

Project Anuran: An ecological research project concerned with the assessment and monitoring of anuran populations in the region around Las Cuevas, Chiquibul Forest Reserve, Belize.

Phase III: Preliminary Report

By

Katie Finlinson, Heather Anderson, Matthew Bol, Noberto Coc, Robert Forbes, and James Humble

September 2002

Katie Finlinson c/o Project Anuran
Institute of Ecology and Resource Management
University of Edinburgh
Darwin Building
Kings Buildings
Mayfield Road
Edinburgh EH9 3JU

Email; projectanuran@hotmail.com

Website; www.projectanuran.org

Summary

In recent years there has been growing concern regarding reports of a global amphibian decline. To some extent, these declines may be explained by habitat destruction, but alarmingly declines have also been reported in pristine areas previously thought to be undisturbed by man. These apparent decreases in amphibian populations are disturbing in their own right, but are also worrying because amphibians are integral components of many ecosystems and serve as excellent bio-indicators of the overall health and resilience of their environment. In order to understand these declines, and ultimately prevent them, there is a need for long-term monitoring studies of amphibian populations. Project Anuran is an ongoing independent ecological research project carried out by undergraduates from Edinburgh University, Scotland. The project was started in 1999 and aims to monitor and assess anuran (frogs and toads) populations in the Chiquibul Forest Reserve in Southwest Belize. This is achieved by collecting annual data about the species diversity and relative abundance of anurans during the rainy breeding season (July – September). The project is primarily based at Las Cuevas Research Station, owned by the London Natural History Museum, which is situated in the heart of the Chiquibul. This is an ideal place for us to conduct our work, as this region remains one of the most pristine and untouched rainforests in the world today. During the 2002 field session, through intensive monitoring of both the vocalising and the non-vocalising anurans, Phase III of the project found a total of 19 anuran species at Las Cuevas. This highlights Las Cuevas as the most diverse site in Belize with respect to amphibian fauna. The information collected by Project Anuran has been added to the growing data bank compiled by the Declining Amphibian Population Task Force (DAPTF) of the IUCN. Collaboration in this way enables a regional picture of the status of amphibian communities to be created, which is essential to resolve the phenomenon of declining amphibian populations and thus take appropriate conservation action.

The Declining Amphibian Population Crisis

The decline in amphibian populations was first reported by herpetologists in the late 1970s (Barinaga 1990; Bury 1999), and appeared to be occurring in areas distributed across the surface of the globe. Concern arises because amphibians are integral components of many diverse ecological ecosystems. In some ecosystems they are the most abundant vertebrates (Blaustein *et al* 1994, Blaustein & Wake 1995) and so their absence can seriously disrupt the functioning of the rest of the ecological community. They provide a prey base for other tropical vertebrates (Beebee 1996) as well as predated upon many invertebrates, especially arthropods (Wake 1991). Therefore their demise can have many repercussions elsewhere in the trophic system. This apparent decline in amphibian populations is disturbing in its own right, but it is also worrying because amphibians serve as excellent bio-indicators of the overall health and resilience of their environment (Blaustein & Wake 1995; Alford & Richards 1999). They have a bi-phasic lifestyle, living on both land and in water at different stages of their life cycle. Their moist skin is thin enough to allow respiration and their eggs lack shells, allowing direct exposure to soil, water and sunlight (Duellman & Trueb 1994; Lips 1998). Frogs also provide a good reflection of local conditions because they exhibit highly philopatric behaviour (Blaustein & Wake 1995). All these factors therefore make amphibians more sensitive to environmental disturbances than other terrestrial vertebrates.

It has been proposed that the declines could be the coincidental effect of natural population fluctuations (Pechmann *et al* 1991; Pechmann & Wilbur 1994; Marsh 2001). However, this is unlikely to be a ubiquitous explanation due to the large number and wide distribution of reported declines. Decreases in amphibian populations have occurred on a global scale, indicating more general environmental problems. In order to monitor and respond to the alarming problem of amphibian declines, the Declining Amphibian Population Task Force (DAPTF) was founded in 1990 under the Species Survival Commission of the International Union for Conservation of Nature (Wake 1991; Flan 1991).

Declines in frog populations may of course lead to local extinction. This can have drastic effects particularly on species that are of limited range, and also live in fragmented habitats - thus hindering migration between communities making opportunities for re-colonisation low or non-existent (Wake 1991; Marsh & Trenham 2000). There have been many causative factors of amphibian declines proposed in the literature. Some will be due to the natural stochastic population fluctuations, but many have been attributed to direct or indirect anthropological activities. These include habitat destruction, poaching, and the introduction of exotic predators and pathogens (Alford & Richards 1999).

Alarmingly, amphibians have reportedly disappeared from pristine areas or areas presumed to be undisturbed by human interference (Blaustein & Wake 1995, Bury 1999, Alford & Richards 1999; Houlahan *et al* 2000; Alford *et al* 2001; Carey *et al* 2001; Gardner, 2001). A number of amphibian population declines and local extirpations have been reported in neighboring countries to Belize (Meyer & Foster 1996; Campbell 1998). Campbell (1998) indicates that 19 of the 49 species of anurans

