. Equitorial montane forest is a more accurate desciption but for the romance and brevity the term cloud forest will be used.

The cloud forests found outside the humid tropics in areas such as California, South Africa, Bavaria and Japan have a long history of research, predominantly into the unique hydrology of the cloud forest, including horizontal precipitation - the collection of water from the cloud by the vegetation.

Within the humid tropics the history of research is short, the ecological significance of these forests only having been realised during the last twenty five years. Cloud forests can be found infrequently in the humid tropics of Africa (see fig 1.1) whereas they are frequent in Southeast Asia, except where the monsoon plays a dominant role. The Andes of South America supports the greatest extent of forest which has been studied far more intensively than other regions.

In the Andes, within 20° north and south of the Equator the tree line is high, maintained by the stable equatorial climate and topoclimatic influence of the Andes. Between 1500 to 3300 metres, dependant on latitude (see fig 1.2) cloud forest is found. Ecuador, positioned on the Equator has, or had, a significant proportion of the Andean cloud forest. Swirling cloud replaces the heavy rain of the lowland forests and hummingbirds and brightly coloured tanagers are to be found in the thick foliage growing on the steep valley sides. The valleys are typically V - shaped, cut down by the fast flowing mountain streams.

Cloud forest vegetation structure differs notably from lowland tropical rain forest. As the slope angle increases the trees become increasingly twisted and dwarfed, some growing almost horizontally. These forests situated on the headwaters of Andean rivers may be regarded as sponges with an important role to play in preventing droughts and floods. The forests develop an organic top soil which the dense interlacing tree roots hold to the valley side. Without the forest the valley would rapidly be eroded. The cloud forest is a fragile and hydrologically vital ecosystem.

Cloud forests exhibit a very high level of biodiversity. The actual figure may be higher than so far discovered due to the high degree of endemism (locally unique species). This localised speciation is thought to have occurred through the isolation of the different watersheds. Such isolation in a seemingly contiguous environment has been described as "islands in the cloud".

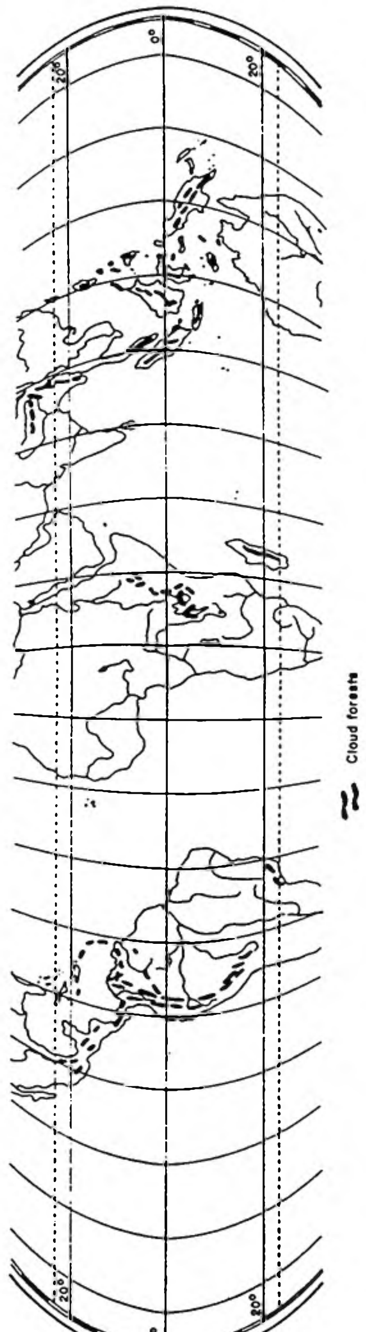


Figure 1.1 *Cloud forest distribution in the tropics and adjacent areas* Modified from Stadtmuller, 1987

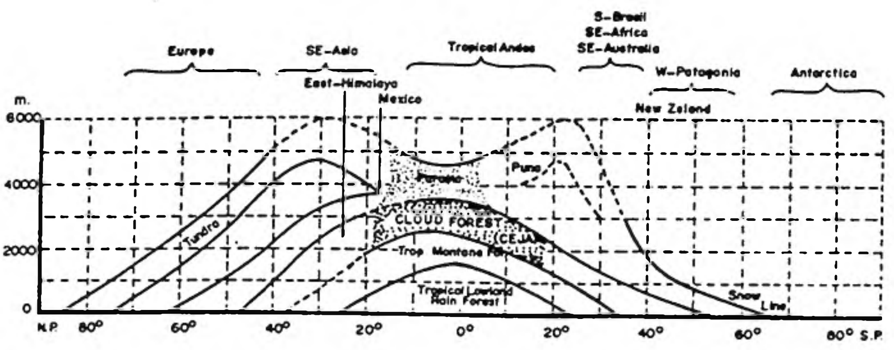


Figure 1.2 *A schematic profile of the world's humid vegetation from north to south pole with emphasis on the tropics* Modified from Stadtmuller, 1987

The abundance of epiphytes (plants growing on trees) particularly mosses, orchids, lichens and bromeliads is immediately evident on entering the forest. These epiphytes are capable of extracting water from the ever present cloud and can thus live independently from the water held in the soil, although a rich humus builds up on horizontal tree trunks and branches. In dwarf cloud forest where the gradient is steep and the trees small, moss can be also found covering the soil which invariably consists of a rapidly decaying layer of peat. Giant ground ferns and tree ferns proliferate within the forest along with vines, bamboos, large leafed shrubs and herbs.

Condors cruise over the forested valleys, nesting on the paramo grassland above the tree line. Within the forest dwell toucanets, hornbills, parrots, a wide variety of manoeuvrable and aggressively territorial hummingbirds along with the ungainly turkey-like guans. spectacled bears. tapirs, white tailed deer and the jagarundi (a small cat) are among the mammalian inhabitants of the forest. Clearly audible but rarely seen are the frogs, their knocking, tapping and dripping calls being heard thought the night.

It has been estimated that the 4% annual deforestation rate will devour the forests of Ecuador in the next 10 to 20 years with the loss of five animal species a day. Clearly work is needed to attempt to approach the conservation of these forests from a realistic perspective.

1.2 Site description

Bosque Protector 15

Bosque Protector 15 (BP 15) is in Canar Province, 60 km north east of Cuenca and 80 km east of the Pacific in central southern Ecuador. BP 15 lies within the Paute basin and contains the catchment areas of the rivers Púlpito, Juval and Mazar, tributaries of the Río Paute which drains eastwards into the Amazon basin. These rivers flow through the rugged terrain of the eastern Andean Cordillera, gathering runoff from the peaks which rise to over 3700 metres. The Cordillera drops away rapidly to the east, into the lowlands of the Amazon basin. To the west lies the main bulk of the Andean Massif.

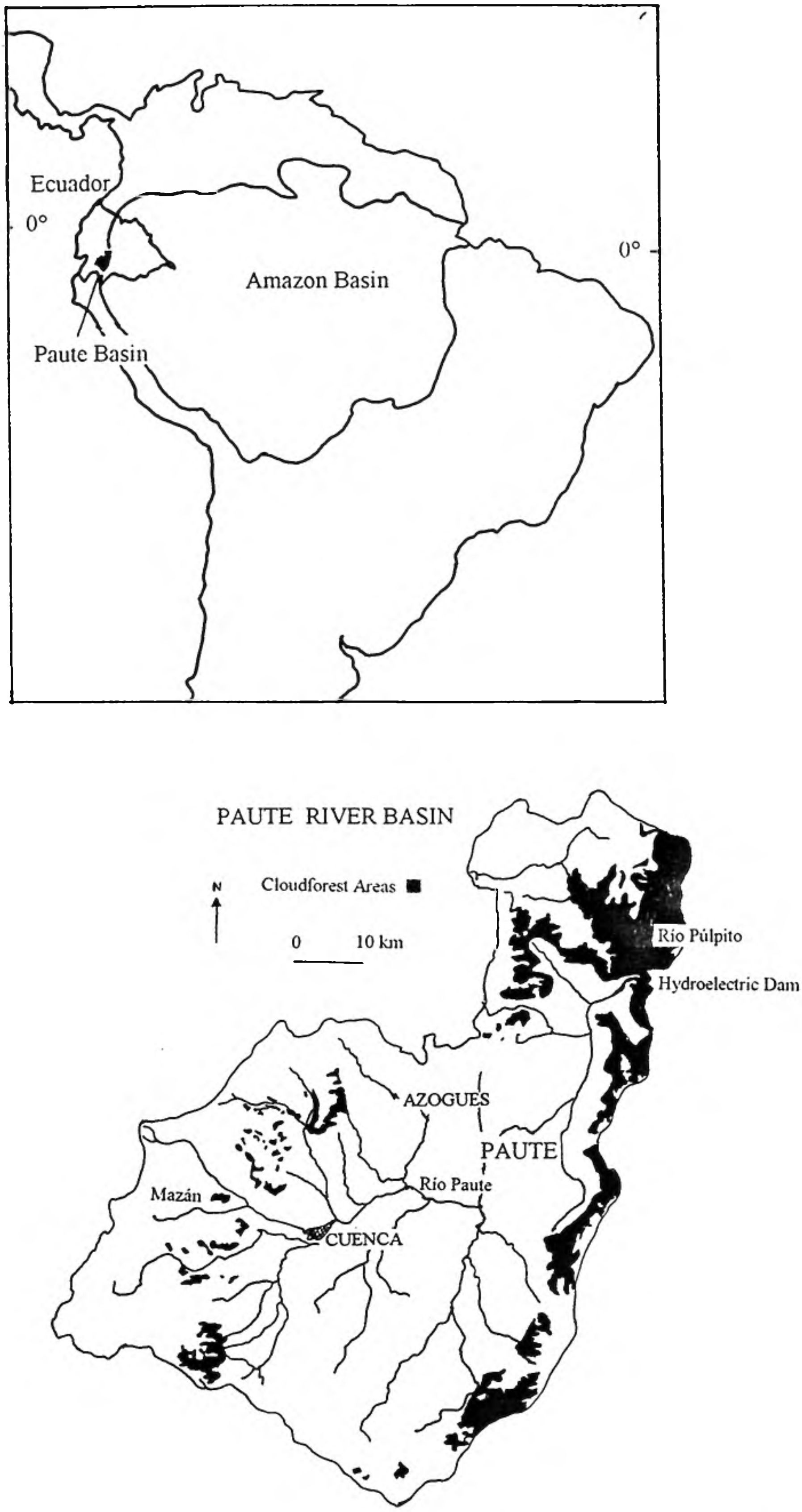
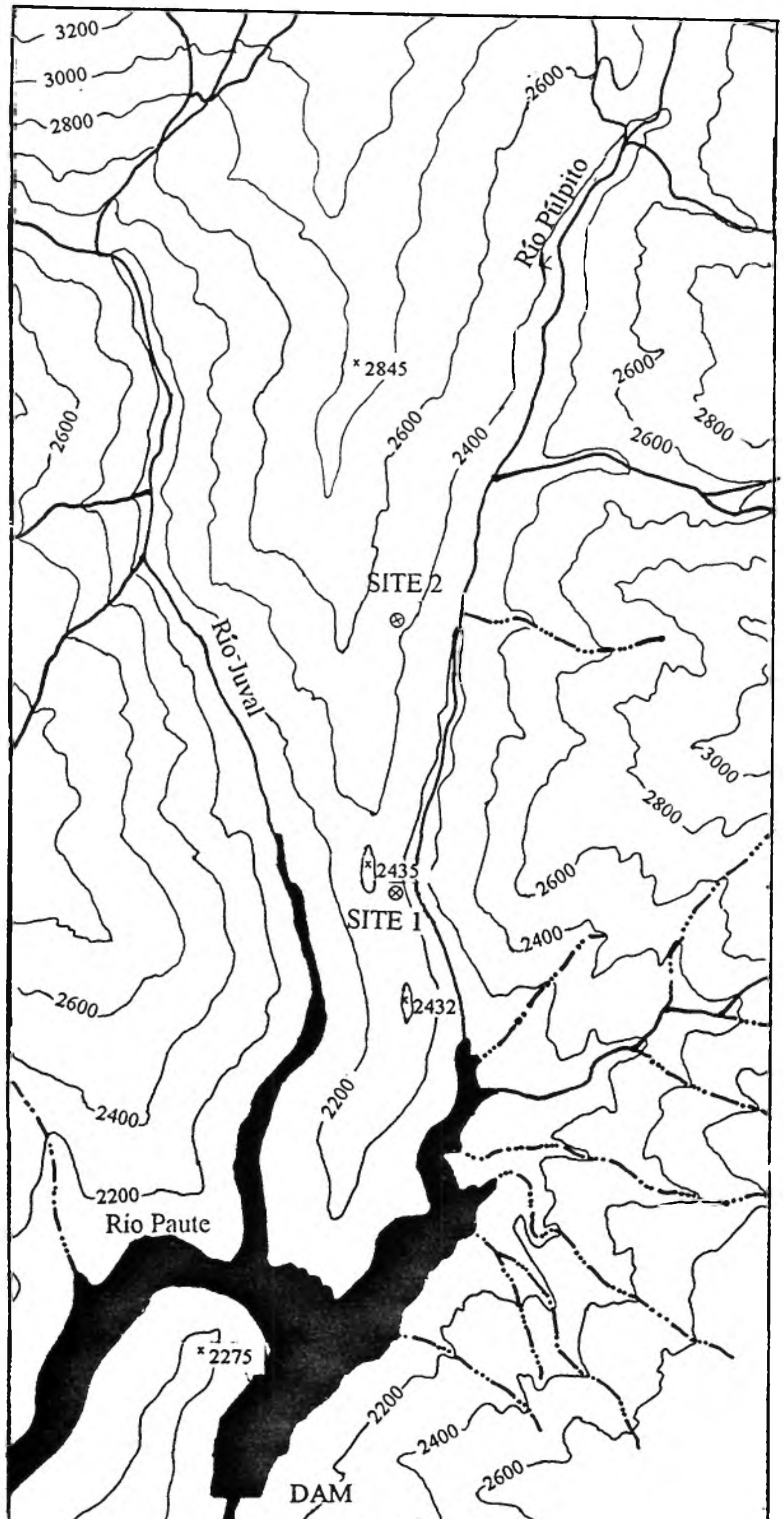


Fig 1.3a *Ecuador and the Paute River Basin*



N

Scale: 1:50,000

1 2 3 4 km

Fig 1.3b *The Rio Púlpito*

The prevailing wind blows from the interior, and is therefore heavily laden with moisture from the warm, humid Amazon region. As the air rises up the eastern escarpment it cools and condenses, forming cloud at an altitude of about 2400 metres. This cloud envelops the mountain sides, causing precipitation and the ever present fog which is characteristic of the area. Because temperatures are so constant throughout the year, the cloud layer is reasonably fixed in altitude.

Air masses moving in from the Pacific are much drier, having deposited their moisture on the high mountains of the western cordillera. The extent and duration of cloud formation is therefore dependant on the relative frequency of winds from the east and west. This is by no means fixed and will almost certainly be influenced by the occurrence of the El Nino events along the Pacific coastline. Hence, the weather systems of the area are unpredictable and whilst there may be no real seasonality, significant annual variation in rainfall and cloudiness could occur.

The Río Púlpito drainage basin

The Río Púlpito is approximately 20km long, draining an area in excess of $100km^2$. At its mouth, the Púlpito lies at 1900m altitude, but its tributaries begin in paramo grassland at well over 3100m. Such steep gradients mean that the floodwaters pass very quickly down valley, and the water level is very responsive to rainfall. The river itself is a sizeable torrent, flowing along a boulder-strewn bed in a series of frothing rapids and slightly calmer pools. It flows into the waters of the lake formed by the Río Paute, a couple of kilometres upstream of Ecuador's largest hydroelectric dam.

The size and ferocity of the river made crossing impractical, so our work was restricted to one side of the valley. In fact, our campsites were on the south-east facing slopes of a ridge which separates the Río Paute from the Río Juval. This ridge climbs steadily away from the confluence of the rivers with the Río Paute, before widening out into a rugged , high plateau towards the top of the valley.

The gradient of the valley sides is extremely steep - 40° or more - so that the river sits in a deep v-shaped notch which becomes progressively deeper as one moves upstream. In some places, the slopes rise in an uninterrupted sweep to mountain peaks towering 1000m above the valley floor. The whole area is contoured by numerous landslips, giving the slopes an almost step-like appearance. Small streams intersect the valley at regular intervals, many of which have cut substantial notches of their own into the hillside.

We carried out work at two sites. At **SITE 1,** 2.5km up valley, the crest of the ridge lay at 2300m, which was unfortunately below the height at which cloud regularly formed. This necessitated a move to **SITE 2**, a further 2 km upstream. In this distance, the ridge rose another 300m, taking the crest to an altitude 500m above the valley floor. Both campsites were situated about a third to half of the way up the ridge, on substantial pieces of approximately level ground.

The weather during the study period (July and August 1991) was predominantly dull and drizzly, with fog lying between 2400-3000 metres. There were occasionally periods of heavier rainfall, and infrequently dry spells which tended to last for several days at a time. Winds were generally light, although sunshine caused differential heating of the valley slopes, leading to strong and very gusty breezes. Rainfall was sufficient to cause extensive waterlogging leading to marsh formation on cleared land, despite the overall steepness of the valley slopes. Low evapotranspiration due to the moist atmosphere and impermeable clayey soils probably lay at the heart of this. No waterlogging was evident in forested areas.

Ecology of Río Púlpito drainage basin

Little primary cloud forest now remains in the Paute basin. In the Púlpito valley a patchwork of mature secondary forest, regrowing scrub, grassland and bog exists. Human influence was startlingly obvious, cleared land having been planted with western rye grass and clover for grazing. Much of the walk from the dam to the second study site passed through rough cattle pasture. In 1991 clearance was evident in at least the lower 15 km of the valley though was greatly reduced around 10 km up valley. No pattern could be seen to govern the clearance except that it occurred near to settlement and generally on the flatter ground.

The area around site 1 was more comprehensively cleared than site 2, with very little forest. There were extensive areas of scrubby regrowth around both sites. At site 2, forest had remained intact along streams and in areas where access was difficult. The crest of the ridge was the most heavily forested land, despite slope angles being less here than on the valley sides. It may be that the flatter land was simply too poorly drained for it to be of any value.

The mature forest that remained was verdant, damp and decaying as cloud forest should be. The majority of the woodland comprises of tree species such as *Podocarpus, Weimannia, Clusia, Oreopanax, Myrtus, Octotea* and *Seronia* which supported the stereotypical profusion of epiphytes. Birds were unusually visible as they flew over the grasslands and congregated in the solitary and consequently unstable forest trees which remain in the grassland.

The only large mammals seen were cattle and pigs which roamed freely. Two spectacled bears were resident in the dam enclosure, and although they are apparently hunted in the forest, populations were said to remain further up valley. The last puma was reputedly killed in the late 80's but on a more hopeful note two condors were found to live in the Juval valley by a national condor count that was in progress during our visit. All in all the status of the remaining forest was hard to establish and declining fast. The ecosystem had been very much disturbed, much had been recently cleared and it is likely that the mature forest had regenerated in the last 50 years.

The dam

The Río Paute hydroelectric dam, completed in 1982 replacing 25 smaller dams, is an important source of power in Ecuador with the potential to generate 4030 million KWH of electricity annually (INECEL 1990). The Río Paute flows directly into the reservoir behind the dam, indeed from the access road it is necessary to cross the dam to enter the Púlpito valley. Uncontrolled deforestation in the watershed has led to significant soil erosion problems and consequent fears of the dam reservoir rapidly silting.

1.3 Basic sociology of the Ecuadorian cloud forest

Cloud forest has always been a fascinating topic for scientists of various disciplines such as geographers, climatographers, meterologists, forest ecologists, botanists, zoologists, hydrologists and conservationists in general. An area which had perhaps been ignored, but which is becoming increasingly important is the sociology of forest regions. The behaviour of the humans determines the fate of the forest.

Deforestation began when the conquistadors brought with them an agricultural system unsuitable to the ecology of the Andes. As the population density increased, more and more of the Paute basin was deforested and the land exhausted. By the 1950s much of Azuay province was severely eroded and partially abandoned. Agriculture was run on a typical plantation system, with one land owner (latifundista) and a large dependant labour force (minifundistas). The agrarian reform acts of 1964 and 1973 encouraged the redistribution of land to the small farmers. To do this without upsetting the powerful Latifundistas, the colonisation of virgin territory was encouraged, and people moved onto increasingly marginal land, such as cloud forest. To hold ownership of an area of land it had to be seen to be in use and was thus deforested.

Through the 1960's and 1970's the national agriculture policy became export orientated and encouraged sugar cane, soya, maize and of course, cattle ranching. The amount of land under pasture increased rapidly, especially after US imports of corn flooded the Ecuadorian grain market in the early 70's. Some 60% of the country's basic food is produced by small farmers working overexploited soils on often marginal land. They are unable to improve their farming practice due to a lack of capital. When the land is exhausted it is abandoned and the workers move to more marginal land or to the bright lights of big cities.

The Púlpito valley has been used as cattle pasture since the mid 70's by the people of Santa Rita, a town some five hours away. Though BP 15 is nominally protected by the MAG and INECEL, this is not enforced and the land can be purchased in Santa Rita. Although crops are attempted they tend to be destroyed by the animals. Hunting and fishing are mainly to support the farmers while they clear forest and tend their cattle. Most of the landowners live in Santa Rita and spend only a small proportion of their time in Púlpito. Those who have lived permanently in Púlpito find food production is good for eight years and then the soil fails.

While the farming practices used are inappropriate to the environment, the campesinos have little available alternative. They are encouraged to use western crop seed, fertilisers and pesticides. Chainsaws now replace the slash and burn that was once accomplished with a machete and the loss of forest is becoming increasingly apparent to them as good wood becomes scarce and houses are made increasingly of wattle and daub. The locals realise the impact they are having on the environment and the falling crop production and erosion is bemoaned. 80% of households do not consider they have enough land to provide for themselves and they realise the increasing difficulties their children will face.

Jon Roberts & Toby Maitland

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2.1 Scientific introduction

The aim of the expedition was to study the hydrology and predominantly aquatic ecology of the Ecuadorian cloud forest and investigate the effects of deforestation with the aim of suggesting curative or preventative measures. The scientific objectives were arrived at initially through the personal interest of each team member and then fitted together to provide a coherent overall framework for the expedition.7 A brief summary of the findings of each project is presented below with further details being given in the individual project reports.

1. The investigation into fog-drip came up with some surprising results. In contrast to studies in other localities, the phenomenon of fog-drip during the very wet period of our stay was not observed. Canopy saturation was by far the most significant factor in determining the volume of water reaching the forest floor. Furthermore, very large differences in throughfall measurement between nearby sites cast doubt on the efficacy of funnels commonly used for rainfall measurement under the forest canopy, where the distribution of major drip points is highly heterogeneous.

2. The fish project was valuable in identifying the existence of the rare native Astroplepid catfish. Trout were also found to have been introduced to the stream, although cohort analysis seemed to indicate the population was not breeding. The immense logistical difficulties that have to be overcome in order to get even this information should be heeded by those anticipating icthyological projects in the raging torrents of the Andes! Circumstantial evidence again points to a likely catfish decline in the Río Paute.

3. The macro-invertebrate community was similarly shown to be adversely effected by deforestation. Modifications in community structure reveal high levels of subsequent erosion and a complete trophic adjustment in stream ecology. Recommendations were suggested to help decrease the impact of limited forest clearance on stream ecosystems and ultimately on sediment loads in the Río Paute dam.

4. The amphibian report showed that deforestation is not conducive to a diverse amphibian population. Seventeen species were identified and found to be significantly more abundant in the densely forested areas than in cleared grassland. Samples were collected and added to the collections of national academic institutions. Various techniques for catching amphibians were evaluated and compromise solutions detailed for the cloud forest environment. Circumstantial evidence points to a general decline in amphibian populations in this area of Ecuador.

5. The botanical project provided a solid grounding for the other projects and highlighted the processes involved in deforestation.

This information when taken together with complimentary investigations of the UEA cloud forest expedition that followed us into the same field form a comprehensive first assessment of this region.

In more general terms the whole problem of mounting a self-contained scientific project with limited time and resources in a new environment was a challenge for us all and the practical field experience of immense value to expedition members both English and Ecuadorian alike.

Simon Hay

2.2 Fog drip beneath equatorial montane forest

Jon Roberts

Abstract

- There has been some recent contention over the existence of fog drip in Andean montane forest.
- This study makes a detailed examination of the process, using a fog collector and throughfall gauges. The data is analysed by means of a multiple regression model.
- Large variations in throughfall percentages were discovered between two nearby sites, casting some doubt on the use of funnels as throughfall gauges in this type of forest.
- It was possible to confirm that, for most of the study period, fog drip did not occur. However, in several cases it is possible that fog drip did occur, but the quantities of water involved were very small in relation to total rainfall.
- The significance of any potential fog drip in this region is minimal, particularly when compared to its importance in other regions.

Introduction

Fog drip is the process in which cloud droplets which are too small to settle on a horizontal surface are blown onto vegetation, forming larger droplets which then fall to the ground and can be collected in a measuring device. It has been the subject of serious study for about forty years, and in that time much evidence has been amassed to support its existence.

Most of the early work was carried out in the United States. Oberlander (1956) recorded 150 cm of precipitation in a six week rainless period beneath a Tanbark Oak in the San Fransisco Bay area, and Parsons (1960) collected 25cm of fog drip during a Californian summer in a standard raingauge beneath a Monteray pine. Vogelmann et al. (1968) used fog collectors to study fog interception in Vermont, and were able to collect 66% more water using raingauges mounted with aluminium mesh screens than with ordinary raingauges.

More recent studies in other parts of the world have generally confirmed these findings. Ingraham and Matthews (1985) studied the contribution of fog drip to groundwater recharge in Kenya using hydrogen and oxygen isotope ratios, and concluded that shallow groundwater contained an unspecified but clearly measurable percentage of fog drip. Cavelier and Goldstein (1989) found fog to be an important water source in the relatively dry forests along the Caribbean coast of South America, but the quantities of fog measured in the same study in the Andes were minimal. The Andes would seem to present something of an exception to the general rule.

A study by Veneklaas and Van Ek (1990) in montane rain forest in Columbia found no evidence of fog interception using fog collectors, although throughfall did exceed rainfall in two weekly periods during the year's study, a phenomenon put down to excessive splash from exposed rain gauges during heavy storms. Vis (1986, reported by Veneklaas and Van Ek) recorded five incidents of throughfall exceeding rainfall in a Colombian forest which he attributed to fog drip, but only six throughfall gauges were used, raising the possibility that random measurement error may have been responsible.

The present research was designed to examine fog drip in the Andes more closely, and to try and determine the cause of the excess throughfall reported by previous studies. Both throughfall gauges and a fog collector were used, and the data were analysed using multivariate regression, a technique which appears not to have been previously applied to this area of research.

Methodology

Study Sites

Measurements were made on the west facing slope of the Río Púlpito valley. Unfortunately, although climatic statistics are available for the area, these have proved to be unobtainable. The annual rainfall at Paute, some 30km away, is 700-800mm, suggesting that the region as a whole is quite dry, but these data are from an unforested area and are unlikely to be representative of the Púlpito valley. The climate figures for Paute show little year-round variability in rainfall or temperatures, and none of the officials or local people who were consulted on this matter were able to agree as to the timing of any seasons, so the conclusions drawn from this rather short study period may be fairly representative of the generally prevailing conditions. Total rainfall during the main four week study period was 104mm. Wind was at all times light, although periods of sunshine did produce occasional gusts up to force 4 or 5. The microclimate of the valley was pronounced, with valley winds often blowing in entirely the opposite direction to the general progression of the clouds overhead. Temperatures showed little variation during cloudy spells, but clear spells brought much warmer daytime temperatures and rather cold nights.

Two sites within the valley were studied. The first, at 2350m altitude, was below the cloud layer, and was subject to only a brief measurement period from 20th July to 30th July 1991. The second site was farther up the valley and at an altitude of 2600m, well within the lower range of the cloud, which tended to form in a band across the valley slopes about 400-500m thick. Thus the upper valley slopes, which reached to 3700m, were often free from fog and cloud. This site was studied from the fourth to the thirty first of August 1991, a total of four weeks.

Both locations had primary forest-like vegetation, although the second site was closely surrounded by mature secondary forest. The canopies were closed, with a profuse growth of epiphytes and moss, which covered tree stems to a depth of 3cm in some cases, and hung in clumps from the branches. The first site was rather lower in stature, with an average tree height of some 8-10m, compared to heights of 15-20m at the second.

