Monitoring Biodiversity: Analysis of Amazonian Rainforest Sounds

By
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THE number of species inhabiting the earth can only be estimated and is a matter of vigorous debate among scientists with estimates ranging from 5 to 80 millions. This is partly due to the fact that so many insect species inhabit tropical forests – especially in the forest canopy (Erwin 1991, Gaston 1991). Due to the accelerated rate of habitat conversion and destruction many of these species will have become extinct before being documented by science and so attempting to inventory the worlds' species is a race against time (Stork 1988). Consequently there is now a need to be able to conduct rapid surveys of forest areas in an attempt to identify the most biodiverse areas (Roberts 1988). Conducting inventories in tropical forests is especially difficult as the complexity of tree architecture provides numerous niches and many species inhabit inaccessible regions of the canopy. Coupled with this, the rarity, excellent camouflage, cryptic lifestyles and nocturnal habits of a great proportion of species makes visual censuses extremely difficult.

The lack of information and the consequent problems associated with biodiversity monitoring has led to the development of 'Rapid Assessment Programmes' (RAP) (Tangley 1992), to identify 'hotspots' of biodiversity and to inventory certain key groups in these critical areas. RAP scientists record the diversity of selected indicator groups which are often by no means sufficient when comparing forests, because different groups react differently to disturbance and other factors (Lawton *et al* 1998). In addition the taxonomic skills required to accurately identify even these indicator groups are labour intensive, costly and increasingly are in short supply.

A considerable number of rainforest creatures indicate their presence acoustically. When walking in a rainforest one can hear a multitude of species even if one cannot see them. Sound analysis through acoustic surveys therefore has the potential to provide an additional window for quick biodiversity assays, particularly in tropical habitats. The example described in this article relates to sampling of the cricket (*Gryllidae*) community of a tropical lowland forest in Ecuador.

Methods

The unaided human ear neither resolves the temporal structure nor the full frequency range of insect songs. Therefore it is necessary to use some form of equipment to aid the human ear. Historically the spectrograph was used and temporal analysis was accomplished by filming oscilloscope tracks (Pierce 1948). However advances in computer technology now allows the use of digital analysis to calculate spectrograms.

Recordings in Ecuador were made with a condenser microphone on a Sony cassette recorder along transects laid out in the forest. These were repeated twice a day at different hours, for two weeks, at each of the sampling locations. The recordings made were then analysed with a spectrum analyser which produces an on-line fast Fourier Transform, visible on a colour monitor.

Results

Frequency bands below 3 kHz are mainly occupied by frogs, birds and mammals, which could be identified by the indigenous people of the area. Short broad-band signals (faint songs with a low repetition rate) were produced by katydids (*Tettigoniidae*), which is probably an anti-predator strategy. Conspicuous, repetitive signals with a narrow-band carrier frequency between 4 and 9 kHz are principally generated by male crickets (*Gryllidae*). Figure 1 gives some examples of graphical displays of songs for typical representatives of major *Orthopteran* groups.

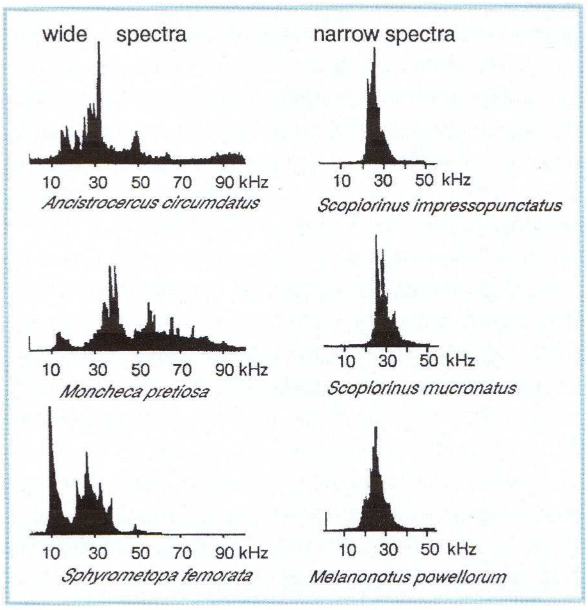

Figure 1 Power spectra of Neotropical *Tettigoniidea* (rearranged after Morris & Beier 1982). Sound amplitude (in relative units on the linear scale) is plotted against frequency. Species on the left have wide frequency spectra, reaching far into ultrasound. Species on the right have narrow carrier frequencies (after Riede 1998, with permission from the author).