in the Monteverde region of Costa Rica have mysteriously disappeared in the last decade. Disappearances from protected areas such as this are distressing, especially as such areas are perceived to be immune to most human disturbances (Blaustein & Wake 1995; Bury 1999). The declines in such remote areas are thought to be caused by the indirect effect of human activity (see Gardner (forthcoming) for a comprehensive review). Depletion of stratospheric ozone and resultant increase of UV-B radiation at the Earth's surface damages frog embryos, thus reducing their chances of survival (Blaustein & Wake 1995; Berger *et al* 1998). The enhanced UV radiation may also contribute indirectly to decline by decreasing the supply of aquatic insects for the frogs to feed on (Lips 1998). Recent remote sensing data from Central America has identified an increase in the levels of UV-B in areas of reported amphibian declines (Middleton *et al* 2001). Increasing acidity of aquatic habitats caused by acid rain also has major deleterious effects on amphibian distribution (Carey *et al* 2001). This is also true of pesticide contaminants that can persist in the environment for a long time and travel long distances via the atmosphere (Lips 1998; Relyea & Mills 2001). Alterations in local weather conditions caused by global climate change can also be harmful to frog populations. A reduction in rainfall, brought on by deforestation, can have a detrimental effect on amphibian reproduction as the specific timing and duration of rainfall act to trigger breeding (Blaustein & Wake 1995; Lips 1998; Alexander & Eischeid 2001). The effects of all these factors reinforce the claim that amphibians can act as valuable bio-indicators of the environment. Furthermore, as Wake stated in 1991, modern amphibians are highly resilient, having been on this planet for more than one million years. Therefore a decline in population now is clearly significant and the potential deleterious consequences this could have for other species is excellent justification for continued research into their global status.

Role of Project Anuran Phase III

There is a critical absence of a consensus on the distribution, extent, and causes of the global amphibian population decline, due to the dearth of short and long-term comprehensive monitoring studies (Wake 1998). Recent empirical evidence suggests that the number and distribution of population declines is presently increasing (Alford *et al* 2001), especially in tropical areas, and with particular relevance to this study in sites across tropical Latin American (Young *et al* 2001). Despite growing levels of concern as to the wider ecological implications for both biodiversity and ecosystem health, there are still three main questions surrounding amphibian declines in which a large amount of uncertainty remains; (1) How to determine real population declines from natural or stochastic population fluctuations? (2) The relative importance of global versus local factors in determining amphibian population dynamics? and (3) Whether agents of decline can be attributed to human-induced changes in the environment? Project Anuran has been able to contribute towards our understanding of the first two questions by collecting data on the patterns of variability in species assemblage composition, species relative abundance, reproductive behaviour, and environmental associations. Understanding natural variability in amphibian population dynamics is becoming increasingly recognized as fundamental to

understanding both the mechanisms that drive population processes and the level of extinction risk (Alford & Richards; Marsh & Trenham 2001; Marsh 2001).

Aside from providing a uniquely comprehensive assessment of amphibian populations, Project Anuran complements similar studies by focusing on an area and species group that remains largely unstudied. There remains a desperate need for studies in the tropics (Pearman *et al* 1995; Wake 1998; Houlahan *et al* 2000), and especially in the neotropics (Young *et al* 2001). Although notable work has been done at high altitude neotropical sites (Guyer 1990; Lips 1998), very little has been done at lowland tropical and subtropical sites – of which Belize contains some of the most pristine and extensive stretches in Central America (Furley 1998). Furthermore, Belize provides a haven for much of the wildlife that has vanished from neighboring countries (Romney *et al* 1959; Hartshorn *et al* 1984; Meyer & Foster 1996), and retains some 75% of its natural vegetation (Harcourt 1984). However, despite this the ecology of many amphibian species in Belize remains largely unknown (P.J.Stafford¹ pers comm, J.R. Meyer² pers. comm.) – reflected by the discovery of 5 of the 33 known species between 1990-1995 (Meyer & Foster 1996). The DAPTF are presently co-ordinating a monitoring program entitled the Maya Forest Anuran Monitoring Program (MAYAMON), as part of a large, internationally funded biological monitoring project of the entire Selva Maya region (Carr & de Stoll 1999). The information collected by Project Anuran is fed into a regional picture collated by MAYAMON using data from studies throughout Belize, the southern states of Mexico, and the Péten of Guatemala. Our study site is able to provide a good comparison against many more disturbed areas in other parts of the region.

Extensive data has been collected describing the relative abundance of species, their spatial distribution, and temporal distribution patterns in presence/absence and reproductive activity, alongside abiotic environmental correlates. Project Anuran has identified Las Cuevas as the most diverse site in Belize with respect to amphibian fauna (Miller & Miller 1995), and has collected one of the most comprehensive amphibian population level databases in Belize (J.Meerman pers. comm.³). Project Anuran has been able to contribute significant information with respect to amphibian population dynamics (Gardner, 2001). This substantial database provides a unique groundwork for highly valuable repeat studies in future years. Project Anuran Phase III has continued to provide an assessment of the study sites monitored during the first two field phases, both for vocalising and non-vocalising species, thus providing 3 years of comparable data. This enormously enhances our ability to provide a valuable interpretation of the inter-annual variability in our study populations.

The purpose of this preliminary report is to provide an insight into the data collected during Phase III and to compare this with the results from the two previous year's field sessions. Furthermore, we aim to outline future output from Project Anuran.

¹ Mr Peter Stafford, Research Biologist, Natural History Museum (London)

² Dr Jack Meyer, Co-ordinator DAPTF Maya Forest Anuran Monitoring Program (MAYAMON)

³ Dr Jan Meerman, Green Hills Butterfly Farm, Belize.

Aims and Objectives

Research Aim: To contribute to the understanding of the ecology and conservation of amphibian populations via intensive assessment of the status of species at the neotropical site of Las Cuevas (N16°44' W88°59').

Research Objectives:

- 1) To continue monitoring of ten sites previously assessed during 2000 and 2001 using tested profitable survey methods
- 2) To conduct survey work to compare the diversity and population status of ground dwelling amphibian fauna at six sites in the Las Cuevas area. Furthermore to assess the effectiveness of various survey methods.
- 3) To conduct survey work to compare the diversity and population status of ground dwelling amphibian fauna at four sites in the Las Cuevas area, in order to assess the congruence of amphibian diversity with the presence/absence of four key umbrella species.