Materials and measurements

Literature on the theory of fog water collection is sparse. Droscher (1986) mentions two approaches, both of which are employed here. The first, excess throughfall, uses the forest canopy itself as a droplet impactor bulk collector. This has the advantage that it directly measures the amount of fog water removed from the atmosphere by the forest and deposited as fog drip on the forest floor. In this study, throughfall was measured using 13 identical plastic funnels of internal diameter 165mm with a 10mm vertical rim, on top of 1 litre plastic collecting bottles. The sample size was originally to have been 15, but several funnels went missing on the journey to the site. They were laid out in two parallel transects 5m apart, one containing seven gauges, the other six, all at one metre intervals. The data from these gauges were combined to form one average throughfall measurement for each twelve hour period. Forest floor vegetation, which was generally sparse, was removed to head height, primarily to reduce the risk of drip being concentrated by these understorey leaves and thus distorting the data.

Rainfall was measured at an open site approximately 500m distant from the throughfall gauges at site one, and 200m distant at site 2. In the first case there was an altitude difference of 100m, but in the second the difference was negligible. The aspect of the sites was in all cases similar (due west) A standard copper raingauge was used for the measurements, placed alongside a further gauge of the throughfall type to allow for calibration.

The second approach mentioned by Droscher is the use of a fog collector, consisting of an impaction unit and a means to transfer the deposited water to a collection vessel. Such a device may be either passive, relying on natural wind as the driving force to deposit fog droplets on the impaction unit, or active, in which droplets are sucked into the collector giving a much higher sampling rate. In this case a passive unit was considered adequate, given the relatively long sample period of 12 hours. A design similar to that in a number of other studies was employed, having been shown to work. It consisted of a double roll of aluminium mesh (1.5 by 2mm holes), 50cm high and 12cm in diameter mounted above one of the plastic funnels. (This compares to the collector employed by Vogelmann et al (*1968*) which used 256 mesh/sq.in. aluminium, equivalent to 1 by 2.5mm holes, in a double roll 16cm high).

Measurements were taken twice a day, at 6.30 and 18.00 hours. The discrepancy in timing was unavoidable due to the danger involved in walking to the sites in the dark. The nature of the analysis, which uses percentage values of the data, means that the impact of this discrepancy is minimal.

Analytical techniques

Previous studies, usually based on weekly observations, have identified possible cases of fog drip as those periods in which throughfall exceeds rainfall. This has, however, proved unsatisfactory and ambiguous in the case of Andean forest. The twice daily observations employed in this study allow for a somewhat different approach using multivariate regression. Only the data for site 2 was treated in this way.

The main assumption underlying this technique is that the throughfall, expressed as a percentage of rainfall during the same twelve hour period, will vary according to the presence or absence of fog drip. Thus, periods identified as having been foggy should have a higher percentage throughfall than periods which were free from fog, regardless of whether throughfall exceeds rainfall. "Foggy" periods were those for which cloud was present for any significant period during the day or evening. Since cloud was normally persistent once it arrived, the classification presented few difficulties. Any period in which the classification was doubtful (which applied particularly to night-time readings) was classed as such and excluded from the analysis.

The regression was carried out on the original data, measured in millilitres, in order to minimise potential errors due to the conversion to millimetres. Where figures are quoted in millimetres, a conversion factor has been applied, derived from a regression between the copper calibration gauge and the plastic funnel, and taking the form

mm = (ml + 2.6)/22.7 (equation 1)

Results

Throughfall measurement

There were very large differences between the percentage throughfall at sites one and two. Site one recorded an average of 120.6%, whilst site two managed only 48.7%. This seems to suggest that site one was experiencing considerable quantities of fog interception, but this is a nonsense since it was below the cloud layer and saw at most a little light mist.

Fog drip analysis

Data were collected at site two over four weeks, giving 56 12 hour periods. Of these, five were classified as doubtful, and excluded from the results. A further three had such small amounts of rainfall and throughfall (less than 0.1mm) that the sensitivity of the measurement technique was exceeded, and the calculations of percentage throughfall were consequently highly unreliable. These too were excluded from the regression analysis. Because the regression includes antecedent rainfall over 24 hours, the first two periods were unusable, and one set of readings which was missed due to illness produced a total of three more exclusions. Altogether, including dry spells in which no rainfall or fog interception occurred, 27 periods were dropped from the data set before analysis.

Two independent variables, rainfall and antecedent rainfall, were then regressed against percentage throughfall using the Minitab statistical package. Rainfall was used in its raw state antecedent rainfall was a compound variable comprising data from the previous 24 hours in each case. A number of different measures for this variable were tried by correlating them with percentage throughfall. Various combinations of 12, 24 and 36 hours antecedent rainfall were tested, with the best correlation being given by the following formula:

Antecedent rainfall in period X = rainfall in period X-1 + 1/2(rainfall in period X-2)

This equation recognises that rain in the immediately preceding period is most important in determining throughfall, but that slightly longer term effects are also present.

The initial regression (equation 3) produced the somewhat surprising result that rainfall appeared to be an insignificant factor in determining the amount of throughfall. The critical t-value is 2.052, a figure which the t-value for the slope coefficient of rainfall (0.51) does not even approach.

Y = 31.2 + 0.159 X1 - 0.01 X2

(2.83) (0.51) R-squared = 36.4%

Where X1 = antecedent rainfall. X2 = rainfall

(equation 3)

When an incept dummy variable for fog was added, the R-squared value improved from 36.4% to 49.0%, and the t-value for rainfall dropped to almost zero, suggesting that the dummy variable for fog was providing a much better explanation of the variability in the data than the rainfall variable. (A dummy variable takes a value of one for a positive event - fog present - and zero for a negative event - no fog)

According to this analysis, both antecedent rain and fog have a significant influence on the percentage throughfall, but a closer dissection of the rainfall data produces a wholly different result. Visual examination of the partial plot for rainfall and percentage throughfall gives a clear indication of the problem. The main body of the data was not in fact in linear form (fig 2.1), and there were two or three points which had low rainfall but unusually high percentage throughfall. The data set was therefore transformed to give a straight line relationship (a prerequisite for regression analysis), using logarithmic values for rainfall (fig 2.2). Three outliers, which were clearly different to the general trend, were then excluded.

A further regression was conducted using this modified data set, with the following result:

$Y = -15.1 + 0.112\ X1 + 12.2\ X4$

(3.63) (3.67) R-squared = 71.8%

Where X4 = log rainfall

(equation 4)

Inclusion of the dummy variable for fog now has virtually no effect , on either the R - squared value , or the levels of significance of X1 and X4. This suggests that throughfall is controlled entirely by rainfall.

The results of this second regression are supported by those from the aluminium fog collector, which at no time succeeded in gathering any moisture in the collecting bottle, nor looked or felt damp at any examination.

Diurnal variation can be included in the regression in a similar way to fog, employing an incept dummy variable, and when this is done, the

R-squared value improves by only o.1%, the day/night variable having a t-value of -0.24 (critical value = 2.064). Percentage throughfall is, therefore, not in the least affected by diurnal changes.

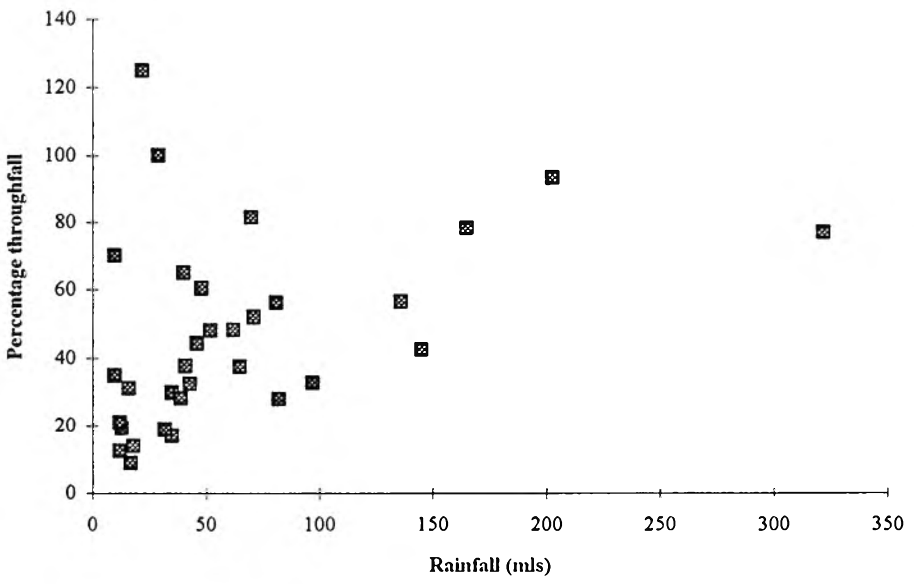

Fig 2.1 *Plot of rainfall and percentage throughfall*

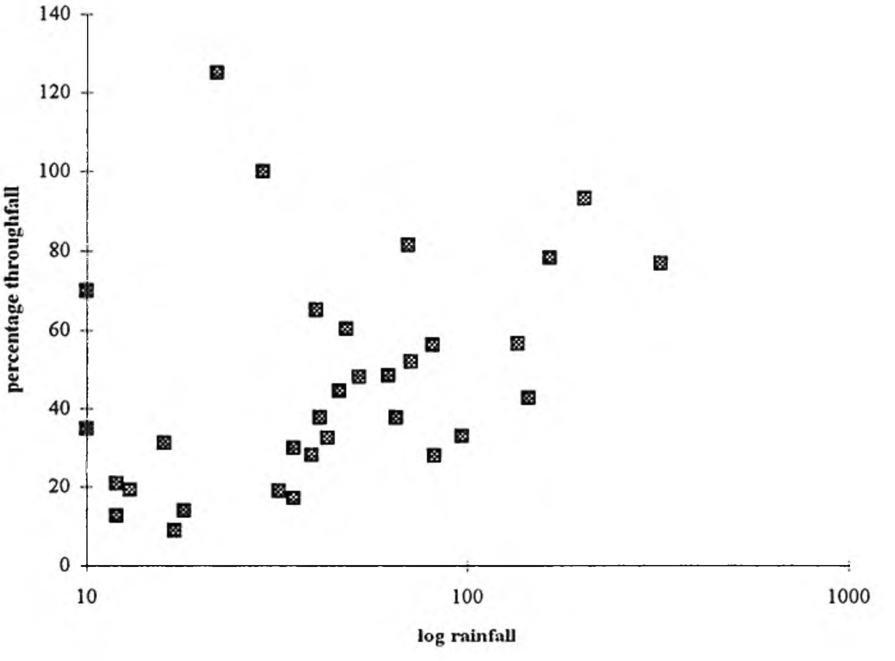

Fig 2.2 *Plot of of log rainfall v. percentage throughfall*

Discussion

Measurement techniques

Crockford and Richardson (1990) conducted a study of the suitability of various measuring devices to the estimation of throughfall, and found that, even with a high placement density, standard gauges consistently underestimated throughfall in comparison to large troughs. Their work was carried out in eucalypt forest, and it may be expected that the problem would be less severe in tropical cloud forest, given the much greater drip-point density of the latter. However, the comparison of percentage throughfall values from the two sites in this study shows that this is not the case.

The explanation for this lies in the nature of the drip points in the forest. At site 1, one of the funnels happened to sit beneath a very high volume water pathway, concentrating water from a large part of the canopy. It collected about five times as much water as the open air raingauge. In addition, this funnel continued to collect significant quantities for up to 48 hours after the cessation of rain. The sampling arrangement at site two contained no such high volume route, and therefore gave the appearance of having much lower percentage throughfall.

The very poor accuracy of the funnels makes comments on absolute values of the throughfall and fog drip impossible, and suggests a potential reason for the fog interception recorded by Vis (1986), whose sparse sampling arrangement of only six throughfall gauges was likely to have been subject to very severe distortions of this type.

However, this study did not aim to make comparisons between different sites, nor to calculate absolute values of fog drip. The only requirement of the data therefore was that they be wholly internally consistent - that one twelve hour period be directly comparable with any other twelve hour period within the four week study at site two. Throughfall gauges of the funnel type used here are adequate for this purpose, although some minor errors may result from the necessity of picking up, reading and replacing the gauges, since it was difficult to ensure that they were replaced in exactly the same position each time. It is possible that a major drip point may have coincided with the very edge of a funnel, and therefore have been included at some times but not at others, but close examination of the data does not reveal any gross instances of this.

The massive variability in throughfall measurements between sites one and two suggests that for comparative work in this type of forest, funnels would produce highly unreliable results, and that troughs of some kind, which cover a far greater area of the forest floor than even a very dense funnel network, would be much more suitable. This is not, however, without some serious practical considerations. Transport of large troughs to a site of any remoteness would be extremely difficult, and the rough, steep slopes characteristic of Andean forest would present considerable difficulties to their installation.

Fog drip in an Andean cloud forest

There was good reason to expect that percentage throughfall would be related to both rainfall and antecedent rainfall, providing strong grounds for the regression analysis to be carried out on this basis. Low rainfall tends to produce lower throughfall since the storage capacity within the canopy is larger relative to the volume of water, and is therefore able to remove a greater percentage of the rainwater before it reaches the ground. Under high rainfall conditions, the storage component becomes relatively insignificant - once it is full, all (or nearly all) the rain incident upon the canopy will reach the forest floor.

Antecedent rainfall is important in determining the size of this storage component, with heavy rainfall in preceding periods partly filling the storage and allowing for higher percentage throughfall than would be the case if the canopy had been dry.

The interpretation of the data from this study depends largely upon finding an explanation for the three points, excluded from the second regression, which showed unusually high values of percentage throughfall for low amounts of rainfall. There is no doubt that for the main body of the data (26 out of 29 readings) fog drip cannot be considered as a contributing factor to throughfall, so that in any event it is safe to say that fog drip plays at most a minor role in the supply of water to the area.

The first possibility which suggests itself in relation to the three rogue periods is that fog was, in these cases alone, acting to supply sufficient water to the canopy to promote fog drip. All three coincided with foggy spells, and all three share the common feature of low rainfall (1.4mm, 0.55mm and 0.95mm) so that only a relatively small amount of fog drip would be required to raise the percentage throughfall by quite a significant amount. The evidence from the fog collector tends to dispute this conclusion; any fog dense enough to intercept on vegetation should, on the evidence from other studies using similar devices (Vogelmann et al, 1968; Cavelier & Goldstein 1989) be dense enough to be susceptible to collection. No unusual weather conditions were noted at the time, such as strong winds which may have pushed sufficient moisture across the leaf surfaces to induce fog drip, or different cloud formations producing denser fog than usual.

An alternative explanation can be constructed by looking at the rainfall over several preceding days. The exceptional periods all occur after extended spells of consistently high rainfall. A fourth period of a very similar type which was not included in the regression shares this attribute. It may be then, that the controls on throughfall which operate on this small subset of the data are somewhat different from the controls which operate on the main body and which are described by the regression analysis. The saturated state of the canopy is likely to be the main factor, with a certain amount of water continuing to drip through from previous periods, and little or none of the water from the additional rainfall going into storage, creating a very high percentage throughfall. This is determined by antecedent rainfall over 48 hours or more - the antecedent rainfall term included in the regression does not adequately describe the state of the storage after a prolonged period of rainfall followed by a sudden drying.

An indication of how much difference a saturated canopy can make is given by a comparison between the daytime period on the 6.8.91, and the nightime period on the 10.8.91. Rainfall was the same on both occasions, but the first was preceded by

36 hours without rain, whilst the second was preceded by 84 hours of quite high rainfall. The figures for percentage throughfall were 13.9% and 110.5% respectively. Clearly, there is a considerable degree of hysteresis in the wetting/drying cycle, in that the extent and rapidity of drying is determined to some extent by the degree of canopy wetness over previous periods. Evidence for this can also be found under high rainfall. Two periods within 48 hours of each other, on the 7.8.91 and the 8.8.91 have very similar rainfall, but considerably different throughfall, lying as they do on either side of 24 hours of very heavy precipitation.

This "saturated canopy" theory also offers an alternative perspective on the excess throughfall reported by Veneklaas & Van Ek (1990). A situation may be envisaged in which high rainfall occurs in the previous week, which then stops at the beginning of the week in which high throughfall is recorded. Drip from this high rainfall period continues into the week in question, giving excess throughfall values for perhaps the first 24 hours. Assuming that the rest of the week remains dry, it would appear that fog interception had occurred, since no detailed breakdown of this weekly data is possible.

There are thus three possible ways in which excess throughfall can occur in weekly data without fog playing any part. These are the process of throughfall carry-through just described, excessive splash from open rain gauges during heavy storms, and measurement error resulting from highly variable drip points coupled with inadequate sampling design. All of these serve to reduce the sensitivity of weekly sampling methods, and render them unsuitable for situations in which the presence of fog drip is not a clear-cut fact.

The case for the saturated canopy theory in the context of this study seems to be very strong, but there are one or two problems with it. It may be that the additional throughfall is not entirely the result of the processes described above, but that fog interception is taking place on the saturated leaves and is able to drip off, rather than going into storage or evaporating before it ever reaches the ground. If only small amounts of water were involved, then the difference that this fog drip made to the percentage throughfall in periods of much higher rainfall would be marginal, and would probably be lost in the analysis. However, if this is indeed the case, then the quantities of water reaching the forest floor as fog drip would be so small as to be insignificant. Assuming that the wetting/drying cycle does contain a degree of hysteresis, so that the percentage throughfall after a wet period is greater than after a dry period, then the amount of fog drip could not exceed a few tenths of a millimetre, given that the throughfall in the four periods under question does not exceed 1.5mm. In addition, it could only occur at times when the canopy is saturated, which make up a small minority of the study period - no more than about ten from a total of 56 twelve hour slots. When considered in relation to a four week rainfall total of 104mm, fog drip could not represent more than four or five percent of the total water supply, if it exists at all.

The lack of diurnal variation in the data is at first a little worrying. It would be expected that evapotranspiration from the canopy should be greater during the day than the night, due to warmer temperatures, greater plant activity and stronger valley winds. However, during rainy periods, the climatic variables remained very stable, with little wind at any time, and only minor temperature variations between day and night. When the sun came out, these differences became much more apparent, but it was rare to have both sunshine and rain on the same day, since the weather tended to be either cloudy and wet or sunny and dry. The classic British "sunshine and showers" situation did not exist, at least not during this study period. There are thus no reasons to suppose that diurnal variations should occur.

Conclusion

These results agree well with those reached by other studies in the Andes (Veneklaas & Van Ek; Cavelier & Goldstein). The latter study suggests that the somewhat paradoxical paucity of fog interception in Andean cloud forest may be due to the "smaller droplet size distribution and liquid water content in the stratiform clouds which predominate in the high Andes", and observations made during this study certainly accord with this view. Even when the fog was very dense, it left no visible signs of wetting upon the environment, and the droplets were too small to be visible to the naked eye at close range.

This study has provided further evidence that fog drip does not occur to any significant extent in the Andean cloud forest. However, to provide a definitive answer as to whether it is occurring at all, a longer term study on similar lines would be required, to test whether high percentage throughfall coupled with low rainfall conditions can result from clear periods without fog.

Water resources in the Paute Dam region

The original aim of this project was to examine the significance of fog water in the hydrological cycle of the Paute dam region. The findings presented here suggest that fog drip is not important, and that the water resources of the area can be satisfactorily assessed using normal rainfall and evapotranspiration criteria. Water from fog does not contribute in any major way to the overall precipitation reaching the valley floor.

Some studies have suggested a central role for fog interception in the maintenance of cloud forest, particularly with respect to the heavy covering of moss and epiphytes on trees. These results do not provide evidence to support such a role for fog in the Ecuadorian Andes. The nature of the rainfall - prolonged periods of light rain and drizzle - means that the environment is kept almost constantly wet. When fog is present, there is usually rain as well. Input of additional moisture from a source other than rainfall is simply not necessary to maintain the richness of the vegetation.

One role which the fog may have is in the conservation of moisture. The epiphytes which we saw were generally designed to act as storage vessels, with a well of moisture retained in a cup-like structure at their centre. This well is recharged by rainfall, but would be vulnerable to evaporation during a prolonged dry spell. When fog is present, the atmosphere is super-saturated, so no evaporation occurs. The UEA expedition, which was present in the area at a different time of year, recorded very little rainfall, but there were extended periods when fog was present. Simply by reducing the amount of evaporation, this fog would help to maintain the lush epiphytic growth, without having to contribute in any significant way to the recharge of the water stored by the plants. As long as rainfall exceeds evapotranspirative capacity, fog interception need have no role.

This is not to say, however, that the forest has no hydrological role, and the effects of its removal were clearly evident on the valley slopes. Trees possess a very large evapotranspirative capacity, and return much of the water falling as rain to the atmosphere. At no time during the fieldwork period was there any waterlogging beneath forested areas. The picture was entirely different in cleared areas, where waterlogging was widespread and apparently permanent in places. Not only does this degrade the quality of the pasture and render the land useless for grazing, but it also increases the risk of erosion through major slope failure. Two such landslides occurred during heavy rain prior to our arrival, leaving deep scars tens of metres across and hundreds of metres long.

The Paute dam is already suffering from severe problems with silting, and mass erosion of the slopes due to deforestation can only worsen the situation. The stability of such steep slopes is precarious even with a full vegetation cover, and the problem of landslides will only worsen as more forest is removed and the root systems left behind in the soil gradually rot away.

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2.3 The effects of rainbow trout introduction on the indigenous fish community of the Río Púlpito

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Edwin Zarate

Abstract

- The aim was to study the fish community in the Río Púlpito.
- It was discovered that the only indigenous fish species is an Astroblepid catfish and that rainbow trout have recently been introduced by the local people.
- Catfish numbers are reported to be declining throughout the Ecuadorian Andes and trout have been implicated in this decline.
- A large but possibly non-breeding trout population was found. Few catfish were found.
- A causal relationship was searched for on the basis of dietary analysis. The results of this are pending but there is much circumstantial evidence linking trout introduction to catfish decline.

Introduction

Fish are perhaps one of the groups most neglected by expedition science and conservation biology. They play an integral role in stream ecosystems which in turn affects the surrounding environment. Just as the animals and plants of the cloud forest need study and conservation, so do the slimy denizens of the forest rivers.

The original aim of this project was to discover what species, indeed families, were present in the cloud forest streams and study how their community is structured. The methodology used by Angermeier and Karr (1983), in Panamanian tropical forest streams provided the basis for the proposed study.

We also hoped that the effects of deforestation on the stream communities could be studied by a comparison between primary and secondary forest. A significant difference was expected as river systems are intimately influenced by the surrounding habitat.

However, none of this was to be and we discovered very quickly why fish are often avoided by most sensible expeditions with short field periods. In this process of discovery (disaster and recovery) we did manage to carry out some interesting work and develop novel sampling procedures that will hopefully help to form a baseline for future studies in this area.

In this work an attempt is made to minimise the jargon and citations without making the work over-generalised and inaccurate. It is suggested that if you want more exact information and an academic background on exotic introductions, have a look at "Distribution, Management and Biology of Exotic Fishes" edited by Courteney and Stauffer. For a general introduction to rivers, read "Freshwater Biology" by Brian Moss.

First change of plan

During the recce trip Dr Barrida of the Escuela Politechnica National revealed that to his knowledge the only group of fish indigenous to the montane forest streams of Ecuador are the Astroblepid family of catfish. It was also discovered that since the 1950s, rainbow trout (*Onchorhynchus mykiss*, Walbaum) have been introduced into the upland waters of the Andes to provide an economic resource, not to mention better eating than the small bony Astroblepids. It has been reported that as the trout numbers increased the catfish population declined and though no relationship between the two has been proven, or looked for, trout have been tentatively cited as a possible cause of the decline. Over fishing of the catfish and land use changes are also considered as possible causes. The project was thus modified to begin to unravel the relationship between the trout and the catfish, assuming both were actually present in the Río Púlpito.

Catfish

Astroblepid catfish are a group with a minimal literature, in English at least. All the information presented here was gained in conversation with Dr. Barrida and Dr. Paul Turcotte. Little of this information is to be found in the standard literature. Though Astroblepids may be almost unknown in the literature, they have been eaten by the Ecuadorian people for thousands of years.

Astroblepids are found between 800 and 3000 metres in the cold torrential streams of the Latin American mountain ranges. To cope with these conditions they have evolved a nocturnal, cryptobenthic habit; living protected from the rapid current under the stones of the river bed, their bodies flattened and elongated with a mottled browny-green coloration. In size they are between 3 to 20 cm. The eyes are degenerate, vision being replaced by tactile barbels around the sucker-like ventral mouth, used (presumably) to rasp algae from the rocks and feed on benthic invertebrates. As with all catfish they are scaleless but unlike many other families of catfish, they lack the subdermal armour plating evolved as a defence against predation.

Some ten species identified on often tenuous taxonomic grounds by Shultz (1949), inhabit the streams of the Ecuadorian Andes, linearly distributed north to south. Much remains unknown about their phylogeny and distribution, the fact that they are the sole group of fish present in what are often large rivers flowing through rich and diverse habitats is somewhat of a puzzle and increases the need for their study and conservation.

Trout

Rainbow trout are a North American species that have been introduced into naive waters since the Nineteenth century. Though many attempts at introduction failed there are now a considerable number of self-sustaining populations existing the world over. Trout can be found in rivers at sea level to lakes and streams up to 4500 metres. They live in the water column, feeding predominantly from the water surface but also from midwater and the river bed. The full force of the current is avoided in the lee of the boulders and in pools, the fish moving briefly into the fast water to feed. Rainbows are aggressive, territorial and able to tolerate a wide range of environmental conditions. They compete for best access to food and for the favourable slow water regions of the river, often with greater success than the indigenous species.

Trout-catfish interaction

A large body of circumstantial and increasingly experimental evidence collected in every continent supports the theory that the introduction of exotic fish including Salmonids, have been involved in the decline of indigenous species. This is thought to occur via a number of interactive processes such as competition for resources, predation, the introduction of disease and parasites and habitat change.

In the mountain streams it is not hard to imagine competition for food and space occurring between the trout and catfish, even though they occupy different temporal and spatial locations in the stream. Predation on the catfish by the trout may be possible, especially where the larger specimens of trout are concerned. In New Zealand, McIntosh, Townsend and Crowl (1992) have implicated rainbow trout in the decline of the dwarf inanga *(Galaxias gracilis*, McDowall) population, which formed a significant component of the trout's diet until the inanga became rare. This decline took only 15 months.

It is all too easy to assume that the trout are adversely affecting the catfish before any evidence is gathered. The big problem in this field is that it is almost impossible to verify a causal relationship between the introduction of the exotic and the possible effects on the indigenous population. Rigorous documentation of such cause-effect relationships requires an experimental design in which appropriate controls and replications are used. All this must be carried out in natural settings and this is hardly a feasible proposition especially where most introductions are not discovered until the exotic population has become well established.

In this study we attempted to take a more mechanistic approach than many previous studies. The decline of indigenous species in the presence of exotics has been recorded by previous studies without attempting to establish a cause-effect relationship. Our aim was to begin to identify possible areas of interaction between the two species and determine if it was the presence of the trout was involved in the catfish decline, or whether some other factor was operant. Competition for food seemed a simple starting point. To do this the fish are caught and their stomach contents analysed with reference to a collection of the invertebrate food sources. Nothing could be simpler.

Second change of plan

On arriving at the study site and actually looking at the river to be sampled it was realised that there was no way that any of the methods we had proposed were going to work in this freezing Andean torrent. Quite what we had expected the river to look like is a mystery, but a rapid revision of plans was called for and the exacting sample techniques soon gave way to the Río Paute Headwater trout fishing project. We were still determined, if at all possible, to work on the trout catfish relationship and spent much time devising new sampling techniques to ensure that useful data would be collected.

Methodology

Study site

The Río Púlpito flows South from its source on the slopes of Mount Púlpito at an average velocity (in August 1991) of 2 $msec^{-1}$. The valley is steep sided and V-shaped with the interlocking spurs typical of a fast flowing upper course mountain stream. Montane forest once cloaked the valley sides, now the river runs through predominantly secondary forest and grassland before reaching the waters of the Río Paute dam some 5km below the second camp. When the waters escape the Dam they flow eastwards, eventually discharging into the Amazon.

A typical riffle-pool formation is exhibited by the stream channel, varying greatly in width and depth as the gradient of the valley changes. At the study site the river is between 6 to 8 metres across and up to 1.5 metres deep, though much is less than 30cm. Where the gradient is steep and the channel narrow, waterfalls and ferocious rapids are found. When the gradient eases off, the channel may be about 30m across with the stream taking the line of least resistance across the much wider bed of the channel.

