1. Introduction

• A database of a total of around 1,200 calls, from 31 bullfrogs was recorded in the swamps of Missouri (Bee and Gerhardt, 2001, J. Comp. Psych.)
• Along with the calls, information about the mass and length of the frogs and the air and water temperature at the time they were recorded.
• Most of the bullfrogs were recorded on at least two occasions, when the air and water temperature were different.
• We analyzed the data to find the effect of frog size and temperature on several features of the calls. Research in this area is ongoing, with the goal of better understanding the sound production mechanism of the bullfrog and how information about frog size is encoded in the call.
• This study sets the groundwork for further investigation of the physics of the bullfrog’s calling mechanism.

2. Features – Three Timescales (see fig. 1)

• Microstructure. We look for a change in the fundamental frequency ($f_0$) of the call with changing temperature and frog size. The software PRAAT was used to extract the fundamental frequency of the stable central portion of each note in the data set using an autocorrelation method.
• Individual note. The rise time, fall time and inter-note interval were measured using a simple model which modulated the amplitude envelope of the call as roughly triangular, fitting straight lines to the onset and offset of the call.
• Whole Call. The number of notes in a call was counted and information in the distribution of note amplitudes across the call gathered. We also gathered information in the amplitude distribution of notes using a simple quantity: the envelope peak rating (EPR).

The motivation: to see if large frogs advertise themselves with a call made up of a different distribution of notes than a smaller frog.

• The envelope peak rating (EPR) is the ratio of call duration to the FWHM of the normalised call envelope.
• Is the variation on each scale dominated by a random instability in the calling mechanism, or is a systematic effect depending upon other factors such as conscious control by the frog, or its size and temperature?

3. Size-temperature trade-off

• The data contains information about the effect of two independent variables: the frog size (which is manifested in mass and length) and the ambient temperature at the time of recording (manifested in the air and water temperatures).
• We wished to analyse the effect of these two variables on each of the measured features. The best visual representation of a function of two variables such as this is a surface rising above the size-temperature plane.
• The configuration of this surface defines the trade-off between the effect of the two variables on the feature in question.
• Each surface is interpolated from a number of points, each point summarises the feature for a cut.
• The model employed is of a power-law relationship between the feature of the call we are looking at and the temperature and mass variables: $f = A M^m$.

Where $f$ is the feature we are investigating, $T$ is the temperature variable, raised to some power, $M$ is the mass variable, raised to some power, $A$ and $m$ are constants.

4. Results (see fig. 2)

• Four surfaces were fitted for two variables of interest, with combinations of mass, length, air temperature and water temperature. Of these, the surfaces which were of greatest interest were the $f_0$ and the inter-note interval surfaces.
• The $f_0$ surfaces show that the fundamental frequency of a large frog is lower than that of a smaller frog. The dependence on body length is $f_0 \propto L^{-1.5}$, $RSD=5\%$ and is stronger than the dependence on mass: $f_0 \propto M^{-0.3}$, $RSD=5\%$. The greater dependence upon length would suggest that the frog is not using a vocal-structure to convey other features.

• The consistency in these results serves to confirm our confidence in the maximum likelihood approach and its quantitative predictions regarding the $f_0$.