Further Objective

- 4) To continue efforts to establish firm links with a collaborative student group from the University of Belize, with an aim to consolidating closer ties between the student community from both institutions who are concerned about ecology and conservation management in Belize. Collaboration will build on firm contacts already established not only in the University of Belize, but also San Ignacio Sixth Form, and local Mayan communities

Methodology and Approach

Site description

Our work is conducted in the vicinity of Las Cuevas Forest Research Station (N16°44' W88°59'), Belize. The station is maintained as a joint initiative between the Natural History Museum (London) and the Forestry Department of Belize, and is situated in the Chiquibul Forest Reserve, north of the main Maya Mountains divide. It stands at roughly 500 m a.s.l. with an annual rainfall of between 1500 and 2000 mm, with vegetation consisting of mostly lowland subtropical moist forest (Hartshorn *et al.* 1984). Since the collapse of the Mayan civilisation c. AD 750-1000 there have been no permanent inhabitants of the region around Las Cuevas, although recent years have seen temporary disturbance due to logging, chicle harvesting, and the natural impact of hurricanes.

Methodology

Monitoring projects are by their very nature limited to following the protocol of previous years to enable a comprehensive and sensible assessment of any changes in species diversity or population status. In consideration of this, considerable advice of the highest quality was sought as to the most appropriate protocol to follow for

Project Anuran (during both Phase I and Phase II), both to enable maximum return and a wide applicability with respect to other, similar Mesoamerican survey work. For the main direction of our work, the assessment of hylid frogs, the following methods have been constructed which are ideal for our aims.

Our methodological approach falls under two directions; that for vocalising species (Field Study 1), and that for non-vocalising species (Field Study 2).

Field Study 1: Monitoring and assessment of vocalising species

Most anuran species, especially in the tropics congregate *en masse* around breeding sites (Duellman & Trueb 1994; Beebee 1996), making the monitoring of vocalising choruses often the most effective technique by which to assess a population (Alford & Richards 1999).

Ten breeding pond sites were chosen during Phase I and II representative of a number of different sub-habitats of the forest around Las Cuevas. Surveys of these breeding ponds ran from 1900 hours to 0200 hours. Each pond was surveyed over at least 5 repeats in concordance with data from Phase II. Measurements taken on arrival at a pond include; depth of pond (deepest part), collection of water sample for pH and conductivity measurements, and a summary weather report. Following this, half-hourly recordings of species abundance and calling activity were made. Measures of abundance follow the Maya Forest Anuran Monitoring Project (MAYAMON) protocol (Meyer 1999) – this is the use of vocalisation categories to assess the abundance of each species for the first fifteen minutes of every hour – categories are as follows (Table 1).

In addition to the vocalisation category an attempt was made to assess calling activity over and above species presence *per se*. This was done using a measure (analogous to the above) of calling intensity - measuring the frequency of calls of an average individual of each species for the first fifteen minutes of every hour. One call is taken as each noticeably distinct vocalisation per individual (Table 1). This is a method devised during Phase I, and proved to be a highly profitable addition to the protocol during the Phase II field phase.

Vocalisation Category (VC)	VC definition	Vocalisation Intensity (VI)	VI definition
1	1-5 individuals	A	1 or <1 calls per 15 minutes
2	6-20 individuals	B	2-14 calls per 15 minutes
3	21-50 individuals	C	5-10 calls per 5 minutes
4	>50 individuals	D	2-5 calls per minute
		E	6-10 calls per minute

		F	11-20 calls per minute
		G	21-40 calls per minute
		H	>40 calls per minute

Table 1.

In addition to the above the air and water temperature was recorded every half hour. Values observed for the entire night were; maximum and minimum temperature, volume of rainfall and duration and number of rainfall events. For each pond an assessment of the floral diversity has previously been made. A re-assessment of this was made during Phase 3 to monitor any local changes in vegetation from previous years. Assessment was made by mapping the area surrounding the pond and noting all tree species with a DBH > 10cm within 10m of the pond edge.

Identification of vocalizations in this study follow reference to a tape produced by J. Meyer and J.C. Lee. Additionally Project Anuran has made its own minidisc recordings of nearly all species encountered at the Las Cuevas site. This represents an important contribution to future assessment of local populations. Visual identification of all species is aided by a practical field guide compiled by Project Anuran (Phases I and II) with reference to texts; Meyer & Foster 1996, Lee (1996), Campbell (1998), Lee (2000) and the Belize Biodiversity Information database.

In addition to the standard survey protocol outlined above, all anecdotal recordings of these species were noted separately, detailing location, time of day, species type and number, and any relevant natural history notes.

Field Study 2: Non-vocalising and leaf litter species

The monitoring of leaf litter and stream dwelling frogs is subject to a variety of methods the effectiveness of which can vary greatly between geographic locations, amphibian species assemblages and local habitat conditions (Pearman *et al.* 1995). Six transect lines were established in a variety of habitat types and were monitored during both day and night.

Transect lines were stratified around areas presumed to be of both high diversity (creeks and the river), and areas noted to be ecologically distinct in terms of forest habitat. Each line was cut to be 500 m in length and 2 m in width. Transect lines were surveyed by two people (selected at random), who walked slowly down the line each disturbing the leaf litter / branches on one half of the transect. Search effort was standardised using a time restraint of one hour per transect, producing an average searching speed of 0.5 km per hour. All individuals sited were noted with respect to species, number, location (nearest 50 m), time and any relevant behavioural observations. A minimum of 5 repeats were conducted per transect, for both the day and night, and searches were spaced evenly across the study period.