Stranded tree trunks, huge water-worn boulders and high banks are a testament to the great seasonal variation in discharge and water level. We visited at the end of what was probably the "wetter season" and the river could obviously hold a lot more water than it did then. During the study period the water level fluctuated rapidly, responding quickly to variations in rainfall. In one night the river could easily rise by over 50cm. It is probable that much of the channel morphology could have been carved by acute flood events rather than prolonged periods of high water.

The water itself was clear and cold, and carries much coarse particulate organic matter (collected by 250μm mesh nets) as is typical of upper course streams. The substratum is varied reflecting the uneven flow, ranging from many tonne boulders in the rapids to fine silt and clay in the pools and backwaters.

Remnant primary forest vegetation mixed with secondary scrub and the bamboo-like *Cusquea* lined the banks. The broken and uneven canopy overhung the water by up to 2 to 3 metres, though it never came close to closing over the channel.

Samples were taken from around 1km of the Río Púlpito below study site 2, exact sample sites being determined by suitability and accessibility. Thus samples were taken where possible and not chosen entirely at randomly.

Fish sampling

Initially we proposed a very systematic and exact sampling procedure using large (10 metre by 2.5 metre) block nets following Angermeier and Karr (1983). Using such nets the stream can be partitioned and all the fish collected from a known area. This was not possible. It was hard enough to stand upright against the current when thigh deep. To rig 1cm mesh block nets across that flow was a laughable proposition. The nets, which were by far the most expensive single items of equipment, were used to stop marauding animals getting into the cooking hut. After the expedition the nets were donated to the Universidad del Azuay and the Politechnica National.

Trout. Rod and line proved by far the most effective sampling method. Not the most systematic technique, but it did work. Lurid spinners and earthworm baited hooks were cast into likely trout swims; the slower water and pools. The aspirant icthyologists used a state of the art 2 metre carbon fibre rod and modern tackle while the local volunteers used coarse handlines and rusty hooks. Experience seemed to count for more than equipment, the catch ratio being about 1:4, science vs local expertise.. The days' catches were examined for parasites and general condition, measured - taking the total, standard and fork lengths - before being weighed and gutted. The stomachs were labelled and set in 10% formaldehyde which was also injected into the larger stomachs to improve preservation. After 3 days the stomachs were transferred to 70% alcohol which is far more user friendly. One has to be VERY CAREFUL when using formaldehyde and syringes, it tends to spray everywhere with traumatic consequences.

Catfish. Catching catfish became an obsessional failure until we enlisted the help of José Poncé. Dr Barrida lent us his specially designed cat fishing net which was ideal for the purpose . This was lost under contentious circumstances, so we made a series of nets, all of which failed in the current except the mark IV which was used successfully by José. Astroblepids reside under stones so the recommended technique - as used by locals for generations - involves one person standing upstream of a likely looking boulder while the other positions the net (or woven rice sack) down stream to catch all that is washed out when the person upstream lifts the boulder. Night fishing can work, trawling the edges of the river with hand nets, kicking up the river bed until fish are caught. This was tried and the combination of the dark, the slimy, uncertain footing and roaring current not to mention the apparent lack of catfish, made it a frustrating and slightly unnerving technique. Once caught, specimens were examined, measured, weighed then preserved whole in 70% alcohol.

Invertebrate sampling

Invert collections were made to provide reference collections to ease the identification of the fish gut contents and to provide an idea of the possible range of food sources available to the fish. Hand sorting of the samples, once collected, is a tedious process requiring a keen eye and much patience. A hand lens, fine forceps and pipette were used to separate the invertebrates from the substratum. Terrestrial and drift samples were relatively free of debris and easy to sort. Benthic samples include a lot of stream bed and take far longer. Sorting must begin soon after collection as live moving specimens are far easier to see amongst the mass of substratum than dead specimens, this applies especially to the small nematodes and early instar nymphs. Classification was carried out to order or family using European keys which in most cases proved sufficient. Taxonomy of the terrestrial inverts was more basic, but classification to order is pretty similar the world over.

Terrestrial invertebrates. An inflatable child's paddling pool (6.3 m^2) was used to catch invertebrates that fell or flew onto the water surface. The pool was placed as near to the water as possible (without endangering the safety of the device) and partially filled with a solution of dish washing detergent (enough to make it a bit frothy) to decrease the surface tension and wet insects more quickly, ensuring no escapees. Canopy characteristics above the containers were recorded. The pool was left at each sample site for 6 continuous 24 hour periods, after which the contents were strained through 250 μm mesh net (the spare surber sampler net), and preserved in 70% alcohol. Two such sets of samples were collected. Invertebrates were later sorted and counted using a 10x hand lens. A dissecting microscope would have helped but we did not have one in the field.

Benthic invertebrate samples were taken in the day from a representative range of substrata in safely accessible areas of the river. A surber sampler with 250μm mesh was used, the sampling regime having been standardised with the Macro-Invert project: 3 sub samples taken at each point were then pooled and the inverts sorted and counted. If possible samples were taken from the trout swims, though the water was often too fast and deep. Marigold style washing up gloves over thermal inners with rubber bands sealing the wrists, save the sampler from the not to be underestimated agony of scooping the river bed into the net in near freezing water. Chest height waders are also invaluable, though bulky and clumsy, they allow the ichthyologist to stay warm and dry, until he is washed over by the current.

Drift was sampled both in the Río Púlpito and the small tributary streams which flow every few hundred metres straight down the valley side and into the river. As drift sampling was not on the original itinerary we constructed a sampler from the ever useful spare 250 μm surber net, cut wood and a large quantity of string. It was possible by careful siting of the device to filter all the water of the tributary streams through the nets, though this sometimes did involve slight modifications of the stream channel. River drift proved harder to sample, either the drag from the net broke the moorings or the whole structure just collapsed under the current. It is worthwhile tethering the equipment to a secure point on the bank, so when all comes adrift, precious nets are not lost. Samples were collected every 12 hours 6 am. to 6 pm. to show possible diel periodicity. Inverts were sorted and counted before preservation in 70% alcohol.

Results

Fish

In total 72 rainbow trout and 12 Astroblepid catfish were caught and studied during August 1991. The catfish were preserved whole, six specimens left with Dr Barrida of the Politechnica National and six with the Universidad del Azuay. The catfish exhibited a wide range of coloration from a light mottled yellow/brown to a much darker green/brown. Identification using Shultz (1949) suggests they are *Astroblepus grivlaxii*. All of the specimens were caught By José Poncé for a bounty of 2000 sucres (then roughly £1.20) per catfish. Our attempts yielded no results, possibly due to the scarcity of the fish but more probably it was the result of a lack of expertise and patience.

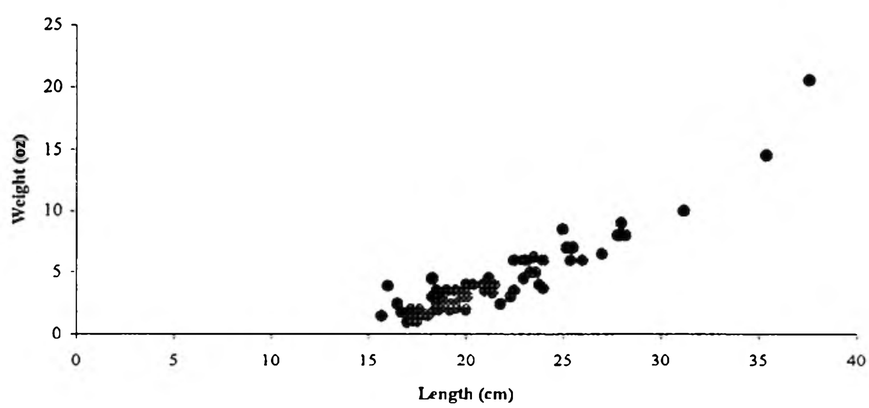

Fig 2.3 *A Graph to show the relationship between fork length and weight of 72 trout caught in the Río Púlpito*

Trout were collected easily, José and his younger brothers providing the majority of the specimens. On examination all the fish appeared to be healthy, without any evidence of external parasitic infection. Measurements were simple though metric scales would have been an improvement. The sample (see fig 2.3) shows a skewed length to weight relationship with a large number of small fish around 20 cm and fewer large individuals. The smallest specimen caught was 15 cm in length and the largest 37 cm. A number of the individuals caught were in breeding condition, including some perhaps surprisingly small male fish. The preserved stomachs still await the long task of analysis at the Universidad del Azuay to determine the fishes' diet and assess any areas of overlap between the trout and the catfish.

Invertebrates

Terrestrial invertebrate samples at site 1 and 2 were dominated by dipterans (see figs 2.4 and 2.5). In 144 continuous hours of sampling at each site 342 specimens were

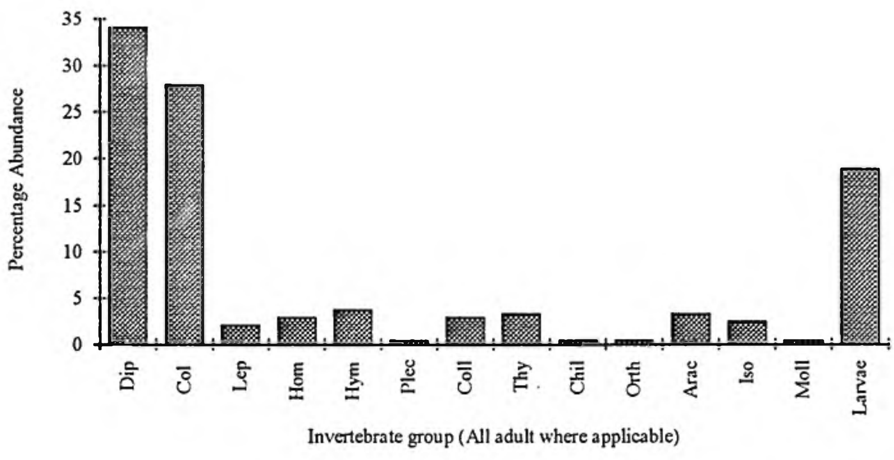

Fig 2.4 *Terrestrial invertebrates incidental on the water surface from 144 continuous sample hours on forested river bank.*

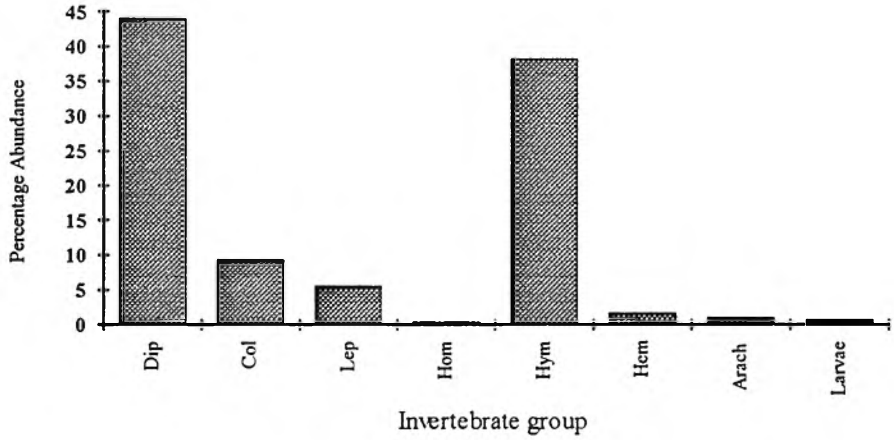

Fig 2.5 *Terrestrial Invertebrates incidental on the water surface from 144 continuous sample hours on cleared grassland river bank*

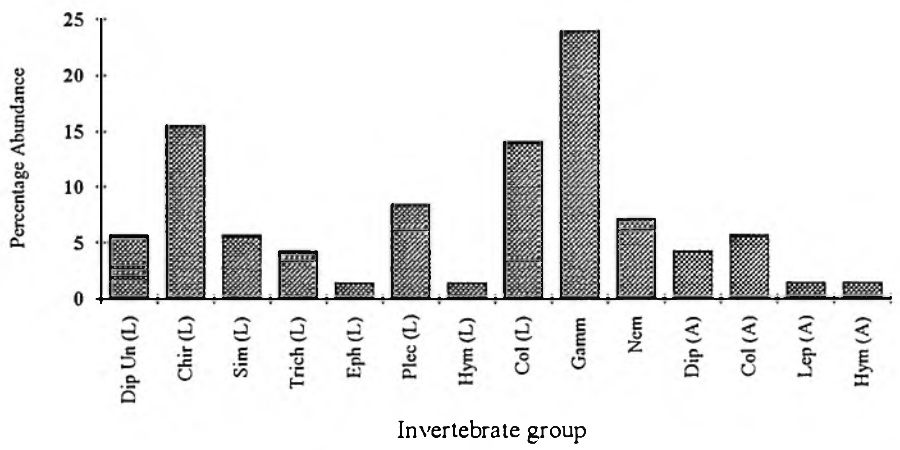

Fig 2.6 *Invertebrate drift from stream 1*

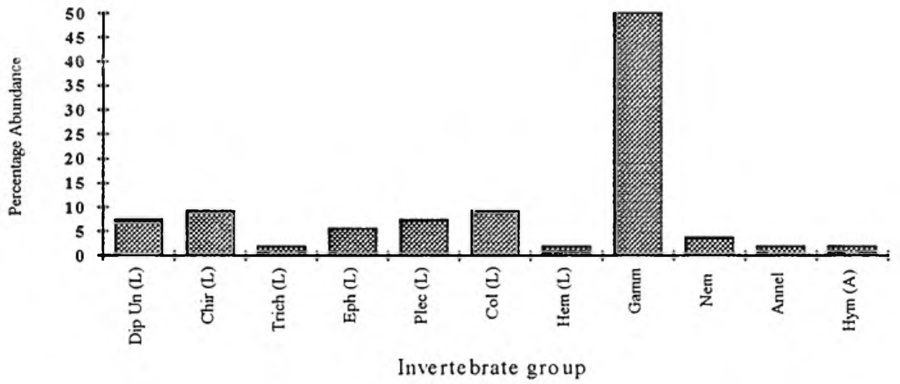

Fig 2.7 *Invertebrate drift from stream 2*

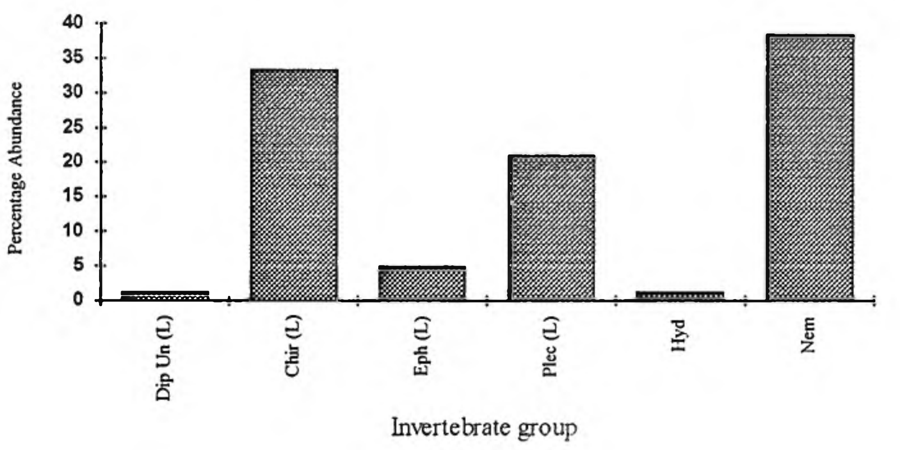

Fig 2.8 *Benthic invertebrates from the Rio Púlpito*

Key

L=Larvae. A= Adult

Annel=Annelida, Arac=Arachnida, Chil=Chilopoda, Chir=Chironomid, Col=Coloeoptera, Coll=Colembola, Dip un=Unidentified diptera, Eph=Ephemoptera, Gamm=Gammarus (Amphipod), Hem-Hemiptera, Hyd=Hydracarina, Hym=Hymenoptera, Iso=Isopoda, Larvae=Unidentified arthopod larvae, Moll=Mollusca, Nem=Nematoda, Orth=Orthoptera, Plec=Plecoptera, Sim=Simulid, Trich=Trichoptera, Thy=Thysanura.

collected under remnant primary forest canopy and 446 in a small grassland area. Classification was carried out as far as time and expertise allowed with some specimens entirely defying our taxonomic skills.

Using the home-made drift sampler we were able to collect the entirety of the drift from two small streams. 5 consecutive 12 hour periods were taken in the first stream below a waterfall (see fig 2.6) and 12 consecutive 12 hour periods at the mouth of the forested stream surveyed and sampled by the macro-invert project (see fig 2.7). From the first stream 71 specimens were collected in the 60 hours between 1800 hrs on 16.9.91 to 0600 hrs 20.9.91. The second stream yielded only 54 individuals in the 144 hrs between 1800 hrs on 21.9.91 to 1800 hrs on 30.9.91. Both showed the freshwater shrimp *Gammarus* to be the major single component. Larval chironomids and coleopterans also formed significant percentages on the sample. River drift was sampled over one twelve hour period, not long enough to produce viable data.

Five sets of benthic samples were taken from a variety of substratum types, though all in a workable depth of water (see fig 2.8). The samples were notably species poor with only 81 inverts collected from 15 single surber samples. Nematodes were the numerically dominant group with lesser proportions of chironomidae and plecoptera.

It could be argued that as the fish stomach contents have not been analysed it is pointless to present data on the invertebrate community sampled. While this may be the case, the data may be of use to someone and does highlight the small size of the invertebrate community in the Río Púlpito and its tributary streams and the significant amount of allocthonous input from the canopy.

Conversation with locals

Much information was gained through conversation with the locals, though it must be remembered that 100% accuracy is not guaranteed, much depending on the initial phrasing of the question. It would seem that trout were introduced into the Púlpito in 1984-85 by the local farmers. Eggs or fry being bought in Cuenca, tipped into the river and left to fend for themselves. Though we were told the population is well established, the introduction of fresh stock still continues. When the trout are caught they are preserved by smoking or drying and provide important dietary protein.. On asking where the best fishing was, we were told that is was definitely better upstream as the trout were larger (6+ lbs) and also that there were no trout upstream as their progress was blocked by a waterfall.

On catfish, all agreed that numbers had declined greatly. Whereas ten years ago it used to be possible to catch plenty - 100 or more in a day - now it was only possible to catch a maximum of 10 or 20 but it was not really worth the effort since there were trout anyway. The trout were preferred to the catfish, being larger, easier to catch and far tastier. It was said that trout have been caught with catfish in their stomachs, though how often this occurred was not known.

It is also worth noting that Mirror carp have been introduced into the waters of the Paute Dam and during the study period the dam managers were contemplating the introduction of the grass carp *Ctenopharynodon idella*, in an attempt to control the dense growth of water hyacinth that carpets the water surface.

Discussion

This is a discussion of the preliminary findings of the fish study. Detailed analysis will occur when the study of the trout and catfish stomachs has been completed. The various methodologies attempted are discussed and then a generalised view of the situation which exists in the montane forest streams of Bosque Protector 15 is presented with reference to similar introduction events.

Methodology

The methodology that was eventually arrived at was a compromise to best cope with the environmental conditions that faced us. In the wetter season at least it does not seem feasible to sample the fish using more representative sample techniques such as block netting, electrofishing or poisoning. Poisoning and electrofishing are by far the most effective sample techniques and may reveal species inaccessible by any other means, as well as providing a more representative sample of the readily accessible species. The efficacy of these techniques relies on high fish mortality which is not really acceptable given the trout's importance to the local people and the possible fragility of the catfish population. If the fish are merely stunned they still have to be collected. This is problematic at least in the wetter season when block nets cannot be rigged across the current.

Hook and line sampling is unrepresentative but was the only alternative open to us. It may have resulted in the lack of small specimens, although this may be caused by the breeding status of the trout population discussed below.

Cat fishing is tricky, but given more time to get used to the techniques and the environment, it should be possible to carry out far more effectively than we managed. Patient stone turning carried out as systematically as possible could well yield results. The most important advice in these situations is to listen to the local experts and heed the advice.

Surber sampling for invertebrates is a standard technique and worked well in the areas of the river that were safe to work, again truly representative sampling was not possible, though for the purpose of stomach analysis it was not entirely necessary. The paddling pool was effective and provided an interesting range of invertebrates which will greatly aid in the identification of the stomach contents. The pool was easy to use as long as sited a safe distance from the grasp of the current and provided entertainment for the local farmers, who were somewhat mystified by its presence.

Many of the invertebrate samples have been preserved and the less readily identifiable specimens are to be worked on at a later date. Drift sampling in the streams was an exercise in ingenuity that provided useful (but unpublished) data when combined with the macro-invert project. The input into the river from these small streams was not insignificant especially when the paucity of the benthic community of the river proper is considered.

Fish

Before the recce trip correspondence was entered into with leading ichthyologists in Britain and in the United States. A wide range of species was suggested as possibly being present, from the elusive and parasitic Trichomycterid family of catfish to Lebisinid charachiforms and hill stream gobies. It was also mentioned that the area had been poorly collected and studied, so to expect the unexpected. Dr Barrida was the first to mention the presence of Astroblepids and trout, that in itself was an exciting discovery.

The trout population in the Río Púlpito is large and the individuals healthy. The local people greatly appreciate the supplementation of their otherwise rather impoverished diet based around the staple maize. The fact that no small trout (<15cm) were caught could be a reflection on the sampling technique or it could be because the trout population was not breeding. Though individuals were caught in breeding condition, no evidence of successful spawning was found. Many explanations for this phenomena are possible: The rapidity of the current may inhibit the building of the nest (redd) by the female. The lack of seasonality may throw endogenous seasonal breeding cycles. It is possible that the trout spawn further upstream where the river is smaller, but since the river is also periodically restocked the population can be expected to remain for the foreseeable future. The small number of larger fish caught could again be due to our lack of fishing expertise, but is probably accentuated by the high mortality regularly inflicted on the population by the locals fishing. Large fish of 40 oz plus are reported by the locals and reasonable extrapolation of the length/weight relationship would support this.

Considering the trout in isolation many questions remain to be answered: Are they breeding in the Río Púlpito? If so, how is this affected by the equatorial seasonality? It is not known what race of trout are present. Race as in humans is a sub-specific classification, involving subtle behavioural and physiological adaptations to the local environment, in the case of the trout to their river of origin. To establish the race of trout present or the mix of races would further the understanding of the situation, as would increased knowledge on the reproductive status of the population.

Astroblepid catfish were, after a considerable amount of despair, shown to be present in the Río Púlpito. Evidence collected, mostly verbal, suggests that the population has declined considerably over the past decade and that specimens caught are now of a smaller size than before. The study has not yet produced concrete proof of any interactive relationship between the trout and the catfish, yet from preliminary observations it would seem that trout can, to a degree, be implicated in the decline rather than just populating the river while the catfish decline for other reasons. It should be remembered that as stated above, it is easy to assume that the trout are affecting the catfish before any information is gathered. While the interaction is not yet proven, we hope the further discussion below will elaborate the situation.

Evidence suggests that Astroblepids have existed in the Andean streams for some time without any piscine predators (who knows what else might eat them?). Possibly as a consequence of this they have lost the armour that covers most other catfish species whose environment is shared with predators. It is also possible that the catfish may have lost the behavioural response to such predation. The sudden introduction of a large number of voracious predators into a population of naive defenceless fish may be expected to have some effect. The predatory nature of the adult trout is well known and is supported in this case by reports of adult trout having been caught with catfish in their guts.

The high numbers of trout may limit the food availability in the river which had previously supported the catfish as the dominant aquatic predator (assuming that Astroblepids are not solely algivorous). The benthic invert data shows a surprising lack of invertebrates and it seems likely that as with the tributary steams studied by the macro-invertebrate project, this is attributable to high spate frequency although unstudied seasonal variance may also be involved. Food availability, which is a common limit to population size, is restricted for the catfish by the introduction of a more efficient collector of that food, the trout. Trout are known to feed predominantly from the water surface and on the drift and the habit and anatomy of the catfish suggests a benthic lifestyle but there is still much possibility for dietary interaction. Benthos, drift and many of the aerial insects with a tendency to impact with the water surface are all intimately related; drift merely being mobile benthos and the insect component of the benthos being the nymphal stages of a significant proportion of the terrestrial invertebrates (Plecoptera, Trichoptera, Ephemoptera etc). Intense predation on any one of these groups by the trout may well affect the availability of the others.

Physically the environment is relatively simple, controlled by the rapid flow of the current, for example there are no large aquatic plants which provide shelter for small vulnerable fish species. In the turbulent riverine environment both trout and catfish seek shelter from the current, the trout in the pools and backwaters, the catfish under stones and boulders. Thus the actual space habitable by the fish is restricted, bringing the two species into closer proximity than might be expected given the size of the river. This close proximity combined with the aggressive and territorial behaviour of the trout may well increase the likelihood of predatory and agonistic interaction. Simply put, the trout probably eat the catfish.

The construction of the dam may act to fragment the catfish population, each population being isolated within the individual headwaters above the dam. It would seem unlikely that torrent-dwelling fish would negotiate a large body of stagnant water to join with the populations of other rivers. Fragmentation of a population leads to isolation from recolonisation and an increased sensitivity to environmental change. It is worth noting that the Río Púlpito extends some 15 kilometres upstream above the study site with many tributary streams and some of this area is probably still uninhabited, forested and may, depending on the trout distribution, still support healthy catfish populations.

Very basically, it would seem likely that the trout eat the catfish food, eat the catfish and that the catfish of the Río Púlpito have been cut off from breeding with others of their species, in other rivers, by the construction of the dam. If a more detailed analysis of the situation is required the information presented can be re-evaluated in the light of hierachical niche theory such as presented by Kroes (1977), or contact the authors.

The above suppositions are as yet unproven and, as we discovered, are somewhat difficult to study, the hidden nature of the aquatic environment calling for an imaginative approach to the possible interactions occurring. Such conclusions are not without precedent. Work in New Zealand on possible interaction between the Brown trout and the native glaxiids, after a considerable period of study came to the conclusion that "interspecific competition for space, perhaps combined with competition for food and predation by trout, could explain declines in *Galaxias vulgaris*" (McIntosh, Townsend and Crowl, 1992) It should be noted that Glaxiids share a more similar lifestyle with trout than do the catfish and that the environment was different, but the comparison is still valid.

Degradation of the environment and the relative biotic simplicity of the montane forest streams may affect the alleged relationship. Herbold and Moyle (1986) hold that many successful introductions are limited to already disturbed habitats where the ecological balance has already been disrupted. Deforestation has direct effects on the riverine ecology as the overall hydrology and biology of the catchment changes. This environmental disruption may allow introduced fish to colonise an area with increasing case.

"As a general principle" writes Welcomme (1984), "it would seem that the more complex the environment into which the fish is introduced the less immediate the impact". The montane forest streams are from an icthyological point of view uniquely simple, thus the impact of the trout introduction may have been very immediate in its effects. Pollution of the water by human habitation and overfishing of the catfish may also play a part in the decline.

Conclusion

The introduction of the trout serves an important role in supporting the local farming community and on a wider scale provides an important marketable resource for the highland regions of South America. A possible consequence of this is the depletion of the native fish stocks. So little is known of the Astroblepid population size, distribution and ecology that this group could in certain areas be under considerable threat of extinction.

Whether it is the trout introductions, human alteration of the environment, over fishing or a combination of interactive factors is not known and this area needs to be addressed further if the sole indigenous fish species is not to be lost.

The benefits of conserving this species must be weighed against the costs to the local trout farmers. It is not easily practical or ethical to remove the trout population, although if the trout are not breeding the population will decline if the introduction of eggs and fry ceases.

Carp (*Cyprinus Carpio*) have been introduced into the Paute Dam and plans were proposed while we were there to introduce the Grass carp (*Ctenopharygnodon idella*) to control the water hyacinth which blankets the surface, speeding the eutrophication of the dam. Both carp species have been shown to have marked environmental impacts when introduced into a naive habitat.

The essential problem is a difficult one, balancing the needs of the current course of development against species and habitat conservation. These are issues that have received much discussion in terrestrial ecology but are rarely applied to fish and the aquatic environment. For a recent discussion of rare fish conservation see Le Cren (1990) and associated papers. The conservation of flagship bird species and areas of tropical forest may not be enough to conserve the aquatic environments. Though they are closely related to the terrestrial system, rivers are governed by different ecological constraints. The rivers flowing through the montane cloud forests of S. America need further study not only to determine further their biology and hydrology but also to begin to address how these rivers and their catchment areas can practically be conserved.