This 'acoustical fingerprinting' of different species allows non-invasive mapping to be carried out and considerations about the structure of the 'acoustic community' to be made. To fully describe a community it is necessary to know both the number of species and also their relative abundance. From this, diversity indices can be calculated which combine both species richness and relative abundance into a single statistic. The most commonly used of these is the Shannon-Weiner Index. In Ecuador the index value was H = 2.789, which is rather low when compared with other values obtained when trapping tropical morphospecies, which can reach values as high as H = 5.0 for moths attracted to light in Papua New Guinea (Herbert 1980). One explanation for this could be that reduced diversity has been observed in communities with strong biotic interactions (Caswell 1976). In this case biotic interaction could perhaps be interpreted as competition for acoustic transmission channels.

Discussion

The example discussed here suggests that calling behaviour can be exploited for biodiversity assays in rainforests. The species-specific songs of crickets are an excellent tool for the taxonomist because they evolved for the recognition of conspecifics, and therefore fulfil the very definition of the biological species concept. The acoustic traces recorded at any one location provide a good indication of the number of species. However a comparison of local with regional diversity will only be possible when a larger database of the sounds in different areas exists. Automating the detection and analysis of the sounds could facilitate this. This allows mapping of the different cricket species in the field. A 'cricket detector' is being developed by using neural networks (Dietrich *et al* 2001), which allows more efficient classification and preliminary analysis in the field by displaying relevant parameters like frequency and pulse rate. Songs of other insects like katydids (*Tettigoniidae*) and cicadas (*Cicadidae*) are more complex than cricket songs (for Cicadidae, see Riede 1995). However acoustical analysis is facilitated tremendously by ongoing advances in computer technology, so that this method will also be applicable to these insect groups within the near future.

One of the most attractive elements of this technique is its non-invasive character, compared to fogging, which is widely accepted by the public and conservation agencies. The other is that it can be adapted to monitor hard to access habitats such as tree canopies, where microphones could be pulled up to the top of trees on ropes.

This acoustic inventorying and monitoring of *Orthoptera* species could provide the necessary data for the development of conservation strategies and for monitoring their successful implementation. Once identified, songs are a highly reliable taxonomic feature and allow determination down to the species level. Although this technique has only been applied to crickets, it has potential to be extended to other insects like cicadas (*Cicadidae*). The songs of many others groups are more complex than those of crickets, but with advances in computer technology it will not be too long before this analysis is fast and easy.

Despite these many advantages, the potential of acoustic surveys is still under exploited. One reason for this might be the poor state of insect song documentation. In most cases *Orthopteran* songs are published as spectrograms and/or oscillograms, but unfortunately scales of temporal and spectral resolution differ widely. Ideally songs should be cross-referenced to the recorded specimens which are often undescribed. The Australian Phonotek (CSIRO) fulfils these requirements and has a preliminary labelling system which assigns number codes for species with uncertain taxonomic status (Rentz 1987, Rentz & Balderson 1989). Perhaps the worldwide introduction of this system needs to be considered, especially as there is such a high number of undescribed tropical *Orthoptera* species. A German bioinformatics project is now trying to digitise and pool major sound collections within one 'Virtual Phonothek' (see www.dorsa.de).

Insects are particularly subtle indicators of habitat quality and diversity (Brown 1989); as cricket habitats are strongly determined by local microclimate, these data could serve as a subtle indicator of climate change in the area.

This paper has demonstrated the numerous values of having a virtual Phonotek library of insect songs for biodiversity. Leading on from this the implications of this technique for conservation are also clear.

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