Identification of specimens for transect lines followed the relevant guides; Lee (1996), Meyer & Foster (1996), Campbell (1998), and Lee (2000).

In addition to the standard survey protocol outlined above, all anecdotal recordings of these species were noted separately, detailing location, time of day, species type and number, and any relevant natural history notes

Weather

Daily recordings were made at 0900 of rainfall volume and duration for the previous 24 hours, maximum and minimum temperature, relative humidity and cloud cover. These were taken using standard equipment from the weather station at the Las Cuevas site.

Results

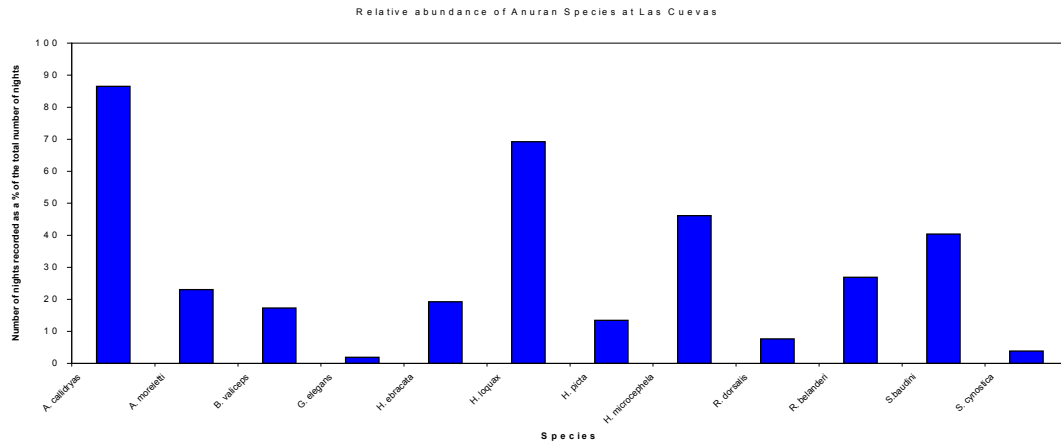
The Table below illustrates the classification of species found at Las Cuevas during Phase III. A total of 18 species were found and this high level of species richness once more confirms the site to be one of the most diverse throughout Belize with respect to amphibian fauna (Miller & Miller, 1995).

Family	Species
Leptodactylidae	<i>Eleutherodactylus chac</i>
	<i>Eleutherodactylus laticeps</i>
	<i>Eleutherodactylus rhodopsis</i>
Bufonidae	<i>Bufo campbelli</i>
	<i>Bufo valiceps</i>
Ranidae	<i>Rana berlandieri</i>
	<i>Rana juliani</i>
	<i>Rana vaillanti</i>
Hylidae	<i>Agalychnis callidryas</i>
	<i>Agalychnis moreletti</i>
	<i>Hyla ebraccata</i>
	<i>Hyla loquax</i>
	<i>Hyla microcephala</i>
	<i>Hyla picta</i>
	<i>Smilisca baudinii</i>
	<i>Smilisca cynostica</i>
Microhylidae	<i>Gastrophryne elegans</i>
Rhinophrynidae	<i>Rhinophrynus dorsalis</i>

Vocalising species

A total of 50 survey nights were carried out during the study, with 5 repeats at each of the ponds. This amounts to a data-set collected over a total of 350 hours.

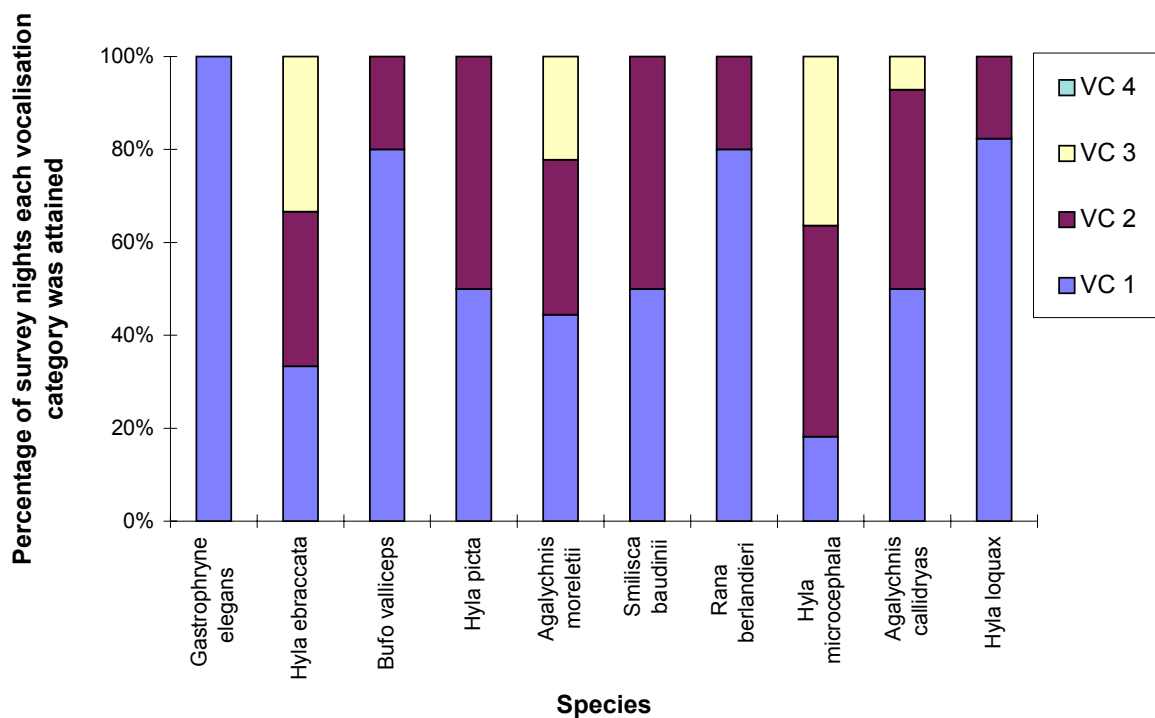
Data was collected to enable diversity, relative abundance, vocalisation activity, and environmental associations between species to all be assessed. Detailed analysis of this year's data-set, together with comparative analysis of data from the previous phases will be published in the main report, which will be available autumn 2003.