Acknowledgements

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2.4 The effects of deforestation on the aquatic macro-invertebrate community

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Veronica Toral

Abstract

- The aim was to compare the aquatic macro-invertebrate fauna of a forested and an unforested stream to reveal the effects of deforestation.
- The macro-invertebrate community was shown to be adversely effected by deforestation.
- Deforestation results in a modification in stream community structure due to the resultant high levels of erosion and complete trophic adjustment of stream ecology.
- Recommendations were suggested to help decrease the impact of limited forest clearance on stream ecosystems and ultimately on sediment loads in the Río Paute Dam.

Introduction

Aims and objectives

The project outline was to investigate the macro-invertebrate fauna of two contrasting headwater streams, One flowing through a forested and the other through a deforested catchment. This comparison was intended to reveal the effects of deforestation on the guild structure of the macro-invertebrate community.

The structure and function of stream ecosystems

To understand the context and rationale behind this project an introduction to the dynamics of stream ecosystems is necessary. All streams have energy inputs arising from within stream photosynthesis (autochthonous input) and from organic matter derived from the catchment (allochthonous input). In forested head-waters, such as the high altitude cloud forests of Ecuador, allochthonous inputs are most important. This is because the surrounding canopy drops considerable amounts of organic material into the stream, while at the same time restricting autochthonous photosynthesis through shading. For example in a detailed study of Bear Brook (a small stream in forested catchment in New Hampshire, North America), the allochthonous production accounted for 99.8% of the stream energy budget (Fisher and Likens 1973). It is therefore incorrect to view forested streams as isolated entities because they will be heavily influenced by the surrounding habitat (Hynes 1975).

This relationship changes as the stream evolves into a river. As most streams progress more water drains in from the catchment, so that they become wider. The shading effect of the canopy is then progressively reduced allowing macropyhtes (large plants) and attached micro-algae (microscopic plants) to flourish. Autochthonous production therefore becomes more important. Further maturation in lowland reaches often results in the water becoming too deep (and often turbid) for significant light to reach the bottom. This restricts macrophyte growth to the water margins but autochthonous production can remain important due to the compensatory growth of phytoplankton in the water column.

The macro-invertebrate community responds to this gradient of resources. Since it is the functional role of these organisms that is of interest, it is not helpful to categorise them into traditional taxonomic groups (Teal 1957). They are assigned to feeding groups or guilds of which the freshwater macro-invertebrates community can be divided into four (Cummins 1974). First, there are the grazers. These are animals that scour the stream bed for attached algae and micro-organisms and include mayfly larvae and aquatic snails. Secondly, there are the shredders, those animals that feed on relatively coarse particles of organic matter (CPOM: defined arbitrarily as above 1mm in size) and these are typified by the freshwater shrimps such as *Gammarus*. In contrast there are the collectors that feed on relatively fine particles of organic matter (FPOM: less than 1mm in size). This particular guild is further sub-divided into those that ingest FPOM from the stream detritus (collector-gathers), good examples of which would include the annelid worms and many dipteran larvae and those that sieve FPOM from the water column (collector-filterers), such as the case-living caddis-fly larvae that spin silk nets to trap FPOM. The final group are the predators that feed on other macro-invertebrates and include dragonfly and free living caddis-fly larvae. Figure 2.9 illustrates the paths of community energy flow through the above guilds.

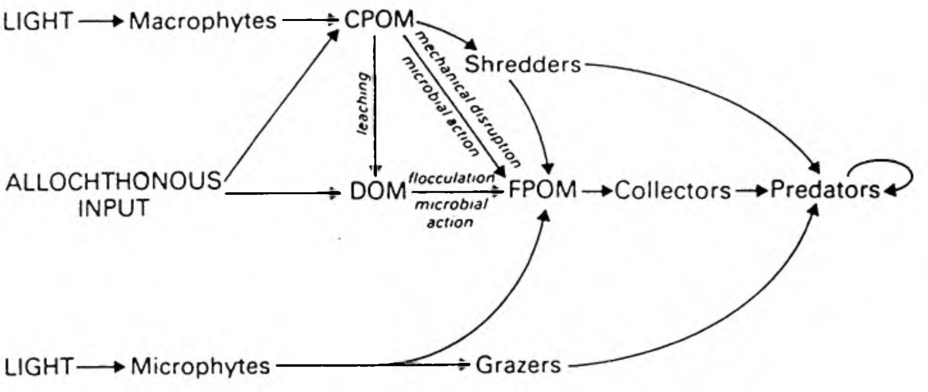

Fig 2.9 *The energy flow through the trophic guilds of a freshwater lotic ecosystem* (modified from Townsend 1981)

It is not only the source of energy that varies downstream but also very importantly its state. CPOM is the dominant constituent of allochthonous input in forested headwaters, which as we have seen becomes a progressively less important input towards the lower wider reaches of a stream. Furthermore, CPOM is processed into FPOM as it is moved downstream by physical degradation and shredder guild feeding (Townsend 1980). Cummins (1974) predicted that changes in community organisation would follow this gradient in energy resource type and Wiggins and Mackay (1978) soon confirmed that the ratio of trophic guilds of caddis larvae varied according to the relative importance of the grade of energy input. The shredders were the dominant guild in upstream habitats and became gradually smaller relative to the collectors as FPOM increased and CPOM decreased downstream. Shredders were also found to decrease in relation to the grazers, reflecting the increased importance of autochthonous production in unshaded downstream reaches. The proportion of predatory genera was largely unaffected. This relationship between the gradient of physical conditions resulting in a predictable series of biological adjustments has been formalised in the river continuum concept (Vannote *et al.* 1980) which is to a greater or lesser extent supported by freshwater ecologists (Moss 1988). For those unfamiliar with the freshwater macro-invertebrates discussed in this section the key by Croft (1986) is straightforward general introduction.

A synopsis of previous local work

Cold high altitude tropical streams are poorly known both ecologically and taxonomically. The work of Turcotte and Harper (1982) in Chirimachay, 20km northwest of Cuenca, is one of the few studies of a freshwater ecosystem at a similar altitude and in a similar region to this investigation. It was conducted in paramo habitat, a high altitude grassland dominated by *Stipa, Festuca, Calamagrostis, Antropogon* and *Paspalum* grasses as well as *Gynoxix* and *Polylepis* scrub (Wolf 1975). The work detailed the dominant elements of the stream fauna Hydracarina, Insecta, Copepoda and Oligochaeta respectively. Through an analysis of population size-frequency distributions, it was suggested the life cycles of representative organisms were not seasonally adjusted. Spates following storms were considered to be the major regulatory factor in benthic fauna density.

Further work in the Río Mazan paramo to the south-east of Cuenca was conducted by the Río Mazan Project in 1987 (Ainsworth 1988). It had a much broader ecological base and was the model for this particular investigation. They surveyed the freshwater invertebrates in different habitats of the Mazan region and used the trophic niche approach as an assay of stream conditions. Low invertebrate densities were again found and also attributed to the high spate frequency. These studies along with the extensive literature that has now been gathered on how stream faunas are affected by physical disturbances will be considered more fully in the discussion.

Methodology

Site description

Two streams were selected on the western face of the Río Púlpito valley. They were both first order tributaries rising 500m and 1000m respectively above the Río Púlpito (itself 2350m above sea level). They were of very high grade for their entire course and were punctuated at intervals by cascades. The substratum was composed mainly of rocks and stones so that the dominant water profile was that of riffles. The streams remained cool at all times (5-10 °C) with an average flow rate of 0.2 m^3s^{-1}. However, being of small volume they were very susceptible to spates. A pH measurement of 6 remained constant throughout the study for both streams. The turbulent nature of the riffles meant oxygen was not limiting. Frogs and tadpoles were rare in the streams. There were no fish but introduced rainbow trout (*Oncorhynchus mykiss*) and astroblepid catfish (*Astroblepidae* spp.) were found in the larger Río Púlpito. Despite the close proximity to the equator, the altitude meant air temperatures were cool (average 10-12 °C). Rain was frequent and prolonged, but mostly light, consequently overall totals were low in the order of 800-1000 mm per year. Fog was common and persistent throughout the study period. There was no distinct seasonality.

Stream 1 was approximately 10 km into the valley and flowed through a deforested area and was not shaded by vegetation until its final reaches. Local migrant farmers estimate that land clearance had occurred approximately 10 years ago and that since the area had been used continually for cattle grazing. The practice of land clearance for agriculture in this region involves the felling and burning the original forest and then leaving it for a year of regeneration. This regrowth is then again burned and a "European" grass mix sown in the ashes. The resulting sward was therefore composed predominantly of perennial ryegrass (*Lolium perenne*) and white clover (*Trifolium repens*).

Stream 2 was 5km further north in a relatively undisturbed area of mature secondary forest. Local residents estimate it to have been in regeneration for over 50 years and this correlated with tree trunk diameter measurements. The stream was shaded along its entire length with percentage cover always exceeding 100%.

Techniques and tips

Initially each stream was mapped so that it was possible to delineate 100 m sampling intervals from the stream mouth to its source. Working progressively upstream (to ensure activity within the stream did not influence remaining sample sites) macro-invertebrates were collected from a new site each day. In order not to be washed away, the macro-invertebrate community is associated with the stream bed; either anchored to rocks and stones as ballast, or creeping into more stable microhabitats under or on the leeward side of stones or in crevices. These bottom-dwelling macro-invertebrates are collectively known as the benthos.

Quantitative estimates of benthic faunal density were achieved with a surber sampler (Surber 1937). The surber sampler is a hybrid of a net and sampling. The frame that supports the net has a similar frame hinged to it at its lower margin which can be pushed down into the substratum. It is of known area (originally and today 1 ft^2 = 0.09 m^2) and thus acts as a quadrat. The substratum within the quadrat frame are lifted and stirred to dislodge the fauna. The current washes the displaced material into the net (mesh size = 250 μm) from which the macro-invertebrates can be collected. In parts of the stream where the quadrat frame was not sufficiently broad to encompass its width, mid-stream samples were taken. Three replicate surber samples were taken at each site. Note that this technique is limited to flowing water regimes were the water is shallower than an arm's-length. For transportation back to the camp the macro-invertebrates were sealed in containers with freshwater and a little substratum.

Hand sorting of the samples so that the organisms could be identified and enumerated rapidly became the largest and most tedious task of the expedition studies. However, it was essential to perform promptly so that the animals were still alive because their movements considerably aided detection. No stains were used to aid identification because of the difficulty of proper disposal. Preliminary sorting involved observation of the sample contents in metal trays and extracting individual animals with forceps (good diffuse daylight is essential for this work). The organisms were dropped into formalin and subsequently identified into trophic guilds by hand lens. Taxonomic designation beyond family groupings was not essential for the study. Furthermore, it can be beyond group expertise and was not possible on the significant percentage of early instar larvae recovered.

Data analysis

The data were pooled to determine the trophic character of each stream. A simple Chi-square statistic was applied to test the null hypothesis that the percentage of individuals in a given guild in stream were not significantly different from those in stream 2. Stream 2 therefore was used as the control.

Results

Taxonomic composition

The taxonomic composition of the benthic stream samples are presented in Table 2.1 While it was not our objective to investigate the taxonomic structure of the two streams it is of value to detail the main trends. Note that all comparisons are by species numbers and not biomass. In stream 1 the insects (54%) were the dominant group due primarily to large numbers of trichoptera and diptera larvae. The next most abundant were the annelids (20%) followed by the crustaceans (13%). The platyhelminths, nematodes, arachnids and molluscs were all present in small numbers, together comprising 13% of the total. In stream 2 the crustaceans (50%) were the numerically dominant group because of the huge number of amphipods. The insects were again abundant (42%) but composed of a more diverse sample. In contrast the annelids were found in very small numbers (<1%). The platyhelminths, nematodes, arachnids and molluscs accounted for the remaining 8% of the fauna. These relationships are perhaps more easily interpreted in figure 2.9.

There were also remarkable differences in the abundance of individuals. Macroinvertebrate densities in stream 1 at 403 individuals/m^2 were considerably lower than those found in stream 2 at 732 individuals/m^2.

Table 2.1 *A table to show the taxonomic composition of the stream*

Order	Family	Guild	Stream 1	Stream 2
Platyhelminthes		P	51	52
Nemathelminthes		CG	7	43
Annelida	Oligochaeta	CG	192	138
	Hirudinea	P	-	-
Mollusca	Gastropoda	G	28	1
	Lamellibranchia	CF	-	-
Crustacea	Amphipoda	S	99	1483
	Isopoda	S	30	189
Arachnida	Hydracarina	P	24	32
	Aranae	P	-	6
Insecta	Ephemeroptera	G	87	237
	Odonata	P	0	15
	Plecoptera	G	26	158
	Trichoptera	CF	265	483
	Coleoptera	P	18	217
	Diptera	CG	153	304

	Stream 1	Stream 2
Total	**980**	**3358**
Area sampled (m^2)	**2.43**	**4.59**
Density (invertebrates/m^2)	**403**	**732**

Stream community structure

Stream 1 had very low numbers of shredders (14%) when compared with stream 2 (49%) where the guild was the dominant trophic mode (see fig 2.10). In contrast the collecting guild in stream 1 was most abundant (36%) followed by the filterer feeders (27%). In stream 2 these guilds each represented 14.5% of the sampled population. The grazers and predators were the smallest guilds in streams 1 at 14 and 12% respectively. Stream 2 was similar with grazers and predators constituting 9 and 10% respectively.

If we assume that the numbers of individuals in the forested stream 2 represent some approximation to natural conditions that will be disturbed by deforestation and subsequent cattle grazing then the application of the Chi-square statistic demonstrates the significance of any difference between the two groups. The shredding guild therefore decreased significantly ($X^2=87.5$, $P<<0.001$) in stream 1. There were significant compensatory increases in the collectors ($X^2=31.9$, $P<<0.001$) and the filterers ($X^2=10.7$, $P<0.001$). Changes in the grazing and predatory guilds were not significant.

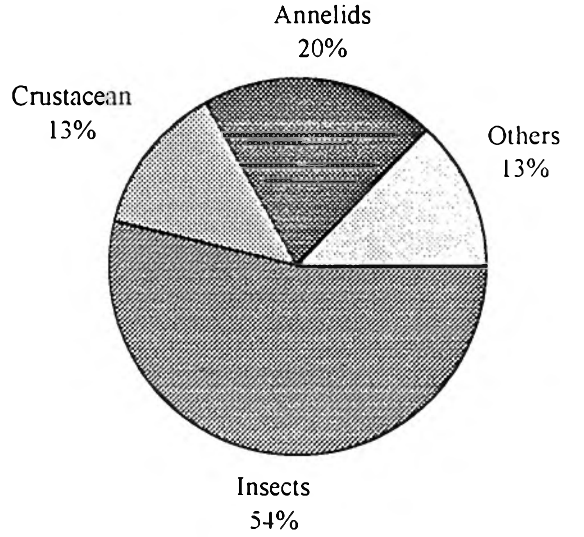

Figure 2.9a *Pie chart to show the percentage of the dominant Phyla in stream 1*

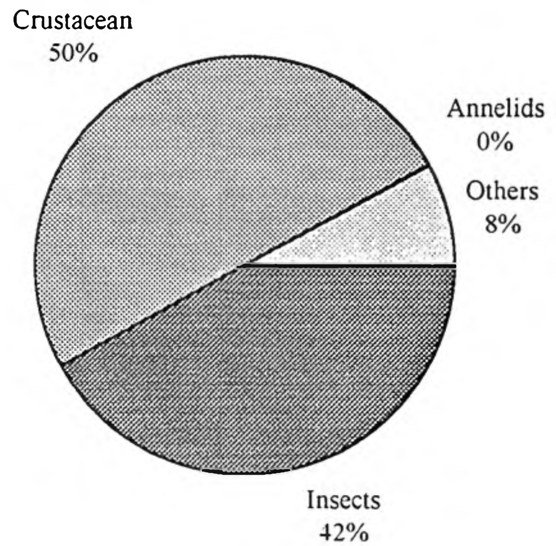

Figure 2.9b *Pie chart to show the percentage of the dominant Phyla in stream 2*

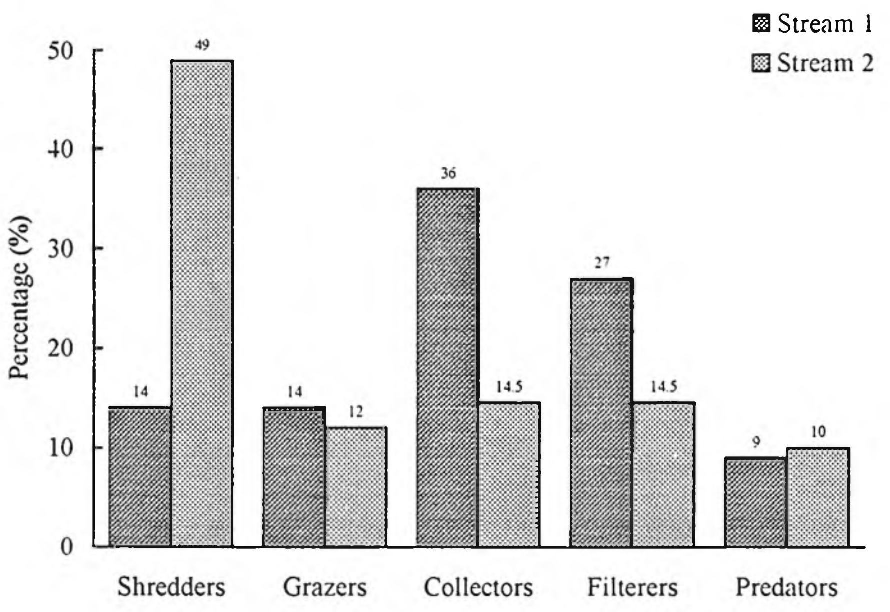

Figure 2.10 *A histogram showing the relative proportion of trophic guilds in streams 1 and 2*

Discussion

Summary

The modifications of stream community organisation on catchment deforestation seem intuitive if the change in energy inputs is considered. When the canopy is removed the primary source of allochthonous input vanishes. The shredding guild therefore suffers but survives in lower numbers on the reduced terrestrial input. The increase of the collecting guild is understood in terms of the extra sedimentation from soil erosion that occurs when the protective forest canopy is removed. Furthermore, deforestation in these regions is complicated by the influx of cattle. Not only do they tend to concentrate around the more lush riparian vegetation but congregate to drink at sites where bank erosion is notably increased. The fine nature of the particles that make up cow manure is a further possible reason for large numbers collecters and especially filterers. The predatory guild is constrained by the number of other macro-invertebrates and as expected the community carrying capacity is not changed as a percentage of overall numbers. The stream itself is opened up to the light with canopy removal so that autochthonous photosynthesis is stimulated. The small and insignificant increase in grazers is problematic as it was assumed this guild would exploit the extra resources. It may, however, be a function of the high number of grazers in stream 2 compared with forested streams in the United States where a typical community percentage would be much less than 10% (Fisher and Likens 1973).

The reduced benthic density of macro-invertebrates in the unforested catchment suggests a greater susceptibility to spates or a lower overall energy base to support the community. While we can not differentiate between these hypothesis on the basis of this investigation it should be noted that the ideas are not mutually exclusive. This was also evident in the nature of the stream bed and the water with a good amount of suspended sediment which became especially evident in the lower Río Púlpito.

Project limitations

A one off sample of the stream is valid in this context because there is no seasonality in this region and no evidence for fluctuating, seasonal populations (Turcotte and Harper 1982). The decision was taken to investigate two streams fully rather than over extend with the limited time and resources available and get only a rudimentary idea of several streams.

It is also necessary to indicate that stream 2 was not a perfect control. Irregularities when compared to forested headwater streams from the northern hemisphere suggest real differences in the community structure or that after 50 years of regeneration the community had not fully stabilised.

Suggestions for future work

These trophic guilds are relatively easy to identify with minimal experience and as such are already in used widely in British freshwater ecosystems to survey water quality BMWP (Biological Monitoring Working Party). The constituent taxonomic groups show a global uniformity in this type of habitat (Hynes 1971) which enables the extension of such schemes to tropical regions.

The possibility for academic extension of these types of studies is vast. Stream ecosystems are also relatively simple and a good model for teaching basic ecology to the uninitiated. However, beyond replication in other forested catchments to test the robustness of the changes documented, the applied application of these methodologies are limited. Further study may resolve details but is unlikely to change the trends and thus conservation. On a personal note of interest however, it would be an important study which sampled the community change in streams where regeneration occurred naturally. The quantification of succession rates may be an incredibly slow process as indicated above.

Conservation potential

Newbold *et al.* (1980) documented the effect of logging on macro-invertebrate diversity in northern California. Community effects *per se* were not considered. Streams with vegetation strips protecting them from the effects of logging maintained their faunal diversity in proportion to the width of the protective vegetation. Buffer strips of only 10m wide were found to mitigate the worst effects of the logging. Rounick & Winterbourne (1982) were one of the first to advocate the maintenance of buffer strips for the conservation of benthic faunas in the forested streams of New Zealand. These strips are also important for insectivorous fish and riparian birds. For a highly detailed examination of forestry management practices on macroinvertebrate biodiversity in the United Kingdom see Weatherley *et al.* (1993). This work illustrates the importance of buffer strips in stream conservation which is further discussed.

Conclusion

The beauty of these types of ecological studies is that they are easily learnt requiring only patience, not taxonomic expertise. They provide an unambiguous assay of the stream conditions and can be used to monitor land use change cheaply. Information on community responses to forest disturbance and associated erosion and sedimentation have been obtained. These data are valuable because they document the effect of land management practices on the aquatic resources of the region. It is hoped the data provide evidence that a more sensitive and enlightened approach to land management policy is adopted in the future.

While complete removal of the *campasino* pasturalists would be at once draconian and undesirable, education about the potential of buffer strips would be of benefit both to the farmers, because it would reduce soil erosion and bog formation on their land, and to the government because the sediment load to the Rio Púlpito dam would be significantly reduced thus saving on the present contacting of dredging vessels. The idea is one of cost effective prevention rather than expensive cure.

Furthermore, the stream fauna has an inherent conservation value in its own right and it was hoped the interest generated in this study may help to highlight this fact. That there is a conflict between stream conservation and deforestation is obvious, yet methods to help preserve aquatic biodiversity are all too evident. There is therefore room for hope.

While it was very depressing to see that large areas of reportedly pristine cloud forest environment were being destroyed, regeneration in many parts was powerful. There are solutions to the many problems of the region which are best addressed by local people being given a rational assessment of the facts. More than any other outcome I hope this project will provide a factual and methodological baseline for aquatic inventory assessment and contribute in some small way to help ease the problems of the region.

Acknowledgements

We would like to thank Dr. Paul Turcotte for replying to our initial approach and making the expedition a possibility through his patronage and logistical help in Ecuador. Thanks are also due to the relevant Ecuadorian authorities that permitted us to work within a beautiful area of their country. We are also grateful to the numerous expedition sponsors who made the work possible and especially to our Ecuadorian counterparts who helped make the whole experience so memorable.

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2.5 The effects of deforestation on the terrestrial amphibian community

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Abstract

- The aim of the amphibian project was to carry out a species census of the cloud forest and deforested area in which we were based, and to assess the effect of deforestation on the amphibians present.
- Between the altitudes of 2300m and 2650m, 82 frogs of 16 species and one toad were found. Of these, the most common amphibian was *Eleutherodactylus peruvianus* which was found to live predominantly in the most densely forested regions.
- In order to establish habitat preferences data was collected in sites ranging from grassland through to ancient secondary forest. Five sites emerged as being the most favourable, none of which had been touched recently, if at all, by man.
- By comparing the relative densities of amphibian species across the study sites, it was statistically proven that deforestation does indeed have a negative effect on the amphibian population.

Introduction

Background information

The moist nature of cloud forest provides an ideal habitat for amphibians, with the water keeping the skin moist enough to act as an all enveloping lung. Frogs and toads dominate, although the rare Caecilidae (burrowing, worm-like amphibians) have also been sighted. Epiphytes revel in the damp atmosphere; bromeliads, orchids, ferns, mosses and liverworts cover the branches of the stunted trees, and tree ferns grow in the damper spots where their prothalli find ample water in which to release their swimming spermatozoids.

Tree frogs may take advantage of the architecture of bromeliads, using pools of water collected at the bases of these epiphytes as breeding sites; other species, such as the *Gastrotheca spp.* and *Eleutherodactylus spp.*, have adaptations which allow them to breed away from water. *Gastrotheca spp.*, for example, brood their eggs in a dorsal pouch, the tadpoles then being released in an advanced stage of development into shallow pools of water (Read, 1986). *Eleutherodactylus spp.* lay yolk-rich eggs, in which the entire development of the tadpole takes place, so that pools of water are not necessary. Most species are nocturnal, the males calling at dusk and dawn and the tracking of male calls at night has proved a productive method of capture in the past, (Read, 1986).

Synopsis of previous work

A report of the 1989 World Congress of Herpetology states that amphibian populations world-wide are in decline, including those of the Andean cloud-forest. This report led to a special US National Research council workshop, ("Declining amphibian populations-a global phenomenon"), with suggestions that the status of amphibians needs to be urgently reassessed. News was brought to the Congress of Herpetology that in the late 1980s, the Monteverde Cloud Forest Reserve in Cost Rica lost its golden toads, (*Bufo periglenes*) and harlequin frogs, (*Atelopus carius*), and that several other species were in deep decline, such as those in the families Centrolenidae, Hylidae, Leptidodactylidae, Microhylidae, and Ranidae (Pounds, 1990).

Many amphibians respire through their epidermis and they are therefore vulnerable to drought and to human activities which cause their habitat to become drier. They are so susceptible to the environment that any change will affect their populations, whereas other animals may take longer to be affected. As a result the amphibians act as biomonitors of environmental change; the study of their populations is therefore rendered particularly important.

Models predicting the earth's climate change, (Wyman, 1990), suggest that temperatures will change, with greater warming occurring as one moves away from the equator. Around the equator, therefore, decline in populations may be attributed to habitat destruction and fragmentation, rather than global warming as a result of atmospheric greenhouse gases. Loss of amphibians in the Andes, where great habitat destruction has not occurred, may be related to the high inputs of toxic pollutants associated with the burning of the tropical forests nearby (Conservation Biology, 1990). Ultra violet light may be affecting amphibian's increasingly as the ozone layer is diminishing. On tropical mountains, sunlight strikes the earth more directly than at temperate latitudes and there is less atmosphere at high elevations to screen out the harmful rays. In addition, the amphibians thin epidermis does not help in protecting it against UV radiation. Acid precipitation has been noted as another possible cause of damage to amphibian populations. Volcanoes may be a natural source of acidity and if a section of cloud forest lies within the ash shadow of a volcano, acid precipitation could cause major problems.

In Central and South America, the major cause of decline appears to be overt habitat destruction and fragmentation, although some species are declining, for unknown reasons, in pristine areas of forest. Around the Universidad del Azuay, in Cuenca, and the surrounding region, amphibians have been noted to be in decline; notably *Atelopus ignescens*, *Hyla biforca*, *Hylapictorata*, and *Gastrotheca* species (Gustavo Morejon Pers. comm.).

The importance of collecting more data on the effect of deforestation on amphibians, and on the decline of amphibians in general is therefore important, not only for pure scientific interest, but also in order to provide an insight into the effect of environmental change on populations.

Aims and objectives

The basic aim of the project was to compile a species census of the local amphibians in the various primary, secondary, and deforested habitats in the surrounding area. The comparison of types and numbers of amphibian species in the various habitats of differing deforestation, can thus provide comprehensive data on the effect of deforestation on amphibians. Secondly, the species census can provide a baseline database for further monitoring of species in the Rio Púlpito Valley, and its surrounding areas. This second aim is rendered particularly important due to the world decline in amphibians. Present population records are imprecise and an international effort is being made to document numbers.

The project was originally intended to be carried out at a height of 3000m-4000m, thus providing comparisons with the herpetological work carried out by the Río Mazan Project, at a similar altitude (Read 1986, 1987). However, problems with the siting of the expedition made it necessary to work at a lower altitude than expected.

thereby proving a direct comparison of similar altitudes impossible. Comparison between the altitudes of 2000m and 4000m is possible but difficult due to the variety of habitats involved.

The main aim of this work can therefore be identified as the compilation of a species census in order to:

- Provide a baseline for further monitoring of the Río Púlpito Valley and its surrounding areas.
- Observe and define the effect of deforestation on the density and variety of amphibian species in the Río Púlpito Valley.

