ANDEAN ULTRASONICS: BIOACOUSTICS OF TWO TROPICAL MONTANE KATYDIDS

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1. INTRODUCTION

Ultrasonics are waves of airborne sound longer than ~1.7 cm (20 kHz) that, by definition, cannot be heard. The term distinguishes sound frequencies above the upper limit of human frequency sensitivity. But of course a dog, a bat or a cricket may hear such waves: animal sensory systems have 'unhuman' capacities. Ultrasonic is only a convenient descriptor for 'wavelengths above the limit of detection', applied illogically to animal species that hear these waves 'just fine'.

Some species of the singing insects known as 'katydids' (Tettigoniidae) produce and hear ultrasonics. The males make their sounds perching on plants. They rub their forewings together, which excites the oscillation of forewing membranes as sound radiators. Male calls travel through grasses, shrubs or forests to be heard by distant females: these females localize the singer and approach him for mating. Why such carriers should be ultrasonic is puzzling, because ultrasonic wavelengths interact poorly with plant environments; they don't carry well, and being higher energy at a given sound level, are relatively more costly to produce than audio frequencies. Ultrasonics would not seem a good choice for a beacon directed to potential mates at long range.

Two such katydid species comprise the genus *Myopophyllum,* both with a very high ultrasonic carrier. This is about the physical structure of their sounds and how they have evolved to make them 'elastically'. At present the 'why' of their ultrasonics remains a puzzle.

2. *M. SPECIOSUM* CALL GENERATION

Myopophyllum. speciosum (Fig. 1) has a duty cycle of <2% (Morris et al. 1994): on average, every 8s they produce a call that consists of two brief pulse trains. Together the two trains are about 150 ms in duration. The first train has 9 pulses in 50 ms; after an interval of 50 ms a second train of 12 pulses is given.

The pulses in the trains are quite short, sinsusoidal and set relatively far apart in time. They repeat at a rate of about 230/s. The spectrum of the call is a single narrow (high-Q) ultrasonic peak averaging 81,000 Hz. This peak frequency is a stable feature of each individual caller, but varies widely between individuals: from 67 to 95 kHz (Morris et al. 1994).

3. A NEW SPECIES AND ITS SONG

In 2003 on a trip to Ecuador, within the valley system on the eastern side of the Ecuadorean Andes where *M. speciosum* occurs, we discovered a second species of *Myopophyllum* (Fig. 2). As for many tropical katydids, this species remains undescribed and unnamed. I refer to it here as *sp. nov.* An adult male was taken at an elevation of about 2000 m, near Cosanga (San Isidro Cabanas). Later nearby, we located several more specimens by the Rio Alisa.

Figure 1. Male of *Myopophyllum speciosum* calling from understory near Baeza, Ecuador.

Figure 2. *Myopophyllum sp. nov.* male from montane rainforest above Cosanga, Ecuador.

We recorded and analysed the call of the new species. Like *M. speciosum* it has a low duty cycle, with two short trains of pulses separated by about a tenth of a second (Fig. 3 top trace). Each pulse within these trains is a sinusoid (Fig. 3 middle trace) of variable amplitude. The spectrum of this call has a single major peak of relatively high Q, centred on 73.4 kHz (Fig. 3 bottom trace). Another specimen was recorded and analysed with high-speed video (Montealegre et al. 2006). Together the two males gave an average carrier of 65.5 kHz (Montealegre et al. 2006, see their fig.4).

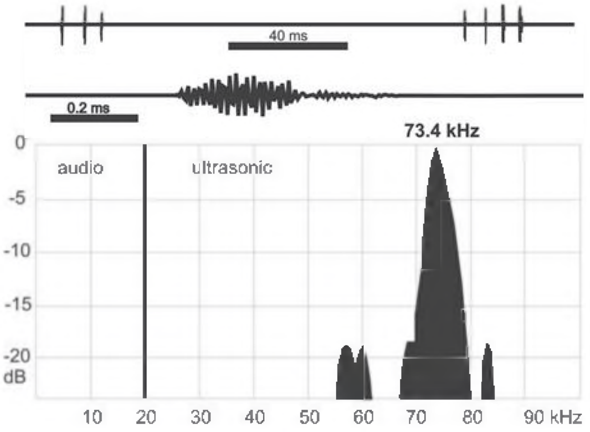

Figure 3. Analysis of one call of *M. sp. nov.* showing time domain and high-Q spectrum.

4. RESONANT VS NONRESONANT

The high-Q spectral peak of both these *Myopophyllum* species indicate generation by a resonant mechanism. Katydids make their sounds by friction of a file and scraper, these structures being on their forewings. Teeth comprising the file on the underside of one wing are traversed by the scraper, an edge of the other wing. This takes place in two ways termed resonant and nonresonant (Elsner & Popov 1978, Montealegre & Morris 1999).

In nonresonant mechanisms each tooth- scraper contact excites forewing membranes that oscillate at inherent frequencies, creating a transient pulse. Many such short complex-wave pulses per wingstroke (one pulse, one tooth) produce a band spectrum. In resonant mechanisms radiator movement gates passage of the scraper along the file. The emitted sound frequency in resonant systems is thus the same as the tooth contact rate: one wave, one tooth.

5. DISTORTION SPEEDS SCRAPER

But how is a resonant mechanism possible at 70 kHz? One cannot contact teeth at rates of 70,000 per second using just the muscle power closing the wings. The rates of tooth contact exhibited by a number of katydid species, notably *Myopophyllum n. sp.* (Montealegre et al. 2006), are beyond the capacity of wing muscles to produce. And high-speed video shows that the bending of the scraper plays an important role. The forewings actually slow during the interpulse intervals and speed up during the pulse (Montealegre et al. 2006). To an extent scraper and wing are decoupled, allowing the scraper to move at different velocities: it lodges briefly behind a file tooth and becomes bent by ongoing progress of the wings. Its distortion stores elastic energy, which when the scraper slips free, contributes to speeding scraper advance. The scraper drives at a rate of 70000 teeth/s at intervals along the file – albeit for only a few teeth at a time.

6. ADAPTATIONS

The songs of the two species are similar and in contrast to most katydid species, it would be difficult to use the physical structure of their calls to distinguish them. So it is unlikely this signal serves to keep females from approaching a wrong-species male. Of course confusion would only arise if the two occupy the same region. They have not yet been found together, and in this mountainous area may well occupy ranges at different elevations.

The best explanation of ultrasonic adaptiveness in *Myopophyllum* remains eavesdropping (Morris et al. 1994). Some bats hunt katydids as food, guided by katydid calls (Belwood & Morris 1987). Ultrasonic frequencies attenuate more severely with distance than audio ones, so using them could reduce singer vulnerability to bats. The paradox of calling to distant listeners with a short-range signal carrier may thus be a trade-off between attracting females and limiting vulnerability to predators. The higher the ultrasonics, the more steeply loudness decreases with increasing distance from the caller. The ears of females of *Myopophyllum* may be tuned to these carriers, helping to compensate for the female's increased localizing difficulties (Mason et al. 1991).

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