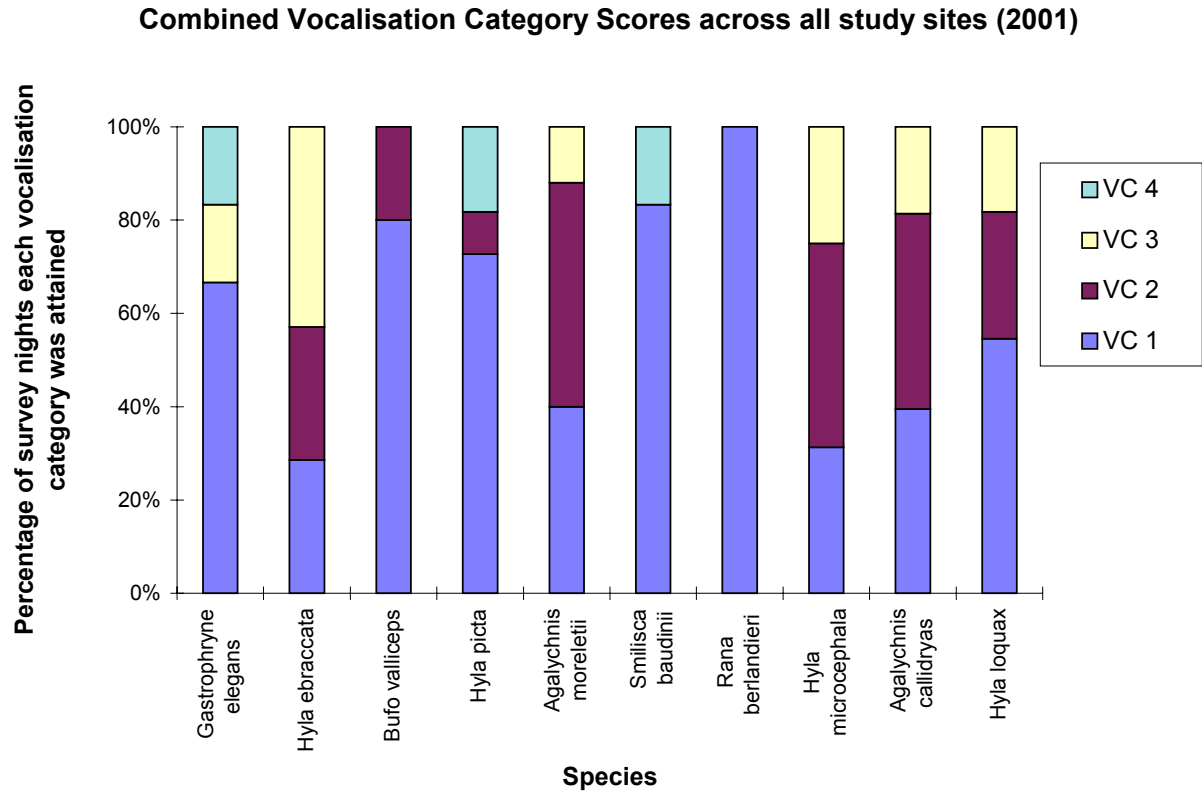
Graph 1 above, illustrates the relative abundance of vocalising anurans found at Las Cuevas.

Graph 2, below: Illustrates the proportion of survey nights in which a species was heard at each vocalisation category (VC) in the year 2000. It allows comparisons in reproductive activity to be made across species. The reproductive activity of some species is characterised by short periods of intense calling activity, whereas other species exhibit a more constant calling pattern.

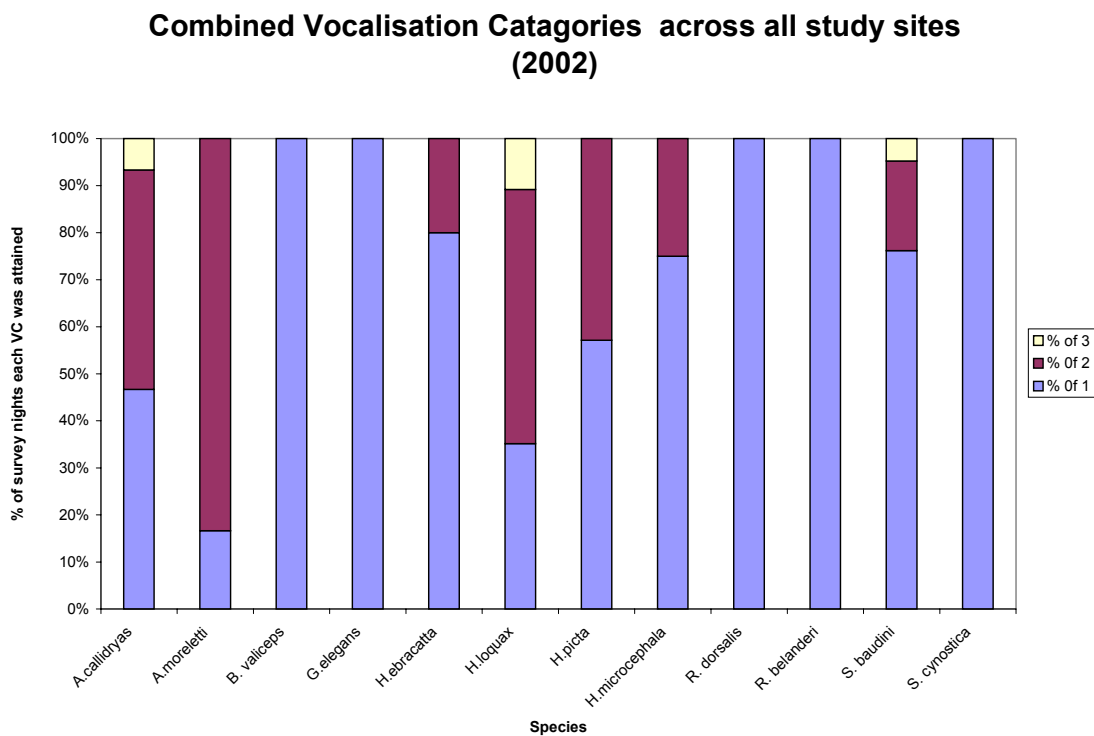
Combined Vocalisation Category Scores across all study sites (2000)