Methodology

Site description

The two campsites that the expedition occupied over the seven weeks were positioned amongst a wide variety of habitat types. This enabled a range of data to be collected; information about species, numbers, and densities of frogs were tabulated for the entire range of habitat types available. In order to aid data analysis, maps were drawn of the workable area, with the different habitats being marked off, depending on vegetation age, type and cover, and each being given a site number. This was done in collaboration with the botanical project, so that the two sets of data could be later related to one another. The habitat types included dense primary and secondary forest; various types of scrubland, grassland, recently deforested areas, (where newly felled trees were littered across the ground), and areas which were dominated by *suro*, a type of bamboo. These habitat sites covered a range of altitudes. A detailed description of all the habitat sites is thus provided below. Sites 1 to 9 are contained in Campsite2; sites 10 to 13 in Campsite 1.

SITE 1: Altitude: 2350m. History: Untouched in the last 20 years. Description: secondary forest with *suro* grass (not in flower), Moracca trees and tree ferns on gently sloping ground. Low tree density.

SITE 2: Altitude: 2400m. History: Untouched in the past 20 years. Description: Secondary forest with much moss and lianas on a steep slope. Denser tree cover results in a darker and more humid interior than site 1.

SITE 3: Altitude: 2400m. History: Untouched in the last 20 years. Description: Primarily covered in *suro* (some of which was in flower), interspersed with tree ferns supporting bromeliads. Steep gradient.

SITE 4: Altitude: 2350m. History: Forest cut years ago, and planted with European varieties of grass. Description: Grassland and scrub on a gentle incline grazed by cattle and wild pigs.

SITE 5: Altitude: 2300m. History: Untouched for the past 20 years Description: Secondary forest covered with epiphytes and interspersed with small areas of *suro*.

SITE 6: Altitude: 2350m. History: Secondary forest cut a few months ago. Description: Newly felled trees left littering the ground to decay before seeding the grass. Rotting trunks covered in new creeper species.

SITE 7: Altitude: 2400m. History : Cut 8 years ago and seeded with European grass. Description: Grassland with standing dead tree ferns.

SITE 8: Altitude: 2650m. History: Untouched in the last 20 years. Description: Secondary forest positioned along the top of the ridge interspersed with a great deal of *suro* grass.

SITE 9: Altitude: 2650m. History: Unknown. Description: Ancient secondary forest, possibly even primary forest, positioned at the top of the ridge. Epiphytes, ferns, and mosses present in a very damp, cloud-enshrouded environment.

SITE 10: Altitude: 2300m. History: Cut within the last 10 years. Description: Regenerating scrub, many *Eupatorium* bushes.

SITE 11 Altitude: 2350m. History: Unknown. Description: Regenerating secondary forest interspersed with patches of *suro* grass on a steep incline.

SITE 12: Altitude: 2450m. History: Unknown. Description: Mature secondary forest with primary standards on a steep incline which decreases towards the top of the ridge.

SITE 13: Altitude: 2200-2300m. History: Unknown. Description: Steep grass-covered mountainside with a few shrubs.

Proposed sampling methods

- Pitfall traps and drift fences (Gibbons & Semlitsch 1981). Drift fences made from 20 to 40m of plastic sheeting with pitfall traps every 2 metres was the proposed main method of catching most types of amphibians. Drainage holes punched in the bottom of the buckets used as traps prevent drowning those specimens already caught.

- Torching (Read 1986). Using a Petzl headtorch the animals can often be located by illuminating their eyes in the torch beam. The most effective times for torching are for the first couple of hours after dark or after evening rain. This can also be performed using a more powerful Halogen lamp.

- Listening technique (Read 1986). This involves listening to the call of the male, usually at dawn or dusk, and circling in on it until the animal is located and caught.

- Actively searching microhabitats (Read 1986). Rocks are turned on hillsides, usually of less than 45 degrees. Thinner, flatter rocks are generally preferred over thicker ones. Flipped rocks should always be returned to their original condition. Leaf litter may be sifted, tree bore holes and bromeliads searched, and cavities in bamboo and tree buttresses may provide shelter in the daytime for nocturnal amphibians. Tropical forests are extremely difficult to work by day and a 'search image' of the prey must be formed in the mind, which takes some practice.

- Hollow bamboo traps (Mark O'Shea - personal communication). This technique is not well known, but is being used in the Caribbean to study frog populations. It involves bundles of hollow bamboo strips being left in vegetation to provide shelter for tree frogs to move in and use.

- Baiting (Myers 1956) This method may seem quite ridiculous, but Myers (1956) describes catching small lizards on the forest floor by baiting; an insect tied to a thin line on the end of a pole may be held in front of likely looking places amongst leaf litter and debris. It was thought that this method may be practicable for amphibians also.

Realised sampling methods

Of the proposed methods the most productive proved to be torching combined with the listening technique and the searching of microhabitats during the day. Drift fences with pitfall traps proved to be impractical as in some places the soil was too shallow and in others the vegetation cover was too dense to set up effective drift fences. Hollow bamboo traps were constructed from *suro* grass, but no frogs moved in for shelter and the method was abandoned for more fruitful ones. The baiting method used previously for small lizards was also unsuccessful, as perhaps expected. In addition to the methods already mentioned, dip-netting for tadpoles was performed with no success, as was "Halogen Lamping"; this involves lighting up a section of stream with a powerful halogen lamp to reveal the amphibians active at night. There were three additional methods suggested in the literature (Simmons, 1989), but not attempted due to practical difficulties, ethical reasons, and inexperience in handling. These were as follows:

- Pistol - a .22 pistol with a long barrel (6 to 12 inches) loaded with dust shot (Schmidt 1951) is useful for collecting fast moving specimens, perhaps; reptiles more than amphibians.
- Slingshot/bean shooter/rubber band - are suggested alternatives to a pistol. Rubber bands are easy to carry and may stun small to medium specimens (Simmons 1989)
- Chemical pistol - specimens may be dislodged from walls and trees using a water pistol containing formaldehyde rather than just water.

Specimen preservation

Preservation of the species was carried out following the guidelines outlined in "Herpetological Collecting and Collections management" (Simmons, 1989).There are three stages to the preservation of a specimen; killing, hardening and preserving. Simmons advises the use of chlorotone to kill the frog. However, this proved impossible due to its expense. It was therefore necessary to use chloroform as a cheaper alternative. Only a small drop of chloroform was needed in each case, which was placed on a piece of damp tissue in the bottom of a small container, and the frog was placed in the container.

Once dead, the frog was hardened in 10% buffered formaldehyde. A tissue was dampened with 10% formaldehyde and the frog placed on the tissue with arms and legs positioned by the side of the body (as far as was possible). A lid was put on the tray, and the specimens left overnight. Rubber gloves were used for all handling of formaldehyde.

The frogs were labelled using cotton and a tag, tied to the leg, and kept in a container of formaldehyde for the remaining time in the field. On the return to Cuenca they were washed in water and then transferred to small containers of 70% alcohol. They were labelled with the following information; altitude, Río Paute expedition, site number and frog number, so that the identified species could be linked to the descriptions, photographs, and drawings of each frog.

Collection management

No amphibian species' keys were available for the altitude and habitat worked in. It was therefore necessary for each species found to be formally identified by Dr. Anita Almendariz from the Politechnica Nacional de Quito. For this purpose, two specimens of each species were collected as far as was possible. One specimen collection was given to Dr Almendariz at the Politechnica Nacional for identification purposes; the other following the Ministy of Agricultures regulation's was given to the Universidad del Azuay, in Cuenca.

In addition to the collections made, each frog was photographed, drawn and described in detail. These details were then passed on to Dr.Almendariz for identification along with the preserved specimen collection. In the cases where more than two frogs of a particular species were caught, they were photographed, drawn and described and then returned to their respective habitats.

Data analysis techniques

Relative frog densities. In order to analyse the data collected on the numbers of frog species found in the various different sites, it was necessary to convert the absolute numbers of frogs per site into the relative density per site. The absolute numbers could not be used for three reasons:-

- Sites were not of a standard size and therefore the overall size of the area searched in each site varied.
- The overall searching time in each site varied.
- The numbers of people searching in each site varied.

In order to equate the data from the different sites it was therefore necessary to find a method of calculating the relative density of frog species. We had no facilities for measuring the areas searched. In any case, this would not have been a satisfactory method of calculating density because it is impossible to comb entire areas for frogs, due to the volume of live and dead vegetation involved.

Instead, we used searching time as a basis for calculating density, on the assumption that the area we searched depended on the time we searched. Searching time includes not only the number of hours during which the site was searched, but also the number of people who searched the site during that time. We thus calculated "man hours" for each site: the total number of hours searched amongst all the people who searched.

MAN HOURS = NO. HOURS SITE SEARCHED X NO. PEOPLE SEARCHING

The number of frogs found per man hour in a site thus gives us a measure of the relative density in that site; that is, the number of frogs you would expect to find if one person searched for one hour in that site. This can be calculated as shown below:

RELATIVE DENSITY = TOTAL NUMBER OF FROGS FOUND / MAN HOURS SPENT SEARCHING.

This can be calculated for both individual species and total numbers of amphibians in the area, or for different groups of frogs. This method was used throughout the analysis of the effect of deforestation on frogs.

The major limitation of this method is that it is based on the assumption that all species of frogs are as easy to find as each other. This is obviously a broad assumption and cannot be taken to be always true. Some species may be more easy to catch than others, or more easy to find; for example, if one species tends to burrow further into leaf litter than another (they might prefer a damper environment), then they would be more difficult to find than a shallow burrowing species.

In addition, it assumes that the ease of finding an amphibian does not vary according to weather conditions. Amphibians tend to burrow themselves further into the leaf litter and soil as the air becomes colder and drier. As both humidity and temperature are variable in the cloud forest, it is likely that in some cases the relative densities of certain areas may have been affected by this factor. As the project only took place over a matter of two months, however, it is hoped that the weather conditions would not have affected our results unduly. Ideally, details of the temperature changes over the time period would have been noted, as was intended. However we were unable to carry this out as both thermometers broke in half due to the jolting of the horses during the trek into the forest! This somewhat foiled us.

Frog distribution. Once the amphibian densities had been calculated using the method described above, graphs were drawn to show the distribution of frogs across the various different sites. They showed that higher numbers and diversities of frogs exist in the older sites of vegetation (that is, secondary and ancient secondary forest), and that correspondingly, very few frogs habited the newly disturbed areas. A statistical test was carried out in order to prove this fact.

Firstly, the nine sites were ranked using the length of time since the last total felling of that site (see table 2.2), as established from talking to the local people (that is, length of time since last full disturbance by man).

Areas which have a high ranked number for the "length of time since last total felling" have had longer to regenerate and therefore will be more densely forested. (For example, site 9 had the longest period of time since last felled, and it is, correspondingly, the most dense forest that was worked in).

These ranked figures therefore provided a quantifiable method of establishing the extent of forestation and deforestation of each site: Sites which had been recently felled (eg. site 6) had a low density of forestation; sites which had not been disturbed for 20 years (sites 1,2 & 9), on the other hand, were more densely forested.

The ranked figure for "length of time since last total felling" provided a variable, describing the extent of forestation, to use in the statistical test; the other variable being the relative density of amphibians. The statistical test chosen was Spearman's Rank Correlation, due the fact that the data involved was ordinal rather than interval. Ordinal data implies that the numbers are ranked rather than absolute, which was the case with the numbers quantifying the 'length of time since last total felling'. The results of this test proved that the relative density of amphibians in an area is correlated to the length of time since last total felling of the area (and therefore to the extent of forestation), at the 0.01 level, or by 1% significance.

Table 2.2 *Table ranking time since the deforestation of each study site*

Description of site	Site no.	Ranked no. showing relative length of time since last total felling
recently felled	6	1
grassland	7	2
scrubland	4	3
suro	3	4
suro, some 2° forest	8	5
secondary forest	5	6
inc. secondary forest	1	7
age secondary forest	2	8
secondary forest	9	9

Results

Seventeen species of amphibians were found in all; sixteen frogs and one *Atelopus* toad. Of these, the majority (9) were of the genus *Eleutherodactylus*. This was not surprising as *Eleutherodactylus* is known to be the dominant group of South American frogs, (Noble, 1931). We found *Eleutherodactylus* mainly amongst the depths of damp rotting leaf mulch on the forest floor, where they are known to burrow in order to avoid drying out. In dry periods they may burrow very deep; this could explain why we found fewer frogs in the last week of the expedition, when the weather was drier.

The reason for *Eleutherodactylus*' success in the neotropics is thought to be due to their method of reproduction, which skips over the aquatic larval stage. *Eleutherodactylus* lay yolk-rich eggs in damp burrows, where the entire tadpole stage takes place inside eggs, from which small froglets squirm. Pools of water are therefore not necessary. This is especially advantageous in high mountains such as the Andes, where the steep slopes give rise to fast-running streams and therefore few suitable breeding pools exist. The distribution of frog species is thus markedly limited by their breeding site preference.

The majority of the frogs found were extremely small, (the largest being 34mm, and the smallest 6mm), and mostly of a dark brown colour, often without any distinctive markings, which made the job of identifying them all the more difficult. However, with the help of Dr. Ana Almendariz, we did manage to identify all our specimens to the genus. Some were unidentifiable to the species, in which case we have used numbers to distinguish between different *Eleutherodactylus* species.

An additional complication in identifying specimens was the presence of sexual dimorphism . For example, the male and female specimens of *Eleutherodactylus spinosus* looked entirely different; the female being much larger and the male possessing epidermal spines. The formation of pigmented spines is a secondary sexual characteristic of a number of male frogs of the genera *Eleutherodactylus* and *Phrynobatrachus.*

A detailed description of each species of frog is thus provided below; in each case the size, colour, and markings were described, including the site and altitude of where it was found. The sizes quoted indicate the range we found, not an ultimate guide to the species' size. Fig. 2.11. gives a list of the species found.

Atelopus nepiozomus

Colostethus pumilius

Eleutherodactylus bromeliaceus

Eleutherodactylus cryophilus

Eleutherodactylus proserpens

Eleutherodactylus peruvianus

Eleutherodactylus riveti

Eleutherodactylus spinosus

Eleutherodactylus sp. 1

Eleutherodactylus sp. 2

Eleutherodactylus sp. 3

Eleutherodactylus sp. 4

Eleutherodactylus sp. 5

Eleutherodactylus sp. 6

Gastrotheca sp.

Nelsonphryne aequatoriales

Phrynosus sp.

Fig. 2.11 *List of Species Present*

Species descriptions

Atelopus nepiozomus

SITE NO. : Found away from usual camp; not in any site, in grassland surrounded by secondary forest. Found dead.

ALTITUDE: Approx. 2450m.

DESCRIPTION: Dorsally a bright lime green with a knobbly texture all over the surface (see Fig. 2.12). Limbs the same colour and texture. Hindlimb digits webbed; digits on forelimb not webbed, but short and stumpy. Underside of body a bright red, with white spots under the chin. Underside of limbs green, with white spots under `hands' and `feet'.

SIZE: SV 43mm, HW 11mm

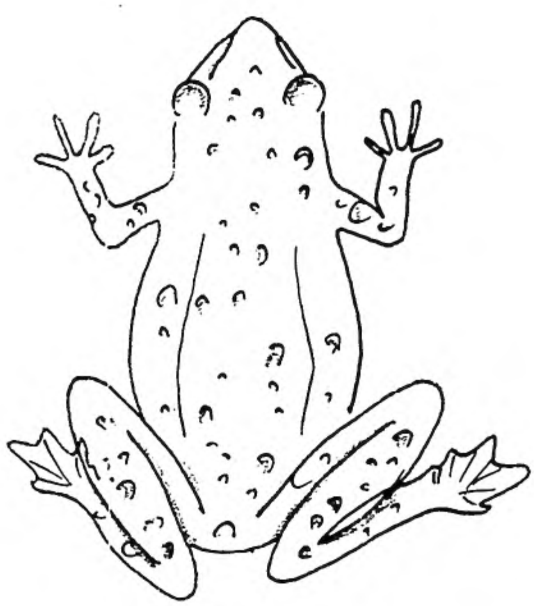
NO. FOUND: 1

Colostethus pumilius

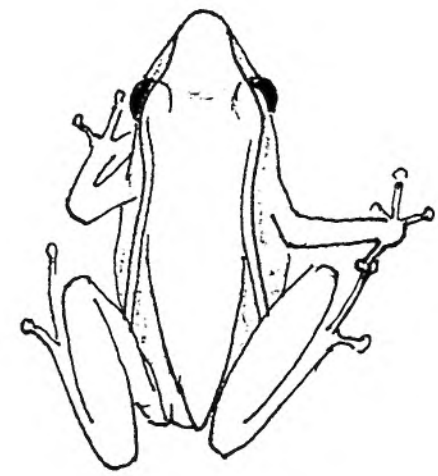
SITE NO.: 9, under and on top of leaf litter

ALTITUDE: 2650m

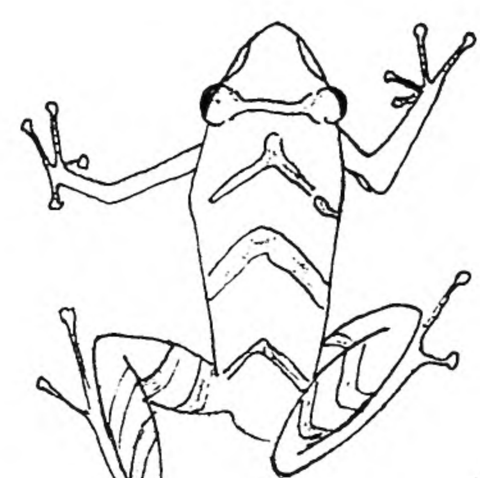
DESCRIPTION: (See Fig. 2.12). Dorsally a yellow-green colour with two thin white stripes bordered in gold running down either side of the back. One narrow dark brown stripe running down the middle of the back. A gold-orange stripe running



Atelopus nepizomus



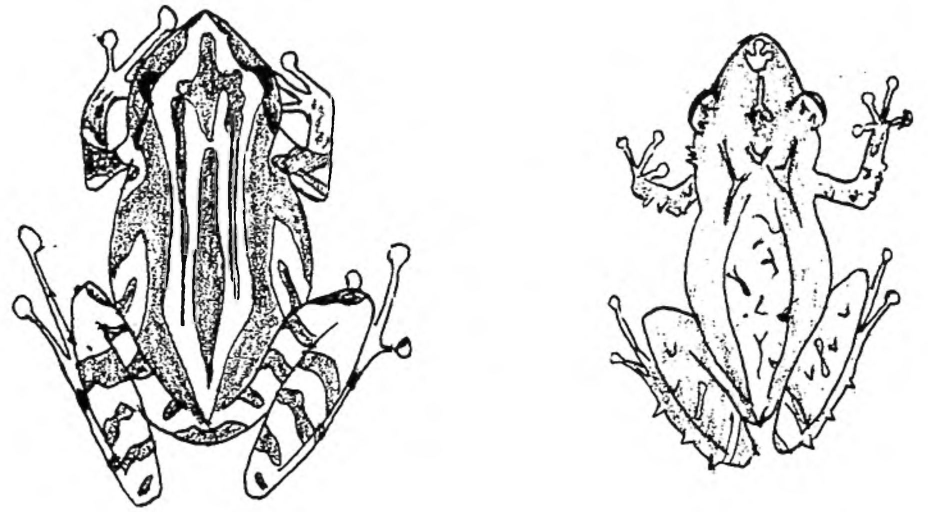
Colostethus pumilus



Eleutherodactylus peruvianus

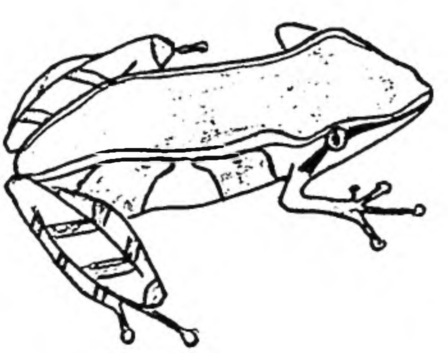
Fig 2.12a *Drawings of frogs*

Female Male



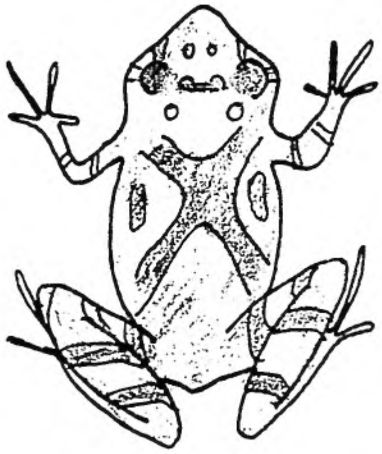
Elutherodactylus spinosus

Eleutherodactylus sp.2

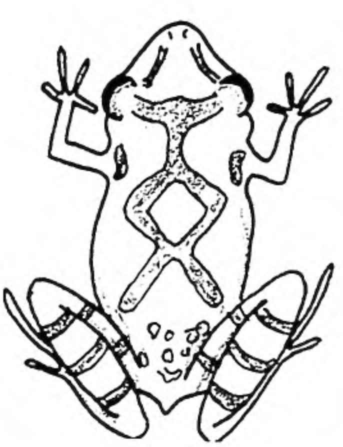


Eleutherodactylus sp.3

Fig 2.12b *Drawings of frogs*



Nelsonophyre aequatoriales



Prynosus sp.

Fig 2.12c Drawings of frogs

the eyes and in the middle of the back. Digits spatulate. Limbs yellow-green. Underside bright yellow, sometimes orange, with white spots.

SIZE: SV 21-23mm, HW 9-10mm.

NO. FOUND: 2

Eleutherodactylus bromeliaceus

SITE NO.: 12, Under leaf litter.

ALTITUDE: 2350m

DESCRIPTION: Dorsally a very dark brown with an indistinct chevron marking across its back, and a black bar between its eyes. Limbs lighter brown with black speckles. Digits spatulate. Ventral side a yellow green colour, of a granular texture, with small white spots and distinct red flashes under the thighs. Eyes orange with black pupils.

SIZE: SV 12mm HW 4mm

NUMBER FOUND: 1

Eleutherodactylus cryophilus

SITE NO.: 7, on top of grass in a bog by a stream. Found dead.

ALTITUDE: 2400m

DESCRIPTION: This frog was found dead, and our description is therefore not representative of the species. A more representative description is provided by the Rio Mazan Project, as follows: Dorsal colour uniform brown with some irregularly placed white spots. Underside granular and reddish.

SIZE: SV 24mm, HW 12mm

NO. FOUND: 1

Eleutherodactylus peruvianus

SITE NO. : 1 2 4 5 9,11,12

ALTITUDE: 2350m-2650m

DESCRIPTION: (See Fig. 2.12, showing range of variation) This species was by far the most common species found in the area. Wide variations were found in the colours of the individuals: the dorsal colour ranging from a bright rusty orange to a very dark brown. However, the markings, though not always distinct, were very characteristic, so that the frogs were relatively easily identified. The main characteristic markings of this species were the two dark rust/dark brown/black chevrons depicted on its dorsal side. These were always of a darker colour than the general dorsal colour, but tended to be of a similar shade. As mentioned before, some frogs had less distinct markings than others. Black/dark brown bar running between the eyes. Black stripe down the side of the nose, and also running from the eye to the arm. Hind limbs generally the same, or of a similar colour to that of the dorsal side. Often striped in a darker colour, though not always obvious. Forelimbs similar in colour to that of the dorsal side, sometimes striped with a darker colour. Digits striped and spatulate. Underside: Red or rusty-orange flashes under the thighs; sometimes also under the 'armpits'. (On some specimens these were not very clear; on others they were not visible at all). Ventral ground colour varied from being orange-yellow, through to grey-brown. However, all had a granular texture on the underside, usually with white spots, sometimes also with brown spots. Occasionally a blue-green patch under the groin.

with white spots, sometimes also with brown spots. Occasionally a blue-green patch under the groin.

SIZE: SV 7-20mm, HW 3-8mm.

NO. FOUND: 39

Eleutherodactylus proserpens

SITE NO.: 6, at the base of a bromeliad.

ALTITUDE: 2350m

DESCRIPTION: Dorsally brown with light brown-cream patches on either side, behind the fore limbs. Skin a bumpy texture, covered with indistinct spikes. Legs and arms brown with cream patches on the ankles. Eyes large, nose pointed, complicated pattern on the nose and face (see fig 2.12). Digits spatulate and striped in red. Ventrally smooth grey with a cream colouration directly under the stomach. Orange patch under the tip of the nose, blue-grey patch under the groin.

SIZE: SV 14mm, HV 5mm

NUMBER FOUND: 1

Eleutherodactylus riveti

This frog was identified using the Río Mazan keys. (Read, 1988). SITE: 10. Found 15cm above ground on recently felled vegetation in secondary scrub (*Eupatorium* plant).

ALTITUDE: 2300m.

DESCRIPTION: Dorsally dark brown with darker brown blotches and speckles. Underside granular, cream colour. Red flashes under thighs and forelimbs. Black bar stretching between the eyes.

CALL: 1 click followed by a slightly rising peep like a hiccup. Heard calling from 6-8. 30pm.

SIZE: SV 26mm

NO. FOUND: 1

Eleutherodactylus spinosus

SITE NO.: 8 & 9, on the top of leaf litter; *suro* and mixed.

ALTITUDE: 2650m

DESCRIPTION (MALE): (See Fig. 2.12) Dorsally very dark brown, with a cream patch extending from behind the head. Skin texture uneven, spines present. Cream patches on ankles and thighs. White lumpy patch on nose,(though this is possibly not characteristic of the species). Ventrally dark grey-green, mottled with black markings. Red flashes under the thighs.

SIZE: SV 17mm HW 6mm

NO. FOUND: 1

DESCRIPTION (FEMALE): Dorsally dark brown with a series of light and dark brown stripes extending from nose to rump (see fig. 2.12). Legs lighter brown with dark brown stripes. Digits spatulate. Ventrally orange-yellow mottled with black. Underside of legs and arms pink-red mottled with black.

SIZE: SV 21-34mm HW 9-14mm

NO. FOUND: 5

Eleutherodactylus sp. 1

SITE NO.: 8, in the base of a fallen bromeliad.

ALTITUDE: 2650m

DESCRIPTION: Dorsal yellow-orange colour. Limbs the same colour with indistinct red-orange flashes on joints. Underside yellow with a few brown-grey spots under the thighs and chin. Internal organs show clearly through the transparent yellow skin of stomach.

SIZE: SV 19mm, HW 6mm.

NO. FOUND: 1

Eleutherodactylus sp. 2

SITE NO.: 2a, 13, 7, all found in the bases of bromeliads.

ALTITUDE: 2200-2400m

DESCRIPTION: (See Fig. 2.12) Dorsally dark brown with distinct light cream or orange lateral flanks. Legs light brown with dark brown speckles and dark brown patches on `knees' and `ankles'. Forelimbs dark brown. Digits spatulate with dark brown stripes. Underside a dark brown-red. Underside of limbs yellow, sometimes light brown, with dark spots. A variation in this species was found in one of the frogs which was dark brown all over and had no cream lateral flanks, and whose underside was also dark brown.

SIZE: SV 9-12mm, HW 3-4mm

NO. FOUND: 3

Eleutherodactylus sp. 3

SITE NO.: 2,4&5. On top of, and burrowed under, a variety of types of leaf litter.

ALTITUDE: 2300-2400m.

DESCRIPTION: (See Fig. 2.12) Dorsally dark brown with two thin paired stripes which follow on down the nose and meet at the tip. The colour of these stripes ranged from a creamy-brown to red and orange. Black stripe on the side of the nose. Laterally a lighter brown with a dark brown ring. Sometimes a red colouration under the thighs. Limbs brown with dark brown stripes. Digits spatulate and striped in a dark brown. Underside varies but generally grey with white spots. Underside of abdomen sometimes had a red or yellowish tinge with white spots. Underside of limbs sometimes yellow with black spots.

SIZE: SV 9. 5mm-15mm, HW 3. 5mm-6mm.

NO. FOUND: 9

Eleutherodactylus sp. 4

SITE NO. : 1, 5, 9, 11. Found on top of and under leaf litter, in the soil at the base of a tree, and in a mossy hole.

ALTITUDE: 2350m-2650m

DESCRIPTION: Dorsally light creamy-brown with dark brown flanks. Black stripe from eye to foreleg, and down the side of the nose. Arms light brown. Legs brown, mottled or sometimes striped with a darker brown, Cream patch on `ankles'. Digits spatulate and striped. Underside of body dark green- brown, sometimes grey with white spots. Faint red colouration under the forelegs, sometimes also under the thighs.

SIZE:SV 9. 5-15mm, HW 4-6mm.

NO. FOUND: 6

Eleutherodactylus sp. 5

SITE NO.: 1, 2a, 2b, under leaf litter and in bromeliads.

ALTITUDE: 2350-2400m

DESCRIPTION: Dorsally dark red-brown with lighter red-brown lateral flanks. A distinct line divides the dark dorsal colour from the light lateral colour. Head an orange-brown colour. A distinct line between the eyes splits the head colour from the dorsal colour. Legs red-brown or green-brown striped with a dark brown. Forelegs dark brown with cream ankles and elbows. Underside of the head and forelimbs brown. Underside of the body and legs varies from light orange-brown to yellow-brown.

SIZE: SV 11-12mm, HW 4mm

NO. FOUND: 3

Eleutherodactylus sp. 6

SITE NO.: 2, underneath damp moss.

ALTITUDE: 2400m.

DESCRIPTION: Dorsally a camel colour (yellow-cream). with dark brown lateral flanks extending up to the underside of the nose. A distinct dark brown bar between the eyes and a short dark brown bar running lengthways down the back. Black stripe along the side of the nose. Black stripe running from the eye to the forelimbs with a cream stripe below. Legs brown with dark brown stripes. Forelimbs a camel colour from the shoulder to the elbow; dark brown from the elbow to the digits. Digits spatulate and striped. Underside dark grey with white spots.

SIZE: SV 9-10mm, HW 3. 5mm

NO. FOUND: 2

Gastrotheca sp. (The knocking frog)

This frog was identified using the Rio Mazan identification keys (Read. 1988).

SITE NO. :10, found 15cm above ground on vegetation at the top of a steep bank.

ALTITUDE: 2300m.

DESCRIPTION: Dorsally light brown with 2 dark brown stripes running down either side of the back. Underside a creamy-yellow colour. granular. Underside of hind legs transparent looking.

CALL: 1 or 2 Intermittent knocks or clicks. like the sound of a wooden xylophone.

SIZE: SV 25mm

NO. FOUND: 1

Nelsonophryne aequatoriales

SITE NO. : 2, on top of leaf litter.

ALTITUDE: 2400m.

DESCRIPTION: (See Fig. 2.12) Dorsally a brown-grey, with a dark brown cross outlined in light grey. Black bar between the eyes. Black stripes from eye to snout, and eye to chin. Legs and arms a grey-brown with darker brown-grey stripes. Digits not spatulate. Underside of head grey and smooth. with a few white spots. Underside of limbs and body yellow and smooth. Groin and top of thighs red, with colour extending up the flanks.

SIZE: SV 25mm, HW 10mm.

NO. FOUND: 1

Phrynosus sp.

SITE NO. :2b, under leaf litter.

ALTITUDE: 2400m

DESCRIPTION: (See Fig. 2.12) Dorsally a dark brown with a black bar between the eyes leading into a dark brown diamond marking. Mottled dark brown markings on pointed rump. Legs dark brown with distinct black stripes. Forelimbs light brown, striped from the elbow to the hand. Digits striped and long, not spatulate. Underside dark grey with white spots. Red tinge on abdomen.

SIZE: SV 11mm, HW 4mm.

NO. FOUND: 1

Effect of deforestation

In this section, results are taken from campsite 2, as those from campsite 1 are inaccurate and could be misleading due to the following reasons:-

- The time spent at Campsite 1 provided a training period for members of the amphibian team to familiarise themselves with the male calls and form a search image of their prey.
- During this time of team inexperience, the rate at which frogs were found was slower than that in campsite 2; frog densities were therefore lower, rendering any direct comparison between the two invalid. The man hours worked needed to be of a consistent quality in order to standardise the data. However, the results from campsite 1 were recorded in the species account, as these results were still relevant to the species census.

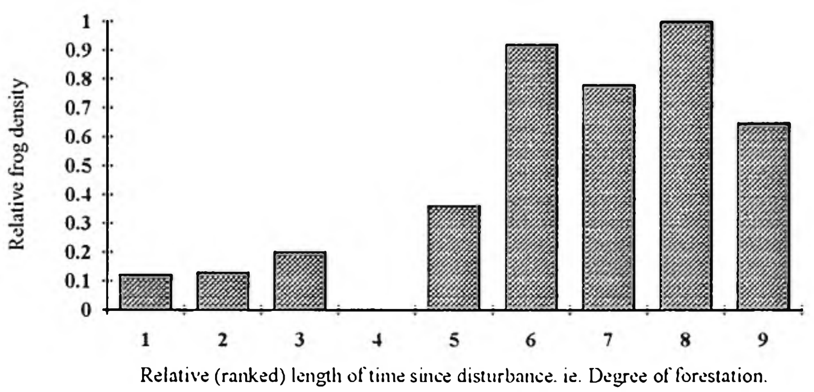


Fig. 2.13 *Relative densities of total numbers of frogs found (all species) against degree of forestation of each site*

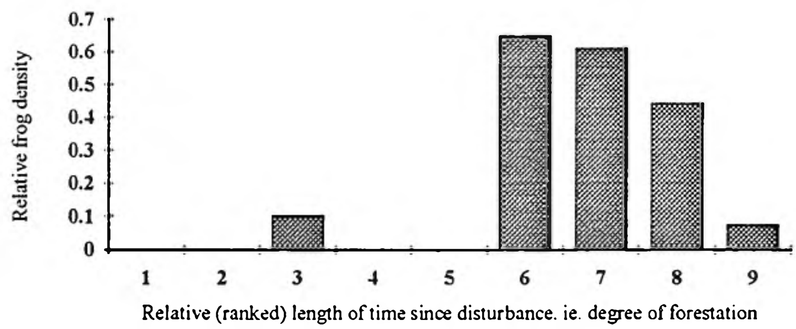


Fig 2.14 *Relative density of Eleutherodactylus peruvianus against degree of forestation in each site*

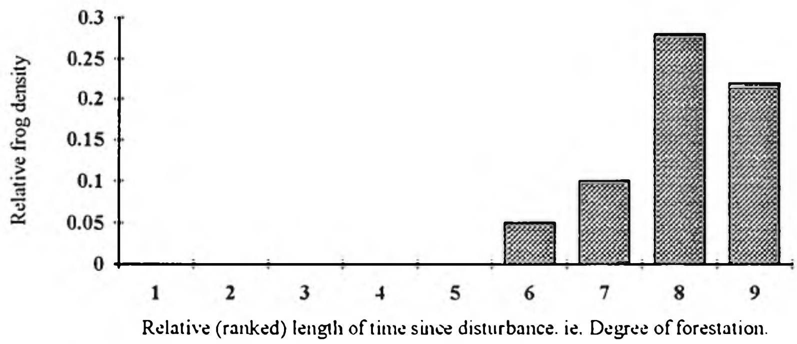


Fig 2.15 *Relative density of Eleutherodactylus sp.3 against degree of forestation in each site*

Looking initially at the results, a significant pattern emerged. Areas of secondary and ancient secondary forest contained a high density of frogs, whereas the recently felled areas and the grassland habitats supported far fewer individuals. (Significant at the 0. 01 level of significance: (See Fig. 2.13) This pattern is obvious in both the graphs showing distribution of all amphibians found (Fig. 2.13),and in the two graphs detailing the distribution of the single species, *Eleutherodactylus peruvianus* and *Eleutherodactylus sp. 3.* (Fig 2.14 & 2.15) It is clear, therefore, that deforestation has a marked effect on the future of the amphibians in this area. This will be further discussed below.

The distributions of more than two single species have not been drawn up due to the low numbers of frogs involved. So few frogs were found in each of the other species, (maximum five specimens), that the data was not scientifically sufficient to merit the drawing of individual graphs. However, the pattern of distribution emerges clearly from the graph incorporating all the species. (Fig. 2.13). The results of the distribution of the single species, *Eleutherodactylus peruvianus* and *Eleutherodactylus sp. 3,* (Figs. 2.14 & 2.15), show that even though sites 1, 2,5,8 and 9 provide the most suitable habitats for the amphibians, there are preferences within species. For example, *Eleutherodactylus peruvianus* is found most abundantly in the secondary forest of site 5, whereas *Eleutherodactylus sp. 3* is found most abundantly in the secondary forest of site 2, further up the mountainside. Still different species were found near the top of the ridge in ancient secondary forest, at altitude 2650m. Altitude may therefore account for some of the differences in distribution between species. Looking at the history of the area, it can be seen that the five most favourable sites (that is, sites 1,2,5,8 and 9), have not been touched by man since he moved into the valley about 15 years previous to the survey. Sites 4 and 7 were both cut 8 years ago and fewer frogs were found to be living in these habitats. Site 6 contained an even lower density of amphibians, and was cut only a few months before the survey. These results are presented in table 2.2 and provide solid evidence for the detrimental effect of man and his habitat destruction on the amphibian populations of the area.

Discussion

From this study of amphibian populations, several conclusions may be drawn, which have significant conservation potential. The results show conclusively that the interference of man has a negative effect on the amphibians in this area.

The 1989 World Congress of Herpetology stated that amphibian populations worldwide are in decline, including those of the Andean cloud forest. Our project looks specifically at decline due to habitat fragmentation and deforestation, and, from our results, it is clear that this is occurring in the Andean cloud forest. However, over the rest of the world it has been noticed that frogs are declining within their natural habitat, and therefore their decline, in this case, cannot be blamed on deforestation. Two possible reasons for decline are offered below.

Decline due to habitat fragmentation and deforestation

The results of our survey, showing the distribution of amphibians across the various habitat types, show clearly that amphibians live preferably in habitats that have not been touched recently, if at all, by man. For example, only one frog was found in the newly felled area (Site 6): *Eleutherodactylus proserpens*. Only two frogs were found in the grassland area (Site 7), one of which was found dead (*E. cryophilus*). These small numbers can be compared to the relatively large numbers of frogs found in the secondary forest areas. For example, in site 5, 25 frogs were found in all. Other secondary forest sites' total figures were similar to this.

It is clear, therefore, that frogs seldom live in felled or grass-seeded areas. There are a variety of reasons for this, which will be discussed below.

First, the deforested habitat provides little shelter for frogs. There is little or no leaf litter, into which frogs burrow to keep themselves moist, and into which Eleutherodactylus spp. lay their eggs. In the forest, on the other hand, leaf litter is often several inches thick and provides ample cover, while the bases of trees, often covered with mosses and lichens, provide many damp, mossy holes in which amphibians thrive. In the felled areas, these niches do not exist, as they are almost devoid of trees. Without trees, there are no epiphytes, such as the bromeliads, in which many species of frogs live, and of course, tree frogs have no home.

The lack of leaf litter affects the retention of moisture within the habitat. Without moss, and dead rotting vegetable matter on the ground, most water soaks directly through the soil, upsetting the entire water cycle. This gives rise to waterlogging in some areas, and excessive dryness in others (As found in site 7, grassland), both of which have an adverse effect on the amphibians, who need the damp mosses and leaf litter in order to prevent themselves from drying out. In the well-balanced forest, however, the layers of dead leaves retain the moisture, which is all too vital for the survival of the amphibians.

Deforestation also has adverse effects on the insect populations within the felled area. Within the cloud forest, food sources for the amphibians are rich; insects, on which the amphibians feed, thrive in the dense and dark secondary forested regions. However, the open expanse of grassland is not a suitable habitat for the majority of insects, so that amphibians food sources in these areas are low, and therefore these regions cannot sustain large numbers of amphibians.

Other reasons for decline

Many factors other than habitat destruction have been suggested to explain amphibian decline. These have already been discussed in the Introduction, but explanations that could be viable in the Río Púlpito area are summarised below:

- Loss of the ozone layer.
- Increase in acidic conditions.
- Habitat contamination by the introduction of game fish such as trout, which upset food chains and deprive frogs of sustenance.
- Chemical poisoning of the atmosphere following the burning of lowland tropical forests.

Amphibians are particularly vulnerable to change in environmental conditions, due to their moist and thin permeable skins. It is through these that they exchange ions with their surroundings and respire. Any slight changes in the environment caused by the above explanations may therefore push the amphibians to their physiological limits. Models of changing climatic conditions predict that there will be greater warming as one moves away from the equator, and that continental interiors will become drier, and droughts become more frequent and intense (Wetherald, 1990). With these changes, plants and animals living at the extremes of their physiological capabilities will decline. This has been observed as some populations are declining in pristine areas for unknown reasons. However, several suggestions have been put forward and it is hoped that the answer lies in the ordinary cycle of nature, and not in the changing atmosphere (J.A. Pounds, 1990), although evidence seems to point to the latter.

From our data it is impossible to state whether decline due to these factors (i.e. reasons other than deforestation) is taking place. However, our results may now be used as baseline information for further monitoring of species' populations, in order to determine whether this type of decline is taking place, as it is in several other areas world-wide. By using the same methods to establish relative densities, as used in this project, future results may be compared to the present ones in order to detect a drop or rise in the total numbers of amphibians.

It is important to monitor amphibian populations because a decline or extinction of a species does have adverse effects on the entire ecosystem. Amphibians give a significant contribution to insect control; therefore, with their absence from the food chain, insect numbers could rise out of all proportion, with drastic effects. Amphibians may carry a potential medicine chest on their backs; they secrete chemical weapons from glands in their skin which may ward off predators, or protect against infection. Medicines are still being discovered, and some species may become extinct before they and their possible medicinal properties are discovered. For example, in 1992, scientists discovered a Ecuadorian frog which secretes a painkiller about 200 times as potent as morphine. (New Scientist, 1992, 30th May).

Most importantly, amphibians are so susceptible to the environment, that any change will affect their populations; they therefore act as biomonitors for environmental change. It is important to study the change in amphibian populations as results from these studies give an idea of how other, less susceptible, organisms could be affected in the future, if man's interference with the environment continues.

Project limitations

Inaccessibility of the forest canopy. A major limitation was the problem of access into the canopy of the forest from where many tree frogs could be heard to call. Without expertise in climbing and without the necessary equipment it was not possible or sensible to venture into the treetops or actively search the bromeliads located higher than 2 metres above ground. However these frogs active in the treetops tend not move down to the forest floor during the daytime or during dry periods where they burrow into the depths of moist leaf mulch. This is where our specimens were most successfully captured.

Absence of amphibian identification keys. As there were no keys available, specimens had to be collected, preserved and taken back to Quito for identification. Some species did not preserve well and others lost their pigmentation or changed colour during the preservation process. This resulted in some difficulties in identification at the Quito end.

The work of the Río Mazan project provided us with a key which proved useful for the identification of some frogs found at campsite 1, but at campsite 2 we found a different amphibian community structure. Though all frogs were identified to genus, in some cases difficulty was found in identifying to the species level. Therefore some specimens are only labelled under the genus and given a species number.

Aspect and soil. Limitations on the planned use of pitfall traps as a means of capturing amphibians arose due to the soil on the steep mountain slopes being too shallow to sink the bucket traps into. In addition to this the vegetation cover proved too dense in places to set up successful drift fences. However, once on site, other methods of capture were found to be sufficiently effective.

Time restriction. As with this type of research, the longer the period over which data is collected, the more valid are the results. Six weeks of field work gave time enough to search all habitat types thoroughly and many different species were found. However, even into week 6, new species continued to emerge albeit at a slower rate. Therefore if the time period could have been extended it is possible that a few extra may have been added to our list.

Altitude. As the sites were situated at lower altitudes than was initially intended, results could not be compared to previous work carried out by the Río Mazan Project

(Read 1986). Therefore, rather than making comparisons with previous work, our data may act as a baseline for further monitoring in the same, or similar, areas.

Climate. The colder the air temperature and the lower the relative humidity, the harder it was to locate the frogs; amphibians tend to burrow further into leaf litter and soil in times of climatic stress (cold and dry). This in turn affected relative density.

Suggestions for future work

The results presented here may be taken as a baseline for further monitoring of amphibians in the same environment. A repeat of the work a few years later may establish whether decline due to reasons other than deforestation is occurring in the Río Púlpito valley. Amphibians are particularly vulnerable to environmental change and declines have been observed in many parts of the world. The exact reasons for these declines may only be estimated at present; whether it is due to direct or indirect effects of deforestation, or different reasons entirely is not yet known. In the event of repeating the work it is useful to have at least one member of the team with some experience of amphibian identification - this avoids laborious and time consuming preservation of collections and subsequent identification using poor specimens.

It was not possible to relate air temperature to number of frogs found. Future work should record air temperatures; this additional information could then be used to iron out anomalies in data which are due to weather conditions. We were unable to do this due to the problems that were encountered with our thermometers.

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Mark O'Shea, Tropical Herpetologist.
Dr. W.E. Duellman, University of Kansas.

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2.6 Botanical study of cloud forest in the Río Púlpito Valley

Paula Cordera

Carol Mahon

Introduction

After clearance of forest by man, whether it be cut and burnt, or cut and neglected, pioneer species will establish themselves and an ecological succession take place until a stable forest environment of climax vegetation is reached. If, however, grass is seeded at an early stage and is subsequently grazed by cattle, any natural succession through regeneration will be prevented. By studying an area using quadrats, plant diversity and vegetation density may be determined, both of which may indicate the quality of the environment.

Botanical specimens present may determine the stage of succession of an area and hence an idea of the length of time since last disturbance by man. Early successional stages are not as "stable" in terms of ecology, nor do they have as diverse a wildlife.

The initial aims of this project were therefore as following:

- To take various sized quadrats from a range of vegetative habitats, from totally deforested areas to secondary cloud forest, in order to give an idea of the differences in plant species diversity and densities between deforested and forested habitats. Differences between the various vegetative types; including those of secondary forest, recently cut forest, burnt forest, rejuvenating forest, shrub areas and grassland can therefore be quantified by comparing results from quadrats taken in different areas. This was to help give a picture of the types of species inhabiting the different vegetative areas.
- The quadrat data was also planned to give an idea of the point of succession of the different areas and thus an idea of the length of time since last disturbance by man for vegetative area.

Methodology

Site description

The botanical project combined with the amphibian project in the choosing and the dividing of sites into workable areas. Thus, the descriptions can be found in both the botanical and the amphibian project.

Nine sites were decided upon. Each site was characterised by a different dominant vegetation type.

SITE 1: Secondary forest with quite a lot of open canopy. Low tree density.

SITE 2: Denser secondary forest - denser cover of canopy. Dank and dark.

SITE 3: An island of *Chusquea* bamboo (*suro*), surrounded by secondary forest. *Suro* found both in flower and not.

SITE 4: Small scrub bushes surrounded by grassland, grazed by cattle and pigs.

SITE 5: Steep dense secondary forest leading down to the Río Púlpito.

SITE 6: Recently cut secondary forest left to rot, but not yet burnt. Much rotting vegetation and dead trunks covered in new creeper species.

SITE 7: Grassland - European species of grass with some tree ferns still upstanding, both dead and living.

SITE 8: Area of *suro* and some secondary forest bordering site 9.

SITE 9: Area of possible primary forest, or at least ancient secondary. A small pocket of ancient forest found on the ridge of the valley, surrounded by secondary forest

Quadrats

Four quadrats were taken in each site: 1 x 1m, 2 x 2m, 3 x 3m and 10 x 10m. The quadrats was first measured out using nylon string and a measuring tape. A diagonal was then made across the quadrat with the string. Vegetation along this diagonal was then assessed as a representative sample of the quadrat.

In the cases of the three smallest quadrat sizes, the following parameters were taken for each plant along the diagonal: family name if known, height, distance from previous plant on the diagonal.

The largest quadrat was intended to give an idea of the abundance of trees in the area. The circumference of the trees was therefore noted, and the height estimated from the ground, standing about 5ft from the tree.

Collections

Specimens were only collected if found in excess of three at one site. They were cut with secateurs, and each sample was preserved in triplicate, pressed in plant presses borrowed from the Universidad del Azuay.

Drying specimens was found to be very difficult despite the use of aluminium corrugates kindly lent to us by Kew Gardens; as a result a number of specimens rotted in the presses.

Fungi were dried in a home-made rack and stored in envelopes or vials when dried. However, some took too long to dry and disintegrated before storage was possible.

Discussion

This project relied mainly on the identification of specimens for its aims to be fully carried out. Unfortunately, problems were encountered in this area despite the use of corrugates, as the air was so damp that it was found that the drying of specimens was not always successful. As a result, very few specimens could be formally identified by Kew Gardens, so few that it seems unimportant to mention them here.

Despite the problems, however, it was possible to come to some conclusions. These are discussed below:

Description of the secondary cloud forest (sites 1,2,5,8 & 9)

Trees were spaced at approximately 0.5-1.5 metres from each other. Fully grown trees were estimated at a height of approximately 6-20 metres. Many younger trees were at a height more of 2-3 metres. The canopy was predominantly closed with the branches of many species being intertwined.

Bromeliads and other epiphytes were found growing prolifically on most tree species, but were not collected due to the height of trees and the possible rarity of the specimens. Very few of the epiphyte species were in flower during the study period which leaves identification up to the experts.

Leafy shrubs and very young trees cover the forest floor, along with an abundance of mosses and lichens growing on dead and decaying wood. Many plants found growing on the forest floor were also found growing on trees along with solely epiphyitic species.

Below the leafy shrubs on the forest floor, a thick detritus layer of rotting organic matter was present. Fungal fruiting bodies were found in the shaded detritus, and in any spaces left by plants. Detritus was also caught in the forks of tree branches and ground plants could be found growing in these caches.

The overall impression was that of incredible dampness, both in and on vegetation, as well as in the air, and that no surface is left uncovered. It was impossible actually to see the trunk of any tree due to the abundance of moss, lichens, epiphytes and other plants covering it.

The problems encountered with specimen collection and preservation meant that the original aims of this project were largely impossible to carry out fully. It should noted that it is inadvisable to rely on the identification of specimens for an entire project; we did not realise this at the time of planning. It is possible to carry out botanical studies in cloud forest but detailed preparation is needed to ensure that the field conditions can be worked under.

However, all was not lost; though few actual species names are known, other conclusions could be made from the work done, relating to the sequence of events surrounding deforestation and its regeneration.

The sites chosen represent various seres (ecological stages) of deforestation and regeneration of this area of cloud forest. The pattern of events lead from the original clearance of the forest, to the development of grassland:

First the trees are felled, - 3 to 4 people could cut down one hectare per week. According to the locals, the rule that applies concerning ownership of land, is that whoever clears unclaimed land is then the owner. The more land the people have, the more cattle they can put to graze on it.

Once the trees are felled, the site is left for some time without removing any felled material in order to let it rot down. However, shrubs tended to regenerate quickly (site 6), sometimes causing problems for the clearers. The usual sequence of events following this, however, was burn the rotting wood then to seed the area with grass, so that the grass would grow up through the charred trunk and ashes. The burnt material rots away providing nutrients for the grass to grow.

The charred land develops into medium quality grassland which can be grazed by cattle. The grassland does not seem to improve in quality over time, due to waterlogging of the soil and subsequent acceleration of slope process caused by the removal of the forest.

The exact age of the forest being cleared was hard to establish. The local people were sure that it was mature secondary forest. This seems likely given that classifying forest in which people have existed for thousands of years as primary/virgin is naive.

Conclusion

Broadly based botanical studies, if they are to be successful are logistically and scientifically testing. They tend to be more labour intensive than other areas of work, collecting large numbers of specimens and statistically valid data. While zoological projects tend to focus on a particular ("sexy") taxon there is a tendency for botanical projects to be more generalistic and are used to provide a grounding for the zoological projects. Underspecialization tends to lead to a diffuse set of results which cannot really be turned to best use. Having said this, studying the botany of the Púlpito valley gave a vital perspective for the understanding of the valley. If the botany had not been attempted it is unlikely that the forest would have been as well observed and the dialogues with the locals on forest use would not have been entered into.

3.1 Introduction

The intention of the logistical report is to reveal the inner workings, the nuts and bolts, of the Río Paute Headwaters Expedition. We hope the information is useful and will at least enable others not to make the same mistakes as we did.

The success or failure of an expedition depends not only on the validity of the scientific methodology but also on the public image of the expedition as well as the health and happiness of the team members. While health is relatively easy (especially with a good medical officer), public image and happiness take a lot of work, a lot of preparation. This is largely the responsibility of the expedition leader, thus the following section is in general my personal opinion, except where otherwise noted.

Money is discussed below in dollars. When we were in Ecuador the rates of exchange were $1.60 to £1 with s/.1100 to $1. It changes fast and dollars are the hardest currency.

For general information on how to survive in Ecuador the Lonely Planet Guidebook proved invaluable. We followed it, and life in the cities was notably easy and enjoyable.

Toby Maitland

3.2 The team

Charlotte Cameron-Beaumont. Fund Raiser. Zoology Graduate. Bristol University (1992). Worked on frog ecology. Now studying feral cat behaviour, for a PhD at Southampton University.

Paula Cordera. Biology Graduate, Universidad del Azuay (1993). Worked on the botanical survey.

Richard Duckworth. Translated and generally helped during the recconaisancee trip. Spanish/French Graduate (1993).

Simon Hay. Scientific Leader. Zoology Graduate. Bristol University (1992). Worked on the aquatic macro invertebrate ecology. Expedition photographer. Now studying tsetse fly distribution using satellite imagery, for a D.Phil at Oxford University.

Rebecca Knight. Medical Officer. Biology Graduate. Bristol University (1992). Worked on frog ecology. Now at Sheffield University, studying for an MA in Landscape Design.

Toby Maitland. Expedition Leader. Zoology Graduate. Bristol University (1992). Worked on the trout-catfish interaction. Now working in whale and dolphin conservation and moving into sustainable development.

Carol Mahon. Treasurer. Biology Graduate. Bristol University (1992). Worked on the botanical survey. Now working in Luxembourg as a recruitment consultant.

Aida Ortiz. Biology Graduate. Universidad del Azuay (1993). Worked on frog ecology.

Jonathan Roberts. Equipment officer. Geography Graduate. Bristol University (1992). Worked on fog interception. Now an Executive Officer for OFWAT. the water industry's regulatory body.

Eduardo Toral. Biology Graduate. Universidad del Azuay (1993). Worked on frog ecology.

Veronica Toral. Ecuadorian Team Leader. Biology Graduate. Universidad del Azuay (1992). Worked on the aquatic macro-invertebrate ecology.

Edwin Zarate. Biology Graduate. Universidad del Azuay (1993). Worked on the trout-catfish interaction.

3.3 From dream to prospectus

The expedition began in the autumn of 1989 with Nigel Winser's famous expedition talk given for the Expedition Society of Bristol University. After this inspiration it was simply a matter of deciding where to go, what to do and who to do it with.

It took a year of enthusiastic research, reading and attendance at weekly Expedition Society meetings for the ideas to come together. Thoughts of tropical forests, mountains, clouds, condors, Inca civilisation, fish and deforestation developed and around these dreamy ideas, a team began to coalesce. Unlike many expeditions, the team remained the same from the inception of the expedition to its conclusion and from an early stage it was realised that the full team would include host country nationals.

In July 1990, Simon received a seminal reply to a letter he had written to Dr. Paul Turcotte of the Universidad del Azuay in Cuenca, Ecuador. Simon had written regarding a particularly interesting paper he had read on the aquatic ecology of the Cajas National Park and the possibility of working there. Dr. Turcotte was enthusiastic for us to work in the region, offering logistical support and the use of the newly built Biology Department, of which he was Director. Suddenly we had a contact, a rough destination and an even rougher aim; aquatic ecology for conservation in the cloud forests of the Andes, which at that stage we knew next to nothing about.

In the summer vacation we visited the RGS to refine our newly found direction and left with maps, reports and addresses. The addresses were followed up and we soon came into contact with the Río Mazan Project, based in Norwich who had been working for a number of years in cloud forest near Cuenca. During that summer the University of Bristol, Isla de la Plata Expedition was working off the coast of Ecuador. On their return they gave us very useful advice and contacts. They also gave us the feeling that if they could do it, so could we.

With the onset of Autumn, planning began in earnest. Weekly expedition meetings (round a good sized pub table) provided the backbone for the nine month critical path. We now had a rough aim; cloud forest conservation from an aquatic ecological/hydrological angle and set the timing for a 10-12 week field period beginning the 1st of July, 1991. To give us money to work with, we put our student loans (£400 x 6 = £2400) into the kitty and decided to do the best work we could. With the groundwork set, the web of contacts could be built, the scientific proposals researched and the logistics planned.

The RGS "Planning a Small Expedition" seminar was a catalytic point where we met an expedition from the University of East Anglia with the same destination and the same motivation. After initial worries about competition for funding, we realised what could be achieved if we worked co-operatively. So we did.

As the prospectus was written, scrapped and re-written, (about 5 times) the aim and supporting objectives of the expedition began to solidify and prioritise themselves. As well as detailing the scientific methodology of the expedition we also wanted the prospectus to be well presented, readable and stylish. It may be unscientific to say this, but a good idea needs good marketing to be successful. To ensure success, as much advice and criticism as possible was solicited. We approached academics with specialist knowledge in our proposed scientific fields of work, to make sure there were no glaring inaccuracies. We also approached the people who administer the funds that would make the project possible. To have their criticism and advice and to be able to put it into practice before the funding selection procedures were gone through, ensured that our concept was realistic, achievable and most importantly, a worthwhile investment. No money, no science.