Graph 3, below: Illustrates the proportion of survey nights in which a species was heard at each vocalisation category (VC) in the year 2001.



Graph 4, below: Illustrates the proportion of survey nights in which a species was heard at each vocalisation category (VC) in the year 2002.



Discussion

The results from Phase 3 (Graph 4) further highlight the existence of variation in reproductive behaviour across species. Explosive breeders such as *S. baudinii* repeatedly obtained high VC scores, whereas in contrast continuous breeders such as *B. valliceps* scored lower average VC values.

There is an apparent decline in *H ebracatta* over the past three years, as during Phase 3 the maximum VC observed was category 2, and this only accounted for 20% of recording nights. In comparison, during Phases 1 & 2 the average VC scores were significantly higher.

It is interesting to note that *G. elegans* was only heard on 3 recording nights for the duration of Phase 3, and only obtained a VC score of 1. This is a dramatic decrease in comparison to previous years. This is quite surprising as it would be expected for *G. elegans* to achieve relatively high VC scores as it is an explosive breeder.

However, it is highly equivocal as to whether these putative declines are real or whether they can be explained by natural population fluctuations. The data was collected at breeding sites, so it is possible that fluctuations in breeding behaviour may be mistaken for population declines. Furthermore, amphibians are especially vulnerable to natural or stochastic population variations. They have a short life-span, exhibit philopatric behaviour, and their sporadic reproductive patterns means that their breeding is highly sensitive to climatic change. It is extremely difficult to attempt to distinguish between stochastic and real declines from just three years of data. Therefore the continuation of the project is vital in order to identify the nature of anuran population fluctuations and to isolate causal factors of decline.

Non-Vocalising and leaf-litter species

Over the course of the field study, 72 transect line surveys were conducted. This is a dramatic increase in research effort compared to previous phases, as during phase III, surveys were conducted during both the night and day. Transect lines have proved the most profitable survey method in the assessment of ground dwelling anurans, hence emphasis was placed on this research method during phase III. The data collected is summarised in the table below.

Further to adding to Project Anuran's data set, the transect survey results form part of a collaborative study with Professor Tim Caro and his research group from the University of Davis, California. The group are investigating vertebrate diversity between different sites characterised by the presence of four umbrella and flagship species. This research has important implications in improving the design of animal reserves.

	No of Transect Nights/ Days	Rana juliani	Rana viallanti	E. laticeps	Bufo campbelli	E. rhodopsis	G. elegans	Transect Success (individ/ transect)
Creek	6	0	0	0	0	0	0	0
Saffron Trail	6	0	0	3	1	0	0	0.6
Fifty Hectare Plot	6	0	0	0	0	1	0	0.16
San Pastor Trail	6	0	0	0	1	0	0	0.16
Nature Trail	6	0	0	2	0	0	1	0.5
Monkey Tail	6	2	4	0	1	0	0	1.16
Total	36	2	4	5	3	1	1	0.44

Anurans at the Inland Lagoon, Duplooy's Botanical Gardens

Further to our ten study sites at Las Cuevas, phase III also assessed anuran diversity at Belize's botanical gardens, near San Ignacio. Over three successive nights, the relative abundance and assemblage composition of anurans was monitored at the inland lagoon; a relatively open expanse of water situated within the gardens (Fig. 1). A total of eight anuran species were found to be present at the inland lagoon, and are presented in Table 2.



Fig. 1: The inland lagoon at the Botanical gardens served as an additional study site.

FAMILY	SPECIES
Bufo	Bufo campbelli <i>Bufo marinus</i> <i>Bufo valliceps</i>
Rana	<i>Rana berlandieri</i>
Hyla	<i>Agalychnis callidryas</i> <i>Hyla loquax</i> <i>Hyla microcephala</i> <i>Smilisca baudinii</i>

Table 2: Classification of anuran species found at the inland lagoon.