While writing the prospectus we applied for and received permission to run the expedition with the official support of the University of Bristol. Also at this time Professor John Thornes very kindly agreed to be our British patron. Having Professor Thornes' patronage and the University name behind us from an early stage, gave us confidence in our ideas.

By Christmas 1990 we had a finished proposal. The three months the prospectus took to write was a testing period, both for the expedition concept and team cohesiveness. The scientific and logistic flexibility built into the prospectus and reliance on the reconnaissance trip to shore up any weak areas, carried us successfully through the fund-raising, the recce and the field period.

3.4 Education Project

It was planned to work with five Bristol Primary schools, producing a fun education pack about the cloud forest and the dangers it faces. The education pack was discussed and initially developed with the Education Department at Bristol Zoo, the Río Mazan Project and teachers from two local schools. The idea was to form a geographical case study for the National Curriculum for 8-9 year olds.

While a lot of work was put into the education pack and two schools were visited with very fulfilling results, in the final analysis there just was not enough time available to do this project full justice. We had intended to bring the children into our experience, allow them to learn about an alien environment from people who had actually been there and perhaps most importantly, plant the seeds of environmentalism in their minds, as if there were not a good few "green" saplings already growing! It was a great disappointment that this project did not work.

To be successful an education project perhaps needs at least one team member dedicated to its co-ordination and management. Both the University of Bristol Henri Pittier Expedition and Savannah Wildlife Project carried out successful education projects. The reason for their success was simply a greater amount of time, enthusiasm and resource being put into the projects, the Savannah Wildlife project having three dedicated education officers. Education projects are definitely worthwhile but should not be tacked on to scientific projects for light relief.

3.5 Fund-raising

I was branded Fund Raising Officer from the beginning, and calmly informed that my target sum was £11,000. Needless to say, I was momentarily taken aback. However, I can say now with hindsight that this seemingly impossible task was possible with some hard work and a bit of determination - not only from the fund-raiser herself, but also from the rest of the team.

My greatest source of initial inspiration was the RGS Expedition Planners Handbook. This gives a long list of ways and means of extracting funds from willing donors, as well as all the essential addresses of trust funds and grant-giving societies. A look at this is essential for all prospective fund-raisers.

Team member contributions

Though not literally fund raising, these are necessary as all trust funds make a point of questioning exactly how much each team member is contributing. Don't expect to get away with a free trip. We put in £400 each, making a total of £2400. It is also a good starter for the expedition bank account.

Commercial sponsorship

It has to be said that this was our single most useless method of producing funds. Between us we wrote to, and subsequently telephoned the managers of what must have been literally hundreds of large companies, all to no avail. It proved to be too much hard work for a non-existent end reward. However, if you are feeling lucky and/or stupid, and, additionally, are convinced that the present economic climate is about to pick up in a big way then go for it! Here are a few tips to help you on your way:

- Telephone before writing to establish the name of the person to whom you should be addressing your letters. Mail addressed to Sir/Madam or Manager is likely to get lost in the secretary's in tray pile.
- Follow up the letter with a second phone call direct to the one in charge of your application. Personal phone calls tend to be remembered; inconspicuous monochromatic letters are filed and forgotten, or, worse, thinly chewed by an over-enthusiastic shredder.
- Why should they give you money? Offer them a reason..... Their name in the media when your expedition is covered, their name on all expedition outputs - from T-shirts to your final report.

Finally, remember that contacts within companies can prove useful; Carol's father managed to extract for us over £300; likewise Simon's girlfriend's father!

Selling T-shirts

This, our most innovative of methods, proved highly successful after a few initial hitches. We learnt by our mistakes and made a final profit in the region of £600.

- Blank T-shirts can be bought cheaply from warehouses and cash and carries. Printers do sell their own but these tend to be more expensive than your average warehouse bulk order.

- Unwanted thermal vests tended surreptitiously to find their way into the bags of T-shirts we were buying.

Trust Funds and Societies

The majority of our money came from this source. These hinge on a well-presented and informative set of proposals and application form. Work put in at the science and logistics end of things reaps rewards like an over-active combine harvester.........And makes the fund raiser's job distinctly more relaxing.

Private sponsors

Good publicity tends to lead towards individual donations. We did not achieve a large amount by this method but every little helps. Contact your local newspapers and radio stations. Jon did an interview for BBC Radio Bristol, which was amusing if nothing else.

Charlotte Cameron-Beaumont

3.6 Reconnaissance

Reconnaissance is worth every penny, even if it is necessary to talk the treasurer into spending all the funds so far raised. To run a short field project without a recce risks wasting any number of people's hard work and support.

To overcome the linguistic barrier, Mick Duckworth, an undergraduate linguist who had previously travelled in Ecuador, became involved. A translator/personal assistant may seem an extravagance, but it worked. Mick spoke the language, knew the country, was very helpful and enthusiastic. Without him, the recce would have been an unproductive nightmare in an alien environment with only a phrase book for a friend.

Before leaving for Ecuador I met up with Nancy Hilgert de Benavides, the Executive Director of CECIA (ICBP Ecuador) Gary Allport (the ICBP/FFPS BP Conservation Competition organiser in 1991) and the UEA team at the ICBP headquarters in Cambridge. Nancy gave valuable pre-recce advice, support and of course addresses. Meeting with the UEA team enabled me to find out what I could do for them while in Ecuador.

Right in the middle of Easter week, Mick Duckworth and I arrived in a strictly Catholic country and wondered why everyone was on holiday. We had 10 days to meet contacts and lay the path for the summer's expedition. We spent three days in Quito where we met with Nancy and also visited the various Universities in search of advice and support. At the Politecnica National we met up with a number of key academic contacts. Dr. Anita Almendaris, a herpetologist, agreed to identify the frogs we collected. Dr. Barrida, the Ecuadorian catfish expert, elightened me about the catfish situation. Dr. Luis Albuja, the Director of the Biology Department gave us their official written support. Written support is a key factor.

In Cuenca we met up with the Ecuadorian team members and Paul Turcotte, who agreed to be our Ecuadorian Patron. Together with Matthew Spencer of Projecto Rio Mazan, we all visited UMACPA (the organisation responsible for the management of the Paute valley) and met with Ing. Giulio Torrachi N. (technical co-ordinator of

UMACPA) and Ing. Zarruma Torres. In that three hour meeting we agreed on the study site, discussed the scientific and conservation potential of the work, tied down the logistics and settled legal and financial matters. Such a meeting, with all the relevant people, with all the necessary resources. three months before the main field period, was on its own worth the £1500 spent on the recce trip.

While in Cuenca we also got the chance to visit the Río Mazan cloud forest reserve, which gave us some feel for cloud forest conditions. In fact this was the most notable flaw of the recce. The Mazan reserve was not the same as the Púlpito valley. The altitude was different. The weather was different. The forest was different. Mazan is a good deal smaller and tamer than BP 15. It can give a false sense of security to have seen a "similar" area, which is quickly dispelled when the actual study site is reached. Always attempt to walk around the actual proposed study site on the recce, taking seasonality etc. into account.

After returning to Quito with the written support of the Universidad del Azuay, The Politechnica National, CECIA and UMACPA we visited the Ministry of Agriculture and Cattle (MAG) and discussed scientific permits with moderate success.

It is impossible to know what you are walking into unless you have been there before yourself. It may be an unromantic approach but if you only have 10 weeks (or even 6 months) in which to settle, get the work done, enjoy yourselves and move out again with due respect to the host country, you want to be prepared. I could go on at length about the endless benefits of recces. Just do it.

3.7 From recce to the airport

On return from Ecuador I found we had easily received enough funding to cover the cost of the recce. The fund-raising under Charlotte's control had been going very well and the bank balance was steadily increasing. It soon became clear that we were going to be able to make it into the field that summer without cutting any corners.

So much had been learned on the recce that virtually every aspect of the planning was altered or redirected. The knowledge, experience and amazing sense of realism gained is hard to pass on to the rest of the team. There was still a lot left to do; before our departure on the 27th of June we had to finalise our arrangements, buy equipment and get through exams.

3.8 In the field

Our time in Ecuador would make good material for an epic novel (which Charlotte is supposedly writing) and it is hard to summarise the complex events that led up to and surrounded the completion of the scientific projects. That is what the rest of the logistical report is for. It is amazing how many crises can arise and be overcome in 10 weeks. I think the only way to understand what went on is to go on an expedition. To put it mildly, there are highs and lows to the experience.

From our arrival in Ecuador it took two weeks of hard work, preparation and eating out at restaurants before we got into the forest. When we got into the forest we realised we were in the wrong area. After an amount of crisis management we relocated to a second study site and completed the scientific research. Perhaps all expeditions exist on the edge of disaster, perhaps it had something to do with our shared determination not to fail but somehow out of chaos, order emerged.

3.9 The Universidad del Azuay

Contacts are all important, and the best contacts an expedition can have are host country team members, who can carry out research and develop the project in a way that would never be possible from thousands of miles away.

Dr. Paul Turcotte, Director of the Biology department of the Universidad del Azuay, agreed to be our patron and five of his students formed the Ecuadorian component of the team. It was attempted to title the expedition officially as joint project between the University of Bristol and Universidad del Azuay, but this was thwarted by lack of time and red tape on both sides of the Atlantic.

Whilst the British side of the expedition funded the project and provided equipment for the Ecuadorian team members, the Universidad del Azuay provided laboratories, transport, local expertise, enthusiasm, help and support. A solid physical and academic base within the host country makes an expedition. From this base we were able to approach academics from other Universities such as Dr. Barrida and Dr. Almendaris.

The successful relationship the expedition had with UMACPA, the eventual arrival of our MAG scientific permits, the 4x4 vehicle leant to us by CREA and the housing provided by INECEL was all down to the work and contacts of the Ecuadorian team members and Dr. Turcotte. More than that, host country team members set the tone of the expedition. They open a country up and let you see inside. Since our return to England, contact has slipped and some of our promises remain unfulfilled.

3.10 Diplomatic clearance

To carry out scientific work in Ecuador requires a permit from the Ministry of Agriculture and Cattle (MAG), based on the Avenida Elroy Alfaro in Quito. To get a permit, it is necessary to include host country nationals in the team and to have the official written support of an "Institute of Higher Research" from Britain and Ecuador. This was easily achieved through the Universidad del Azuay. Not only do host country nationals bring an expedition to life but they are also a legal necessity.

The correct procedure for getting permission involves going through the Embassy in London who are very helpful, and providing them with the details given below. The Embassy should be informed of your intentions early on, as it may take well over 6 months to conclude the exchange of paperwork. The end result is a six month research visa which is necessary if the expedition is more than 90 days in the field, 90 days being the length of the tourist visa. A research visa also means that you pay the same price as an Ecuadorian citizen to visit the Galapagos islands, a tourist has to pay about 500% more.

Although we began dealings with the London Embassy in November 1990 and visited MAG head offices during the recce, it was not until we had been in Ecuador for two weeks, the permits finally materialised. To get the permits, Veronica met us in on our arrival in Quito and we visited MAG, as soon as my head had stopped spinning from the journey. We took copies of all the paperwork we had so far submitted to them and the letters of support the expedition had received from English and Ecuadorian Institutions. We found out exactly what it was they wanted and that day Veronica rewrote the application in perfect Spanish. Then, with considerable assistance from Dr. Turcotte and Ing. Torracchi Nazzi of UMACPA (who had already given us permission to work on their land), the permits arrived.

If the application is written and signed by both the British and Ecuadorian expedition leaders, not only will the language be correct but it will also be a far more credible document. The protocol suggested below should not be followed without first, talking with the Ecuadorian Embassy and finding out if it is still correct and second, finding out exactly how it applies to a specific expedition. It can be interpreted in many ways and could so easily have changed.

Permit Protocol as understood in 1991

Write, in fluent Spanish, a letter to:

Dr. Sergio Figueroa
Subsecretaria Forestal y de Recursos Naturales Renovables Division de Areas Naturel y Recursos Silvestres
Ministerio de Agricultura y Ganaderia
Quito

The Embassy in London should deal with the correspondence in which the following should be included:

- The objectives of the expedition (avoid jargon).
- CVs of all expedition personnel.
- Passport numbers of foreign personnel.
- A pledge to:
  A. Give replicate collections of all specimens taken to the Museo Ecuatoriano de Ciencias Natural and the Ecuadorian Instituition under whose auspices the expedition is working (see final point).
  B. Support an equal number of Ecuadorian nationals while in the field.
  C. Send copies, in Spanish, of the finished report to MAG, the Museo and the supporting Ecuadorian Institution, giving full recognition to the work of all Ecuadorian nationals involved in the project.
- A letter from a British "Institute of higher research" vouching for the team members and supporting the project.
- A letter from an Ecuadorian "Institute of higher research" sponsoring the work.

3.11 A plea for diplomacy

The pledge that has to be made to receive permits from MAG to be able to work in Ecuador, while perfectly fair, is hard for undergraduate expeditions to keep in the way that they want it kept. I discovered whilst talking to academics and bureaucrats that a degree of ill will exists toward many past British undergraduate expeditions. Perhaps this has occurred as Ecuador receives a disproportionate number of projects due to its it political stability. The feeling was not too serious but it was there. It was said that plant and animal collections had not been made to usable standards, and that they had not been treated with the respect they deserve. It is inevitable that inexperienced undergraduates make some mistakes and fail to fulfil some promises. I know we tried our best but still we made mistakes. It is not just a case of running an expedition that "just about works" and "gets the data". Serious thought is needed as to the impact the expedition has, not just on the biological environment of the study site but also and perhaps more importantly on the culture it enters. It is often said and often forgotten.

The perfect solution is not to make any mistakes but that requires a lot of experience, and that is what expeditions are designed to provide. In the meantime, while the experience is being gained, find out which other British expeditions are working in Ecuador the same year you plan to visit. Get together with them all as early as possible and discuss who in Ecuador you plan to work with. There are not many Universities and conservation organisations out there and they are all very busy. Share contacts and present them with a well co-ordinated co-op of individual British expeditions. It will make your lives and theirs a lot easier and a lot happier if you do this.

3.12 Travel

England - Quito, Ecuador

Avianca (The Airline of Columbia), was at around £500, the cheapest way to get to Ecuador and they allow a 60kg luggage allowance per person, if requested.

Quito - Cuenca

By bus or plane, north to south, along the valley of the volcanoes. The bus takes around 11 hours and costs around $5. The Plane costs around $20 and takes an hour and a half. Both journeys are worth taking, the bus shows the state of the land and the bases of the volcanoes. From the plane the tops of the volcanoes can be seen above the clouds (and they give free drinks).

Cuenca - Paute Dam

There is a bus travelling this journey which was used when other transport could not be organised. It cost around $4 and took 6 hours. The preferred method was to be driven in the Universidad del Azuay and CREA (Cuenca's parks department) 4x4's. At one stage it was necessary to complete this journey by taxi, which cost $22.

Paute dam - Study site

First the dam has to be crossed and this was achieved either by log raft or a hand operated cable car-like device (metal cage running on a steel hawser stretched across the dam). The raft could only used when the wind had blown the impenetrable water hyacinth, which covered the dam surface, to the other end. Luckily for us, both major crossings were accomplished on the rafts. It is possible to cross the 400 metre cable with a small, home made pulley, a bit of wood and some rope (string). This method was tried and I was told only afterwards that previously someone had fallen off and died in the exciting process. There is a tax of $20 payable to the head of the valley community for the use of the crossing. It is worthwhile finding out exactly who this is before waving money about.

Horses and guides took our equipment along muddy forest paths and across pasture, from the dam to the first study site, with the team walking some distance behind. Horses cost around $5 a day and guides the same, although the price depended how the situation was handled and how desperate or rich we were looking. Horse prices did suffer a degree of inflation as the locals realised we were reliant on them.

On first entering the forest, due to a small breakdown in communication, we did not actually know where we were going and the guide took us to where he wanted to go. Travel in the forest requires a knowledge of the area, a map or the ability to speak good Spanish. To start with we had none of these things.

3.13 Equipment

It is not the intention here to set out a complete list of all the equipment required to undertake a cloud forest expedition. Much of it is common to virtually any expedition and the scientific equipment is very specific. For general equipment there are adequate lists available elsewhere. There are however a few key points specific to this expedition which will be concentrated on, in the hope that they make life a little easier for any one choosing to follow in our footsteps.

What to buy in the UK

The biggest problem lay in deciding which equipment to buy in the UK and take out with us and which to buy in Ecuador. The obvious worries were over availability and quality. Contact with our Ecuadorian Counterparts was invaluable but we were left with a few tricky decisions. In the end, anything which was critical in terms of quality (tents, sleeping bags, waterproofs and almost all the scientific equipment) was obtained in the UK. This included five additional sets of rucksacks, sleeping bags, karrimats and waterproofs for the Ecuadorians, on the basis that the whole team ought to be equipped to the same standard.

The decision turned out to be correct, in so far as decent quality basic camping equipment and clothing are simply not available in Ecuador. One critical mistake was our choice of footwear. The only way to avoid permanently wet feet and/or blisters is to wear good quality wellies. These cannot be purchased in Ecuador. Go for something with a good height in the leg - the mud can get quite deep. Don't be fooled into thinking that Gore-tex boots and gaiters will be more comfortable and just as waterproof - they're not.

Tents need to be thought about seriously, they are your home while in the forest. We took five, 3-man Caravan ridge tents to accommodate 11 people. Caravan supplied these to us below cost price (around £120 each). The tents were shared with UEA expedition who were in the field from October. The tents performed well, though it is worthwhile pre-treating the fabric and seams to improve the waterproofing. In Ecuador we were fortunate in being able to borrow (and just about transport) a large family tent from the Universidad del Azuay, as well as finding the second site ready equipped with a sturdy little hut built from tree fern trunks and corrugated aluminium. This we adopted as the cooking hut and built tables to work on. Without these additional spaces life would have been fairly miserable. Some sort of sheltered area where everyone can gather out of the rain is essential for a prolonged visit to the cloud forest. A large tarpaulin, properly supported, might be adequate. [Note: a three man tent should not be expected to take more than 2 people. particularly when there are permanently wet clothes to be dealt with.]

A good 3-season sleeping bag treated with Nikwax TX-10. will keep you warm and dry at night. We used 8 "Rainbow Warriors" from Taunton Leisure which were at the time under £35. Karrimats make life more comfortable. While mosquito nets were not necessary on the valley side. the profusion of midges by the river has to seen to be believed.

The importance of good quality clothing should not be forgotten. Altitude, dampness and prolonged lack of sunshine can make the cloud forest decidedly chilly. Money spent on polyester fleece. thermal base layers (Polartec. Synchilla. Ultrafleece. Lifa etc.) polycotton clothing (Rohan, Mountain Equipment. etc.) plus a warm hat and gloves is a worthwhile investment and is just about all you need. It is possible and cheaper to live in "normal" clothes but if you spend a lot of time in the open and are unable to dry out, you will get cold, damp and start to rot and once you start its hard to stop (until the next sunny day). Socks are particularly liable to decay unless they are synthetic.

The value of Gore-tex in a humid environment is debatable. While it probably performs slightly better than impermeable fabrics, it is expensive. doesn't like mud and soon starts to smell. Less expensive breathable fabrics (Cyclone) seemed to work just as well and a good comfortable waterproof jacket with sizeable pockets was well worth it. Wax jackets were not a good idea, they quickly get sodden and heavy, needing constant reproofing which isn't easy without a hairdryer or at least a clean cloth. Perhaps the best value waterproofing method is a military poncho combined with good high wellies.

Petzl Zoom head torches are a godsend. The big flat batteries (mm1203's) are unavailable and the adapters (3xAA batteries) waste a lot of charge. Either take flat cells out with you (probably worth it) or get a Petzl Mega which uses three of the larger c cells which are available. Take spare bulbs too.

Watches. Every team member should have a wrist watch. This may sound obvious but some people do not wear watches. In the UK this may work. but when people need to be organised and co-ordinated in a foreign country a degree of synchronisation is useful.

What to buy in Ecuador

When it comes to buying hardware (cooking equipment, tools, polythene sheeting and various bits of plastic which you know will come in useful somehow), Cuenca cannot be bettered. There is a shop just off Gran Columbia devoted solely to selling plastic sheeting. which can be bought by the metre in your choice of colour and gauge. No doubt the rest of Ecuador is not much different. A brief list then of vital equipment that can be easily obtained in Cuenca.

- Heavy gauge polyethene. Sufficient quantity to go under all the tents in a double layer, to prevent rising damp. It is very useful stuff and costs around $1 per metre.

- Rope. Vital. The locals never seem to have enough to tie loads onto horses. River crossings are likely and a bit of rope could save your life. Take at least 100 metres, its cheap and for some odd reason is sold by the pound weight.
- Plastic flour sacks. To put equipment into before loading up on the horses. Generally useful around the camp.
- Cooker. We obtained a large double ring gas stove, which ran off an enormous cylinder. Cooking 3 hot meals a day for 11 people requires a substantial quantity of heat, and hence some fairly substantial equipment. Pots, pans and eating utensils were also easily obtained, as were plastic washing up bowls, water carriers etc.
- Lamps. Good quality Coleman petrol lamps. The correct fuel (i.e. unleaded petrol) was a bit more difficult to come by, and we relied entirely on the guile of our Ecuadorian colleagues for this. Spare mantles are essential.
- Spades, mallets, machetes (don't forget a sharpening stone) etc. were widely available, but take one spare of everything - spade handles (a spade being very necessary to dig long, deep toilet trenches) have an alarming propensity to break.

Finally, a reminder that the little things should not be forgotten: Toilet roll (vital for morale), water containers, Plastic bags (various sizes, for keeping just about everything dry). String, thousands of metres of several different types. Glue (araldite is very useful) and sticky tape. Cutting implements (saws and machetes) are essential and fun.

Never under estimate the usefulness of simple tools and materials for constructing things around the camp and customising scientific equipment. It is possible to run an expedition on the minimum of lightweight equipment but if transport can be arranged and the environment allows, the better equipped and more organised the camp is, the happier people are. It is suprising how much time there is in the field to sit around and potentially do nothing (tropical forest becomes mundane disturbingly fast). If there are tools and materials about, home improvement, arts and crafts can become quite an obsession. Also, the better organised a camp is, the less impact it has on the environment.

On completion of the field work the expedition camping equipment (stove, rucksacks, sleeping bags, waterproofs) and scientific equipment (surber sampler, net, dissection equipment and field guides) was left with the Universidad del Azuay for future field work. One tent had been mauled by a soap eating pig, the remaining 4, were used by the UEA expedition After both project had finished in the field the tents were split between the Universidad Del Azuay and Projecto Rio Mazan, who UEA were collaborating with.

That which was not practical to carry back to Cuenca or would be of use to the locals (used plastic sheeting, rice sacks, string, machetes, rope, water containers, even used peanut butter jars) was distributed on the last field day. They had put up with our presence for 7 weeks and everything that we gave them was gratefully accepted and then argued over. They really do not have very much.

Jon Roberts

3.14 Food

Food was without a doubt, the most contentious issue of the expedition and some of the most bizarre lines of logic and morality I have ever heard came out as each individual fought for their "rights". That having been said, we had three cooked meals a day of a varied and balanced nature. Some pride was taken by the chefs of the day to create a gastronomic masterpiece, although some took more pride in their work than others. Cooking was organised on a rota with two people cooking and tending the camp each day.

Breakfast at 7.00 (8.30 on Sundays) initially consisted of porridge, until this was thankfully superseded by Granola (oats fried in margarine with sugar, raisins, quinoa etc.), although this did result in a breakaway porridge faction. Large amounts of coffee and hot chocolate seemed necessary before work began.

Lunch was the main meal. Carbohydrates were supplied by rice, pasta, potatoes, bread, salad and fruit. Tinned tuna, sardines, mackerel and eggs soon became all too familiar, although attempts were made to disguise this with white sauce, curry, bolognese, chilli and other more mysterious variants. In fact, there were a number of good cooks (and a number of appalling cooks) and Paula actually knew what to do with all the local food. Trout, caught in the name of science, provided good fresh meat. We also had "Carve" a textured soya protein and lentils, which made a change and kept the vegetarian happier. The evening meal was packet soup with increasingly inventive accessories.

The food was bought by the sack load from Cuenca, where there was no lack of variety, Ecuadorian supermarkets being just as good as English ones. A small settlement on the other side of the dam provided emergency supplies and there was a definite lack of variety there. With various people moving backwards and forwards to Cuenca we had a reasonably regular supply of fresh fruit, vegetables (including tree tomatoes), rum and tobacco (unsupplied smokers become dangerous people). Local milk and cheese was eventually trusted and Ecuadorian chocolate is very good if you like it dark. Kilos of the stuff were bought and in the evenings it was avidly consumed, hoarded and fought over, along with mugs of rum. Honey and peanut butter also became valuable currency.

We spent an average of $1.40 per person per day, although it would be possible on less.

3.15 Medicine

The medical officer may hold a key position in an expedition relating to both the health and morale of the members. The medical officer has a basic knowledge of first aid and is responsible for obtaining and distributing the contents of the medical kit. Knowledge of the usage, dosage and side effects of medicines carried on the expedition was vital; a useful source of information is the British National Formulary which is published twice a year. This information was also written down and kept with the medical kit at all times.

Possible medical hazards in the particular environment visited were attended to and the Tropical Medicine Unit in Oxford was contacted concerning this. Advice on vaccinations was also given. The rabies vaccine was recommended and attention was brought to Bartonellosis, a disease spread by the sandfly, which is endemic in some of the high Andean valleys. In such damp conditions feet should be looked after and kept as dry as possible. Cuts and blisters require regular checking and dressing.

Pre-field preparation

Contact with Dr Butler of the Student Health Centre was made - regular meetings were invaluable, as was attendance at a First Aid Course held by the British Red Cross. Previous immunisations were checked and updated if necessary. Requirements and recommendations for additional vaccinations for Ecuador were attended to; these were recognised in three groups:

- Required by international regulations: Yellow Fever vaccination - an international certificate is required.
- Recommended for the protection of health: Polio, Typhoid and HepatitisA. Rabies was recommended by the Unit of Tropical Medicine, Oxford.
- Advice from the World Health Organisation: Cholera.

The WHO actually advised the discontinuation of the Cholera vaccine although some countries still require a valid cholera vaccination certificate. Although the vaccine is not entirely effective we received it as an extra precaution against the recent Cholera epidemic which had spread north from Peru.

Anti-malarial drugs (Paludrine and Nivaquine) were prescribed in good time to allow for the course to start one week before departure, despite the fact that the majority of our time was spent at altitudes too high for mosquitoes.

Long-term illnesses and allergies to any medicines carried amongst expedition members were noted. Requirements of permission for the importation of any of the drugs carried was checked and each member underwent a dental check-up prior to departure.

The medical kit

Three waterproof boxes contained the base camp kit and small field kits for day outings were taken from this base kit. We were fortunate to have a medical centre five hours walk away, just over the lake, in case of emergencies.

The base camp kit consisted of:

Medicines

Paracetamol tablets 500mg
Dihydrocodeine tablets
Potassium permanganate crystals
Iodine antiseptic paint
Sterilised saline solution
Diclofenac 'Voltarol Retard' suppositories
Chlorpheniramine (Piriton) tablets 4mg
Loperamide (Imodium) capsules 2mg
Co-trimoxazole (Septrin) tablets
Amethocaine eye drops
Chloramphenicol eye ointment
Senokot tablets
Erythromycin tablets
Vioform hydrocortisone cream
Athletes foot cream
'Diorylate' tablets
Flagyl tablets 800mg
Anthisan cream
Flea powder

Dressings

Wound dressing 15BPC
Crepe bandage
Triangular bandages
'Melonin'non-adherent dressing 10x10cm
Elastoplast 'airstrip' dressings
Roll of zinc oxide plaster
Injection swabs
Elastic adhesive bandage 7.5x4.5cm
'Steristrip' tapes
Sterile cotton wool balls
Gauze swabs
"Tubigrip" size C
1m Cotton conforming bandage 7.5cm

Equipment

Scissors
Safety pins
Paper clip
Thermometer, centigrade
Cotton wool tipped sticks
Syringes 5ml & 10ml
Needles 21G and 23G
Drip needle x2
First aid manual
Instructions for the uses and side effects of the medicines.
Log book to record illnesses.