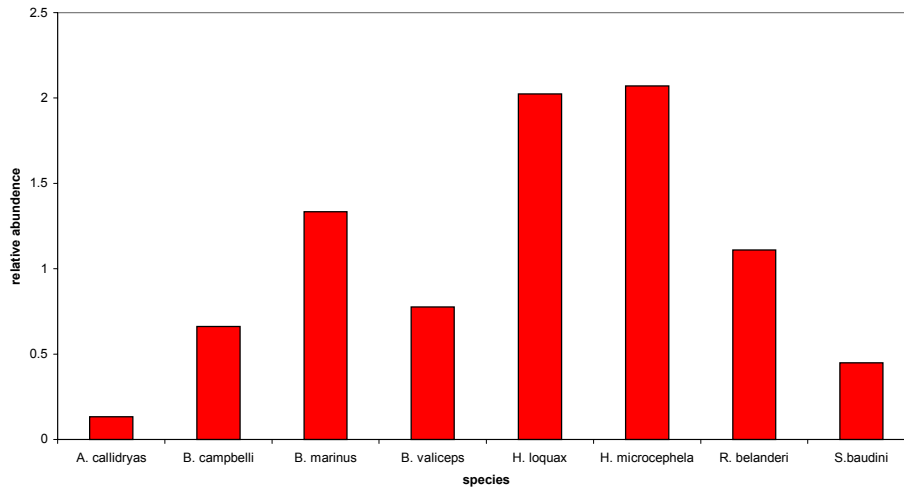
The relative abundance of species observed is summarised in graph 5 and presents a number of interesting results. Firstly, although limited, the presence of *A. callidryas* is surprising given the nature of the study site. It has been well reported that *A. callidryas* preferentially inhabits areas with a high degree of canopy cover, and this observation is supported by the findings of Project Anuran over the past three phases. Therefore the presence of *A. callidryas* at the inland lagoon –an open expanse of water- is intriguing.

A second worthy point to note is the high abundance of Cane toads (*B. marinus*). No *B. marinus* were found at Las Cuevas during phase III and although a few individuals have been observed during previous phases, it is by no means to the same extent as the numbers discovered at the inland lagoon. This may be explained as the botanical gardens are on the outskirts of San Ignacio and *B. marinus* is common in areas populated by humans. This species primarily occupies open habitats and has become a human commensal –living in and around towns.

Further to inhabiting the inland lagoon, *S. baudinii* were also found living by the stream that runs through the orchid house in the gardens. *S. baudinii* preferentially deposit their eggs in shallow water and thus the stream presents an ideal environment.

Graph 5: The relative abundance of anurans observed at the inland lagoon. Relative abundance was calculated using average Vocalisation Category (VC) scores.

Relative abundance of anurans at the inland lagoon



Our results illustrate sympatry between *B. campbelli* and *B. valiceps* at the inland lagoon. These two anurans closely resemble each other and were long considered to be the same species until as recently as 1994 when *B. campbelli* was first described as a distinct species (Meyer & Foster, 1996). Although morphologically similar, *B. valiceps* may be distinguished from *B. campbelli* as it has shorter legs and more rugose skin. *B. campbelli* is abundant in disturbed habitats, such as the inland lagoon, whereas *B. valiceps* is more commonly found in areas of primary forest. At present, little is known in regards to the ecological relationship between these two species and further information regarding their distribution needs to be obtained before any definite conclusions may be drawn.

Future output of Project Anuran

- Completion of the main report consisting of an in-depth comparative analysis of the entire data-set collected over the duration of the project. Full analysis of three years of data will enable the elucidation of patterns and trends in species richness, relative abundance, and reproductive activity, both within and between study sites.
- We are planning to give a variety of presentations, both within and outside Edinburgh University, outlining our objectives, the importance, and the results of our work.
- The Project Anuran website (www.projectanuran.org) is to be updated, hosting results from Phase III. Publishing our results on the web allows widespread accessibility of information about Project Anuran.
- Planning for Project Anuran Phase IV is already underway, and it is hoped that this additional phase will build on the success of the previous phases.

Thankyou

The project would not have been able to take place with out the help of: The British Ecological Society, The Scottish Royal Geographical Society, The Royal Geographical Society, The Barnson Bequest, The Weir Fund for Field Studies, The Davis Fund for Field Studies, Lord Hylton, Sir David Mcalpine. Norton Hill School, Milfield School, Thomson Yates Chartered Surveyors, Lyon Equipment, Peter Furley, John Wilkinson, everyone at Duplooy's, Sharon Matola, Peter Stafford, Chris Minty, Chapal and Celia Bol, Mr Bo, and Enrique. For this we give much thanks and appreciation.

References

- Alexander, M.A. & Eischeid, J.K.** (2001). Climate variability in regions of amphibian declines. *Conservation Biology*, **15**, 938-942.
- Alford, R.A. & Richards, S.J.** (1999) Global amphibian declines: a problem in applied ecology. *Annual Review of Ecology Systematics*, **30**, 133-165.
- Andelman, S.J. & Fagan, W.F.** (2000). Umbrellas and Flagships: efficient conservation surrogates or expensive mistakes. *Proceedings of National Academy Science USA*, **97** : 5681-6238
- Barinaga, M.** (1990) Where have all the Froggies gone ? *Science*, **247**, 1033 – 1034.
- Beebee, T.J.C.** (1996) *Ecology and Conservation of Amphibians*. Chapman and Hall.
- Berger, L. Speare, R., Daszak, P., Green, D.E., Cunningham, A.A. et al** (1998) Chytridomycosis causes amphibian mortality associated with population decline in the rainforests of Australia and Central America. *Proceedings National Academy Science USA*, **95**, 9031-9036.
- Blaustein, A.R. & Wake, D.B.** (1995) The Puzzle of Declining Amphibian Populations *Scientific American*, **272**, 56 – 61.
- Blaustein, A.R., Wake, D.B. & Sousa, W.** (1994) Amphibian Declines : Judging stability, persistence, and susceptibility of local populations to local and global extinctions. *Conservation Biology*, **8**, 60 –71.
- Bury, R.B.** (1999). A historical perspective and critique of the declining amphibian crisis. *Wildlife Society Bulletin*, **27**, 1064-1068.
- Campbell, J.A.** (1998) *Amphibians and reptiles of Northern Guatemala, the Yucatan and Belize*. University of Oklahoma Press, Norman, OK
- Carey, C., Heyer, R. Wilkinson, J., Alford, R., Arntzen, J., Halliday, T., Hungerford, L., Lips, K., Middleton, E., Orchard, S. & Rand, A.** (2001) Amphibian declines and environmental change: use of remote sensing data to identify environmental correlates. *Conservation Biology*, **15**, 903-913.
- Carr, A. & de Stoll, A.C.** (eds.) (1999) *Biological monitoring in the Selva Maya*. US Man & Biosphere Program, Tropical Ecosystem Directorate & WCS. Unpublished
- Caro, T.M.** (2000). Focal Species. *Conservation Biology*, **14** : 1569-1570.