Problems Encountered

As with most expeditions, we were lucky to avoid any serious incidents during our 10 weeks. Our water was collected straight from a spring source at the first campsite, and from a small stream running through untouched forest at the second, and was clean and fresh. Occasionally the scientific projects would put their researchers in risky situations. For example, Jon was attacked by a defensive female owl after walking too close to a nest early one morning. On another occasion we almost lost Toby, when the device he was attempting to cross the river on collapsed under his weight. He returned to us drenched, but alive, after having been fished out by Edwin, Eduardo and Fabian Toral who discovered him whilst washing. The only major flow of blood I had to deal with again belonged to Toby, who managed to slice his finger with a knife whilst decorating our toilet screen with *Suro* vegetation.

On return to the city the medical kit was donated to a state hospital in Cuenca, the Hospital Regional Vincente.

Supplies Used

The contents of the medical kit were used for various purposes on the expedition as outlined below:

- Dioralyte tablets were dissolved in water and the solution taken after periods of diarrhoea and/or vomiting for rehydration.
- Paracetamol tablets were taken for mild aches and pains.
- A tablet of dihydrocodiene was taken to ease more severe pain on one occasion.
- Erythromycin antibiotic tablets were used to clear up persistent stomach upsets.
- Iodine antiseptic paint was painted onto cuts, grazes and open blisters.
- Elastoplast was used for cuts (mostly from penknives) and blisters.
- Steristrips closed up a deeper penknife wound.
- Micropore tape was useful for cuts and blisters.
- Calcium Carbonate buffer came in useful as an indigestion remedy.

Advice for future expeditions

- Erythromycin proved to be a very useful antibiotic.
- A tube of antiseptic cream, for example 'Savlon', may be a good addition for those who object to their cuts being washed out in potassium permanganate or iodine and alcohol.
- Indigestion tablets would have been a useful addition to our medical kit as one member had to eat the calcium carbonate buffer intended for the formaldehyde fixing solution for specimen collections.
- Hand washing and disinfecting facilities near the toilets are necessary in the maintenance of hygiene.
- Two tablespoons of sugar mixed with one teaspoon of salt and dissolved in one litre of clean water may be used as a cheaper alternative to dioralyte for rehydration purposes.

Rebecca Knight

3.16 Photography

This is a brief section about expedition photography. The first part deals with the photographic aims of the expedition photographer, the second with problems specific to photography in tropical cloud forests, the third, is simply a list of the equipment we took and the last some general points by way of conclusion.

Photographic aims

When you get allocated the joyous task of expedition photographer it is important to consider you aims. Primarily you should try and produce a photographic documentary of the expedition which means your personal photographic preferences have to take second place and you must think how to tell a pictorial story of the expedition's progress. Remember that endless evocative views of forest clad mountains may be personally satisfying but will not help relay the ins and outs of your "expedition experience" to others.

Slide presentations given on your return are part of the repayment to sponsors and also partly how the success of the expedition is judged. Furthermore, good compositions require experimentation and this is especially true in novel environments. Make sure you devote sufficient time to the photography. It will be well worth it in the end. It is also wise to collaborate with whoever is going to give the post-expedition presentations as they may have ideas for images and have perspectives on events that you had not considered.

Although it is advisable to have one member of the team in overall responsibility for photographic matters, it is worthwhile encouraging camera use by other team members. Different people will take different shots in different styles, you never know what will be useful.

Cloud forests and cameras

Cloud forests are not friendly to cameras or the photographer. The environment is perpetually humid, rain is frequent and conditions of low light are the norm. This results in two distinct problems, first you must take adequate precautions to protect your equipment from the damp and second you must be prepared for photography in low light conditions. Some advice to counter these problems is given below. The cloud forest is a beautiful place, however, and with a little preparation you can do it justice.

Damp

- The classic advice for keeping equipment dry is enclosing it in sealed polythene bags with silica gel. We found this to work very well. Silica gel was purchased cheaply in bulk from Boots the Chemists and sewn into many small cotton bags. Care must be taken to sew the silica gel into cotton bags efficiently. I found to my peril that split bags release abrasive silica gel next to your lenses.
- Fully automatic cameras which are heavy with electronic components are neither as resilient when it comes to water damage, nor as easily fixed as older mechanical alternatives. These can be picked up relatively cheaply on the second hand market and are worth considering at the outset.

Light

- Conditions of low light can cause poorly exposed and blurred photographs. Low aperture lenses, flash-guns, fast films and tripods can all be used to help compensate.
- The lower the aperture of your lens the more light it can let in (and generally the more expensive it will be!). Go for the lowest aperture you can afford. Fixed focal length lenses have lower apertures than zoom alternatives, but are more restrictive when composing shots. Fixed focal length lenses are also the heavier choice as you need more lenses to cover the same range in focal lengths.
- Fast films are a cheaper alternative to than ultra low aperture lenses and the quality sacrifice is almost negligible with good modern film. We took a range of film speeds as we were unsure about the exact conditions although the bulk was 400 asa which gave good results.
- Flash guns are a way of providing your own light. They are full of electrical gadgetry however and as such should not be entirely relied upon. Remember that flashes are also useful for adding sharpness to objects in windy conditions.
- Tripods enable you to take longer exposures with a cable release or camera time-delay. They are most helpful with gloomy landscapes and inanimate objects. A monopod is a less heavy alternative but I did not have one at the time.

There are therefore several ways to help you get the picture on gloomy days but these will vary according to circumstance. Go for the lowest aperture lens possible, take some fast film, a flash and a method of stabilising the camera and you won't go far wrong.

Equipment list

Nikon-F301 with 35-105mm and 60-300mm zoom lenses
Pentax K1000 with 35mm lens
Olympus OM-10 with 35mm lens
2x lens converter
2x & 4x close up filters

TTL Flash-gun
Tripod
12 x 36 Kodachrome 64asa slide film
12 x 36 Kodachrome 200asa slide film
24 x 36 Fujichrome 400asa slide film
Spare batteries for camera and flash-gun
Plenty of cleaning equipment
Silica gel and polythene bags
A very sturdy camera bag

Concluding points

SLR cameras are heavy and cumbersome. On a small expedition being the photographer is not likely to be your only role, so you will not have your camera available at all times. Compare this with the well known fact that all the best photographic opportunities of your lifetime occur when you are fed up with carting around your camera bag. You have a dilemma. A good compromise is to take along a small automatic camera that will fit in a pocket and not strain the back. They are also easy to hide and enable you to take candid photographs more discreetely. This usually has the benefit of giving more natural results and becomes especially important toward the end of a field expedition when people have not had a proper wash for a few months and become camera shy.

Remember to take along adequate cleaning materials. It is hard to keep anything clean in wet and muddy conditions when confined in a two man tent. My camera was probably cleaner than me for the bulk of the expedition!

Take spares as accidents can happen (these can be largely prevented with a sturdy camera bag with lots of extra padding). Photographic equipment is scarce and very expensive in Ecuador.

Do not be stingy on film you will only regret it. We budgeted for a 36 exposure film each day and that worked quite well for our three month expedition.

Finally, although you are not be expected to produce photographic masterpieces a fair level of technical competence and familiarity with your equipment should ensure good results. If you do not have these skills practise before you go!

Simon Hay

3.17 Finances

In the UK

Once funds are raised they need to be kept track of. This is a difficult but very necessary task. Whilst in England the finances were banked in a current account with the Nat West. The cheque book required two signatories. Each British team member being eligible to sign.

Exact financial management is theoretically a simple business, in practice it is almost impossible. The expedition budget provided a useful framework, a guestimate, of how much money was needed, but until it was all raised and then spent, religion seems more useful than economics. The philosophy followed was to assume that the necessary funds would be raised, to keep as close a track of the finances as possible but not to worry unduly about spending the money on whatever was a "vital investment". Vital investments tend to be seen differently by different people.

It was always known how much there was in the account, roughly how much there was still to come in and how much was being spent. It was a matter of mentally juggling the figures and to a degree, praying. We were fortunate in the fact that the fund-raising quickly created a healthy account. This enabled the reconnaissance trip to take place in Easter which was definitely a vital investment.

Before leaving for the field, control of the account was handed over to Peter Maitland, to ensure that finances were still accessible from Ecuador. In case of financial disaster (and to secure libation) every team member took personal travellers cheques and credit cards.

In Ecuador

£3000 was taken into the field to ensure that all costs could be covered. This was taken in US$ and £sterling travellers cheques. Changing money in Quito and Cuenca was simple once local business hours were realised. The dollar is the hard currency, the Sucre, the official currency. Money should be kept in dollars until needed as the exchange rate can rise and fall. Exchange houses - *casas de cambio* - were easily found and were quicker, less intimidating and generally more efficient than banks. Photocopies of the first few pages of the passport were needed but copy shops were again, easily found, though this would not have been the case in smaller towns.

Life in Ecuador was not expensive, a hotel room costing $2.50, a good meal $2. Equipment tended to be nearer UK prices, as a lot of it was imported. Uncooked food was cheap but prices can mount up catering for 11+ people.

To keep exact accounts in the field was difficult. As in the UK, the total amount of money left in the bank (the bum bag) was always known and a careful track of spending was kept to ensure that remaining field costs could be covered, plus a contingency for emergency. While in the field it was necessary to be more careful about funding vital investments/equipment/five course meals, that team members tend to demand. The money had to last.

If an expedition budget is carefully researched and fund-raising is successful, prudent, level headed management of the finances will ensure the expedition will return from the field with sufficient money to handle post-field expenses.

Cash flow

It would be useful to give a detailed financial breakdown of income/fund-raising and expenditure. If this was given it would not be 100% factual. The figures below are a close approximation to the accounts. Whilst the pre-field expenditure was well documented and controlled, spending during the field period was more flexible within the limits of the total amount of money held. This is perhaps a dangerous admission to make but it is very easy to get carried away with science and forget about the exact handling of money. However, this is not the most advisable route to follow. The more seriously financial management is approached the more the hard-raised funds will achieve.

	£
Funds raised	**10900**
Pre-field expenditure	
Reconnaissance	1500
Insurance	900
Flights	3150
Equipment	1640
Admin. & misc.	680
TOTAL	7870
Field expenditure	
Accommodation	300
Food	980
Transport	320
Equipment	350
Admin. & misc.	90
TOTAL	2040
Post field expenses	
Scientific follow-up	120
Admin. & misc.	130
Report (English and Spanish)	740
Total	**10900**

Carol Mahon & Toby Maitland

3.18 Living in the forest

Or, How to Entertain your Friends with Trout and a Black Bin Liner

We realised that we'd misjudged our equipment as soon as our feet hit the forest path. Heavy rain over the previous three days had created a trail of viscous brown porridge, a foot or more deep. Boots quickly filled and squelched - mine were to remain in much the same condition for the whole of the next seven weeks. The misery was compounded by the look of smug satisfaction on Simon's face - he was the only one to have brought a decent pair of wellies with him. The Ecuadorian variety, which several of us possessed, had the advantage of being easy to strap onto a rucksack, which was fortunate since they were almost totally useless for putting on your feet.

That initial walk into the forest was, without doubt, the most horrible experience of all, tempered only by a sense of awe that at last the expedition proper was underway. A certain amount of miscalculation as to how much equipment people were able to carry in their packs meant that the horses were somewhat more weighed down than was strictly decent. They still, however, managed to maintain a better pace than we did.

Horse problems were a recurrent theme throughout the project. As time went by, we amassed more and more equipment, but the supply of horses seemed to dwindle. The local farmers, well versed in the laws of capitalism, were not slow to exploit the imbalance of supply and demand. They apparently took great delight in finding their most cussed beasts for our use, with the result that at one point we were left in charge of an animal which had refused point blank to have anything strapped on its back. Much panic ensued when the horse, in search of greener pastures, broke its moorings and wandered off. It was found after some time beside a stream, looking pretty pleased with life. This same horse was later to attempt the impossible by mounting a mare whilst both animals were fully loaded with equipment. Full marks for determination, but none for common sense.

First camp, 5 km up valley, was a ramshackle affair. Only half the team were present to begin with - the Ecuadorians were due to join us after the end of their exams. Accommodation consisted of 5, 3-man tents, although they rarely housed more than two people (which was more than enough by anyone's standards). We also had what was laughingly described as a cooking shelter. This was Toby's pride and joy, concocted out of bamboo poles and polythene. Provided that the wind didn't blow too hard, it was just big enough to keep the cooker dry. The cook, unfortunately, got wet.

Huge quantities of polythene was one of the expedition's chief assets. Double sheets went under all the tents, which had pretty flimsy groundsheets, and kept us completely dry from below. Flysheets tended to leak a little if you should happen to slip downhill during the night, pushing feet hard up against the fabric. The shorter team members therefore tended to stay dry, whilst our illustrious (and tall) leader received a regular soaking, until we were able to find him alternative accommodation.

This arrived at the second site, further up the valley, in the form of an eight-man family tent, the sort you might see on any Forestry Commission campsite during the summer holidays. It was perhaps a little incongruous, but gave us acres of space to work in. It rained almost all the time - we went for two weeks without a glimpse of sun - so a large, dry gathering place was almost essential.

The second site was doubly blessed by the presence of a small hut, purpose unknown, built out of tree ferns and with a corrugated iron roof. This became the cooking and eating shelter, and was generally reckoned to be a distinct improvement over the previous arrangement. The tree ferns didn't fit together too well, so there was plenty of ventilation. Given the mild, but distinctly unpleasant stomach bugs which were our constant companions, this feature was much appreciated.

Which brings us to the subject of toilets (we might as well get this out of the way in one go). The forest soil at the campsites was quite deep - we were probably sitting on the spoil of an old landslip - so digging wasn't too much of a problem. It has to be said, though, that in spite of these liberated times, the women did their utmost to avoid the task. Eleven people, all eating like wolves, fill a five foot deep trench pretty quickly, and we left only just in time. The spade handle had broken after two trenches, so a third was out of the question. We quickly developed a system of calls to establish occupancy, and even had an "engaged" sign (red or green circle) on a bush, but nobody ever remembered to turn it back to green.

Water gathering, that other essential of life, was shared out on a rota basis. We drank water straight from a stream (which came through the forest, not pasture where there were dangers from cows), and didn't come down with anything too horrible. The chief problem was that the path (along with the camp in general) became extremely muddy and slippery, and by the end of the expedition water gathering came low on our list of favourite activities.

One of the results of this was that excessive washing came to be frowned upon. In fact, some of the team members (I'm too ashamed to name them) went for the whole seven weeks without anything more than a splash of water on the face. Inclement weather was trotted out as the usual excuse, but the Ecuadorians didn't seem to see this as a particular problem, and were in general far cleaner than their western counterparts. Clothes washing was made difficult by the lack of drying conditions, and could anyway be a hazardous business - a precious pair of Rohans was lost to the clutches of the river. Where your own socks are concerned, the smell doesn't seem too bad, but Carol was forced to outlaw their presence inside the tent in a desperate effort to save herself from olfactory annihilation.

The effects of living such a life became increasingly apparent as time went on, in terms of our mental well-being. A general regression of humour to early childhood took place, culminating in the presentation of a puppet show constructed with the aid of a black plastic bin liner and two trout (the unfortunate victims of scientific research). A secret competition was instituted to see how much garlic could be put into a meal before people noticed -this was abandoned when the volume of garlic required simply became too large to prepare. When a pig with a particular penchant for blue soap bars arrived on the scene, nobody was particularly surprised, although elaborate defences had to be constructed to safe guard remaining supplies. The pig got round these by the simple expedient of breaking into an unoccupied tent and stealing the soap from a washbag.

On the food front, we fared considerably better than the pig, although there were some fairly ferocious arguments at first over what constituted a fair share, and whether people should be forced to eat porridge. The stove was a standard 2-ring camping affair, run from very large gas cylinders which were a considerable pain to transport. We were helped in supplies of these by a local boy who seemed glad of some company, and assisted Toby in his project by catching large numbers of trout with very little equipment (i.e. a hook and a piece of line). Local expertise should not be ignored if you want a project to be successful.

Overall, we had very few disasters. A complete lack of fog at the first site was a bit of a worry for the fog project, and Toby's near death in the river could have been a setback (although it resulted in extra peanut butter rations all round, so nobody really minded). The sheer size of the team was perhaps the biggest problem, but accommodation and cooking facilities were robust enough to cope with the demands. If you like mud, and you don't mind becoming slightly mad for a few weeks, then this is definitely the life for you.

Jon Roberts

Section 4

Summary of the past and a view to the future

4.1 What did the expedition achieve?

There is nothing surprising about the findings of the scientific work. The fog interception study supported previous work carried out in the Andes which refutes the role of fog interception as being important to the hydrology of the forest and shows deforestation to severely affect the region's hydrology. The icthyological work found a previously unreported fish community under threat from a commonly introduced species, the trout. The macro-invert work found that the fresh water invertebrate community can clearly be shown to respond to changes in terrestrial vegetation. The frog project highlighted the decrease in frog diversity that occurs with the loss of forest, and the botanical work set the foundation on which the other studies sat.

Though to discover exact details of the effects of deforestation and to statistically prove the case it is necessary to work in the field, the general trends shown by most of the scientific findings could be predicted from an armchair in a good library. Deforestation is well known to result in the loss of the biodiversity, stability and sustainability of the environment. No-one needs to be told that the removal of the forest will result in disaster. What then did the expedition achieve? Can the expensive field work be justified? Initially (to me at least) it seemed that the answer was no, that the forest was doomed and that time and money had wasted studying it. It was perhaps this feeling which lead to the recalcitrant attitude which somewhat delayed the writing of this report. What was the point when it was all so hopeless? Over time attitudes change and answers begin to emerge.

The details of the scientific work are valuable. Each project suggests small points of further study and elements of an overall management plan specific to the Púlpito valley. The hydrology is especially important, water management being a vital role the forest fulfils. Once the forest is removed the effects this has on the hydrology of the region need to be understood for effective management plans to be formulated and applied.

The scientific work also adds to the increasing body of knowledge on the effects of deforestation and human impact on the environment. This is especially valuable in little studied areas such as cloud forest. The studies conducted by the Río Paute Headwaters Expedition and the UEA Ecuador Cloud Forest Expedition can be seen with the work of Río Mazan Project as forming the baseline of ecological work in the forests of the Paute basin. It should be noted that work is carried out in cloud forest by Ecuadorian Institutions and NGO's but funds are short and the publications are not available in Europe, just as "western" journals are too expensive to be available in Ecuador. The scientific work of the expedition also points towards refinement in the methodologies employed, to increase the efficiency of any future projects working in similar fields.

Much of the value of the expedition came from the carrying out of multi-disciplinerary work by students, academics, governmental and non governmental workers from Ecuador and the UK The science provided the framework to live and work within a threatened area of forest. While there, it was possible to collect a lot more information about the region than can be conveyed in strict scientific terms. The scientific findings of the expedition can be combined with the work of the UEA expedition and general observation to give a more complete understanding of the situation.

4.2 Suggested future work

The state of the Paute Basin is on a blunt knife edge. it could improve or slowly continue to decline. The hillsides are bare and eroding. the dam is silting. the climate is seemingly becoming dryer and the remaining pockets of forest are being cleared by peasant farmers who know the consequences of their actions. There are plans to reforest the region but the money provided for the purpose does not trickle down to the people who live on the land. A clear consequence of deforestation was seen at the start of May 1993 when an estimated 200 million cubic metres of mud slid down a valley side through the town of Paute and on into the river. This resulted in flooding. loss of housing. roads and farmland. the amount of mud disrupting the function of the dam further downstream. Though deforestation cannot receive 100% of the blame, it was doubtless a major contributing factor. Clearly remedial measures are needed but the political situation does not make it easy for Ecuadorians or foreigners to become involved in the conservation or sustainable development of the region.

In north-west Ecuador the Global Environmental Facilities Ecoforest 2000 project was planned to be set up. The project was conceived as a long-term forestry scheme planting tree farms for sustainable use and lessening the pressure on the primary rain forest. Funded by the World Bank the at first sight laudable initiative was soon criticised by local communities and conservation organisations for alleged insensitivity to the communities and an unrealistic approach to conservation. the role of the campesinos as agents of deforestation having been forgotten. The Ecoforest 2000 project was managed without involvement of Ecuadorian environmental groups and the local community. This combined with the Ecuadorian Government's hostile environment for foreign aid. due to its lack of policy and resources for the management and protection of forest led in March 1993 to the World Bank freezing funds and the project collapsed. Thus doubt was cast on the potential for alternatives to the continuing destruction of the forest in Ecuador. Are the politics too sensitive for foreign organisations to become involved?

In Ecuador there are many people working towards the sustainable development and conservation of the environment. Politics and subsistence economics commonly stand in the way of such development. In the Paute basin the problems of deforestation are generally caused by the *campesinos,* yet many of the same people would be happy to plant trees if provided with the trees. the technology and alternative ways to provide income. It would seem that any future project wishing to work in the area could achieve much if the project were initially small scale and carefully coordinated with and predominantly made up from the local communities, government bodies and NGO's. This is not a simple proposition and would require much careful planning, the politics and economics needing equal if not greater attention than the biodiversity and ecological stability of the region. No amount of panic about the loss of species is going to produce improvement.

In the specific case of the Púlpito valley the forest is cleared by the people of Santa Rita who have only 3-5 ha of land per family in Santa Rita. The yields of often agrochemically treated western crops are low and the soil is degrading. this combined with the economic depression which has lead to a reduction in the migrant labour market, forces the inhabitants of Santa Rita into the Púlpito Valley. To conserve this forest or similar areas of forest and ameliorate the lives of the local people a number of possibilities are suggested below, these ideas arose from the work of both the Río Paute Headwaters Expedition and the University of East Anglia Ecuador Cloud Forest Expedition.

The viability of the presented ideas is very much dependant on what work is being done by Ecuadorians in Ecuador and much careful research and development is needed. Information presented in books such as "Managing sustainable development" (Carley and Christie, 1992) should be read to provide a broader perspective, give background information and suggest a skeletal management protocol.

Reforestation

The funds from present government afforestation programmes are failing to reach the minifundista landowners. It is also the case that World Bank funds only provide for exotic species such as Eucalyptus, Pine and Cyprus which are wholly unsuitable for sustainable conservation orientated forestry. Afforestation will directly benefit the local community providing firewood and building material and if the forest is managed carefully biodiversity should be partially preserved.

As is suggested by the UEA report, a project could be formulated to provide the locals with the knowledge of germination and cultivation of indigenous local species. Fast growing species could be planted to stabilise the soil while slow growing wood could form a longer term project. The people definitely seem to have the foresight to realise the value of such actions. If it were possible to develop a long-term reforestation program and if the planting were carefully managed it should be possible to stabilise the soil and work with remaining pockets of forest creating buffer zones around the mature areas. Buffer zones could also be planted along watercourses to reduce erosion and conserve the aquatic environment.

Such reforestation has been achieved with varying degrees of success in other regions of Ecuador. If the political as well as ecological management practice of the success stories were studied, it should be possible to learn from them and refine the propagation and management techniques while perhaps adding the advantages of the latest western scientific theory.

Traditional Agriculture

The agricultural methods often in practice and increasingly being introduced are entirely unsuited to climate and soil of the region with "modern" cash crops and the use of agrochemicals becoming common. Traditional practices such as crop rotation and intercropping have died out with crops such as the Chacra potato, which grows every year without reseeding, having almost disappeared due to the competition with western cash crops. There is much that could be done to restimulate traditional agriculture, for example the technology developed by the Inca is not available to the campesinos, history often seeming to begin with the Conquistadors.

Organic Agriculture and Agroforestry

The UEA sociological report states: "New methods for cultivating these difficult soils need to be developed using our present knowledge of organic agriculture and agroforestry" Innovations are being made by the local farmers. In the nearby town of Huasipamba there is a household that is already experimenting with many organic practices. If such people were encouraged and offered new and appropriate techniques and materials these could be passed through the local communities. A rapid diffusion in ideas may occur if the correct skills and resources are available to the right people. It should be noted that the correct people to disseminate such ideas may well be host country NGO's but the technology and resources still have to come from somewhere.

The dam

The Paute dam as provider of a significant proportion of the nations power and having resulted in a considerable foreign debt and is a sensitive issue that plays a central role in the politics of the region. To attempt to alleviate the problems of silting and eutrophication, research is being carried out by Ecuadorian academics. While it may be possible to lessen the problems of the dam by becoming involved in the development of the region, to be involved directly in this issue could be problematic.

Education

Education of the local people is central to all of the proposed projects, education into agricultural environmental and economic issues. It is necessary to involve the right people as teachers. Information is neither readily accepted from, nor appropriately disseminated by foreigners.

Tourism

Tourism was proposed in 1992 by the University of East Anglia and Bristol Expeditions as a way of financing the development and conservation of the area. There are possibilities here. The Púlpito valley is beautiful and access is reasonably easy. As with all the proposed projects much work needs to be done to test its validity. Tourism may be seen as an "eco-error" but finance is needed and this is a possible source.

Ecuadorian Institutions and NGO's

There is an increasingly active and efficient network of NGO's building up in Ecuador. The conservation bodies such as *Cecia* and *Tierra Viva* are working hard for the conservation of their country and the relatively new *Fundacion Grupo Esquel Ecuador* is working to co-ordinate realistic "grass roots" rural development. There are an increasing number of Ecuadorian experts whose advice and help should be solicited but the co-operation and services of these people should not be freely assumed by western projects.

The expedition worked succesfully with the Universidad del Azuay and the regional land managers UMACPA. If such relationships can be developed and strengthened, it should be possible to build a project from the ground up with Ecuadorian citizens, rather than working them in at a later date. It should be noted here, that the development of the Ecuanex, a full APC Internet node to which all the Ecuadorian Universities are linked, makes transatlantic communication immeasurably easier (read Krol or Ritner if you do not understand this).

Río Mazan Project

The Río Mazan Project based in Norwich and Cuenca have been working for the conservation of the Mazan valley cloud forest for around 10 years. They carry out afforestation work, ecological research and education projects. A strong network of contacts has been developed and Mazan started the only Ecuadorian volunteer ecological group " Amigos de Mazan". Any further work conducted in the area should be co-ordinated closely with Mazan. There is already a strong infrastructure developing with the potential to support an increasing degree of integrated environmental management.

Biodiversity

While the conservation of the biodiversity of the region is at the heart of the matter it must be achieved through the development of the local community. They live there and they have just the same rights as everyone else. While it may be an "eco-utopian" view to fantasise the expulsion of the local people (and BP 15 has been put forward as a National Park), everyone's life is part of the biosphere and should be managed as such. In the case of the Púlpito valley this seems to mean working the development of the local community in with the minimum loss in biodiversity. While loss will occur, it would be far worse were nothing attempted.

Catchment Conservation

The conservation of the forest in the Púlpito valley would best be managed treating the catchment as a whole. Not only does this give a well delineated area but it is also the most appropriate approach from an ecological viewpoint. As the products of the erosion of the Púlpito Valley directly silt the dam, it would be in the interest of the local government, if provided with the correct skills and resources to control deforestation and subsequent erosion in the valley.

Catchment conservation requires a solid understanding of the region's hydrology, physical geography, ecology and sociology. If this is achieved by a predominantly Ecuadorian group it should be possible to realise the management of the region in the simplest, most efficient way. Such a management program should be run firstly for and eventually by the local people.

Potentially included in the management of the catchment are the issues of reforestation, traditional agriculture, primary health care and agroforestry. These have been achieved in grassroots development programs elsewhere in Latin America and should be possible in Ecuador, politics, finance and motivation willing (if it is not already being practised).

Catchment conservation also leads to an increased precedent being placed on the conservation of the watercourse, which is not only important to the local biota but also to the Amazon, of which the Púlpito and Paute are headwaters.

4.3 Conclusion

The above provides only a rough sketch of the possibilities, but with research and development it will become clear exactly what can be achieved. Such plans have been tried in various continents around the world in different habitats, maybe even in regions which are comparable to the Púlpito basin. The information on the success and failure of previous and contemporary projects is there to be applied with skill and sensitivity to new regions. To do this the political and economic situation must be carefully assessed and worked with in the most appropriate manner. There are whole volumes of ecological theory yet to be applied. This needs to be done with the education of the people, to allow them to develop their own lives.

At the present time many people are trying to achieve sustainable development and the conservation of environment and answers are not obvious. It simply remains for more people to become involved, testing out and evolving methodology, each working towards a small part of the successful management of this planet.

The Río Paute Headwaters Expedition was truly a co-operation between many different individuals and bodies, from the union of undergraduates from the Universities of Bristol and Azuay with the close co-operation with the University of East Anglia and Río Mazan Project, to the expertise, advice and support offered free of charge by British and Ecuadorian academic, governmental and non-governmental organisations as well as the locals in the Paute Valley. The belief and hard work of so many people made this project come alive. Thank you.

Toby Maitland

4.4 Suggested reading

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