- Donnelly, M.A. & Guyer, C.** (1994) Patterns of reproduction and habitat use in an assemblage of neotropical hylid frogs. *Oecologia*, **94**, 291-302.
- Duellman, W.E. & Trueb, L.** (1994) *Biology of Amphibians*. John Hopkins University Press.
- Furley, P.A.** (1998) History and Destiny of Middle American Forests: The Inheritors of The Mayan Landscape. *Human Activities and Tropical Rainforests*. (B.K. Maloney ed.), pp. 101 – 132. Kluwer Academic Publishers, Netherlands
- Gardner T.A** (2001) Declining amphibian populations: a global phenomemom in conservation biiology. *Animal biodiversity and Conservation* **24 (2)**: 25-43
- Gascon, C.** (1991) Population and community level analysis of species occurences of Central Amazonian rainforest tadpoles. *Ecology*, **72**, 1731-1746.
- Guyer, C.** (1990) The herpetofauna of La Selva, Costa Rica.. *Four Neotropical Rainforests*. (A.H. Gentry ed.), pp. 371-385. Yale University Press
- Harcourt, C.** (1996) *The conservation Atlas of Tropical Forests of the Americas*. IUCN.
- Hartshorn, G. et al** (1984) *Country Environmental Profile of Belize : A Field Study*. Robert Nicolait & Associates USAID San Jose
- Heyer, W.R. Donnelly, M.A., McDiarmid, W. Hayek, L.A. & Foster, M.S. (Eds.)** (1994) *Measuring and monitoring biological diversity: Standard methods for amphibians*. Smithsonian Institution Press, Washington
- Houlahan, J.E., Findlay, C.S., Schidt, B.R., Meyer, A.H. & Kuzmin, S.L.** (2000). Quantitative evidence for global amphibian population declines. *Nature* **404** : 752-755.
- Lee, J.C.** (1996) *The amphibians and reptiles of the Yucatan peninsula*. Cornell University Press, Ithaca, London.
- Lee, J.C.** (2000) *A field guide ot the amphibians and reptiles of the Maya World*. Cornell University Press, Ithaca, London.
- Lips, K.R.** (1998) Decline of a tropical montane amphibian fauna. *Conservation Biology*, **12**,106-117.
- Marsh, D.M.** (2001). Fluctuations in amphibian populations: a meta-analysis. *Biological Conservation*, **101**, 327-335.
- Marsh, D.M., & Trenham, P.C.** (2000) Metapopulation dynamics and amphibian conservation. *Conservation Biology*, **15**, 40-49.
- Meyer J.R., Marlin, J.A. & Arrigoni, J.E.** (1999) A proposal to continue and expand the Maya Forest Anuran Monitoring Project in southern Belize. Unpublished Report.
- Meyer, J.R. & Foster, C.F.** (1996) *A Guide to Frogs and Toads of Belize*. Krieger, Florida
- Meyer, J.R.** (1999b) MAYAMON – Maya Forest Anuran Monitoring Project – General information for participants. Unpublished
- Middleton, E.M., Herman, J.R., Celarier, E.A., Wilkinson J.W., Carey, C. & Rusin, R.J.** (2001). Evaluating ultra violet radiation exposure with satellite data at sites of amphibian declines in Central and South America. *Conservation Biology*, **15**, 914-929.
- Miller, B. & Miller, C.** (1995) National protected areas management plan – zoological report : Faunal and site analysis. Unpublished Report.
- Pearman, P.B., Velasco, M. & Lopez, A.** (1995) Tropical amphibian monitoring : A comparison of methods for detecting inter-site variation in species composition. *Herpetologica* **51** 325-335.

- Pechmann, J.H.K., Scott, D.E., Semlitsch, R.D., Caldwell, J.P., Vitt, L.J. & Gibbons, J.W.** (1991) Declining amphibian populations: the problem of separating human impacts from natural fluctuations. *Science*, **253**, 892-895.
- Pounds, J.A. & Crump, M.L.** (1994) Amphibian declines and climate disturbance : The case of the Golden Toad and the Harlequin Frog. *Conservation Biology*, **8**, 72 – 85.
- Relyea, R.A. & Mills, N.** (2001). Predator induced stress makes the pesticide carbaryl more deadly to gray tree frog tadpoles (*Hyla versicolor*). *Proceedings of National Academy Science USA*, **98**, 2491-2496.
- Simberloff, D.** (1998). Flagships, umbrellas, and keystones: Is single-species management passe` in the landscape era? *Biological Conservation*, **83**(3): 247-257.
- Wake, D.B.** (1991) Declining Amphibian Populations. *Science*, **253**, **860**.
- Wake, D.B.** (1998) Action on Amphibians. *Trends in Ecology and Evolution*. **13**, 379 – 380.
- Young, B.E., Lips, K.R., Reaser, J.K., Ibáñez, R., Salas, A.W., Cedeño, J.R., Coloma, L.A., Ron, S., La Marca, E., Meyer, J.R., Muñoz, A., Bolaños, F., Chaves, G. & Romo, D.** (2001). Population declines and priorities for amphibian conservation in Latin America. *Conservation Biology*, **15**, 1213-1223.