SONIC EXPRESSIONS OF CHANGES IN THE PERCENTAGE COVER OF PURPLE MOOR-GRASS, BY ALTITUDE, UNDER HILL SHEEP GRAZING IN WESTERN IRELAND

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ABSTRACT

Preliminary investigations into the sonification of data representing the percentage cover of Purple Moor-grass as a function of altitude over a 14-year period from 1995-2008 are presented. The source of the vegetation data was the Teagasc Hill Sheep Farm in Leenaun, Co. Mayo, which was grazed at 0.8 ewes/ha/yr. Purple Moor-grass was the dominant vegetation species. It underwent several contrasting changes by altitude over the 14-year period. Sonification was applied to these changes in order to enhance the comprehension and interpretation of their graphical presentation for attendees at lectures/conferences who suffer from impaired visual but not acoustic acuity. Five auditory graphs were created, each representing unique changes in percentage cover of the vegetation, especially Purple Moor-grass by altitude. Each auditory graph was designed to convey an accurate representation of the data, highlighting important features. Visual graphs corresponding to the auditory graphs are also presented.

1. RELEVANT BACKGROUND

1.1. Sonification and Auditory Graphs

Sonification is defined as "*the transformation of data relations into perceived relations in an acoustic signal for the purposes of facilitating communication or interpretation.*" [1] In this study we use the technique of Parameter Mapping Sonification [1][2]. This involves the mapping of data to an acoustic parameter (e.g. pitch, loudness, duration, timbre) of the sound such that a change in the data represents a perceptible and logical change in the acoustic parameter. The mapping should be such that the listener can perceive and interpret the important features in the data. A review of current research in Parameter Mapping Sonification is presented in chapter 15 of the Sonification Handbook [1]. Auditory graphs, sometimes referred to as sonified or sound graphs, are the auditory equivalent of visual graphs. In a study that tested the effectiveness of sonified graphs, Bonebright *et al.* [3], showed overall good accuracy in a task requiring students to match

visual graphs with the equivalent auditory graphs. The results also demonstrated no effect of musical experience for this matching task. The authors found that the lowest accuracy occurred for graphs that lacked a definite shape and for those with more than one variable. They noted that this could be because the processing of more variables is more challenging and time consuming. In general, it appears that, when created well auditory graphs are an effective method of data presentation [4].

1.2. The Data

The Teagasc Hill Sheep Farm, Leenaun, Co. Mayo, which was the source of the data, occurs in the western hill and mountain landscape of Ireland and has an average annual rainfall of 2100 mm. It contained c. 250 ha of unimproved (not fertilised), semi-natural, hill vegetation, which was grazed under a mainly free-range system by hill sheep at an annual density of 0.8 ewes/ha. Walsh [5] collected the vegetation data in the June to August period in each of nine years from 1995 to 2008. Almost 60 species of vegetation were present among which a deciduous grass known as Purple Moor-grass was clearly dominant throughout. The percentage cover of the vegetation was based on an estimate of species frequency using a flexible quadrat, 1.8 cm x 1.8 cm, to give 100 hits per hectare. The percentage cover of Purple Moor-grass and that of several other species was quantitatively analysed as a function of soil type, altitude and physiography over the 14-year period (from 1995 to 2008).

Here we present auditory graphs created from the data representing the percentage cover of Purple Moor-grass as a function of altitude. There were three altitude bands: < 150m, 150-225m, >225m, referred to as altitude band A (low), altitude band B (middle) and altitude band C (high) respectively.

2. AUDITORY GRAPH DESCRIPTIONS

A series of auditory graphs were created using Pure Data [6]. Pure Data is a graphical data-flow programming language that is used for sound and music creation and processing. It is freely available on a variety of platforms and allows for freedom in

sound design and in experimenting with different mapping parameters. It has been used in previous sonification and auditory graph applications. Some examples include Holmes [7] who designed an interactive display for ground level ozone concentration data and Pauletto and Hunt [8][9] who created an interactive toolkit for application in physiotherapy, flight analysis and in the sonification of EMG data.

2.1. Data Mapping

Vegetation data was not collected in five of the years (2000, 2003, 2005, 2006 and 2007) during the 14-year period (1995-2008) [5]. Therefore, sonification was confined to nine data values for each of the altitude bands.

The vegetation data is presented in five different ways each representing a different aspect of its percentage cover and change over time. Sonification, mainly following the guidelines outlined by Brown *et al.* [10] and Flowers [11], was applied to each aspect and is described in sections 2.2 to 2.6. The corresponding audio files are available on the electronic version of the conference proceedings. The percentage cover for each year was mapped to the pitch of the sound. Many sonification designs involve mapping the data value to pitch and, in his paper that summarises what does and does not work in auditory graphs, Flowers [11] advocates pitch as a convincing parameter for representing changes in data. The percentage cover data values are given to two decimal places and if mapped directly to pitch would be too low to perceive. Therefore a constant was added to all values such that the lowest pitch was middle C (261.6Hz). Across all auditory graphs the pitch range is kept between middle C (261.6Hz) and the G three octaves above (1568Hz). This ensures that all pitches are in a comfortable listening range [10]. The decimal places in the original data were preserved so some of the pitches fall between two notes e.g. a value of 60.71 corresponds to a pitch between C and C sharp.

In addition to displaying an accurate representation of the data, auditory graphs should also be pleasing to listen to and not tire the ear. Brown *et al.* [10] advocate the use of more complex musical sounds rather than sine tones in sonification. Here, we represent each one of the three altitude bands by a sound of unique timbre. The timbres were designed to be easy on the ear and to give a clear unambiguous sense of pitch. Altitude band A is represented by an enveloped phasor sound. Altitude band B is represented by a sound with 8 harmonics created by additive synthesis. Altitude band C is represented by a sound created through wave-shaping synthesis.

2.2. Auditory Graph 1: A comparison between the percentage cover of Purple Moor-grass at the beginning of the 14-year period and that of intervening periods at A low, B middle and C high altitudes

The data is graphed in Figure 1. Three separate auditory graphs, one for each altitude band, were designed to present a comparison between the percentage cover of Purple Moor-grass in 1995 and that of each subsequent year over the 14-year period. In each auditory graph the data is presented as a series of melodic interval pairs: the pitch of the first note represents the percentage cover in 1995 (diamonds in the visual graph) and that of the second note is the percentage cover for the

intervening year (height of bars), beginning with 1995 and ending with 2008. An increase/decrease in the pitch of the second note compared with that of the first indicates an increase/decrease in the percentage cover between the base year (1995) and the intervening year. A silent gap is used to represent the years where no data was available.
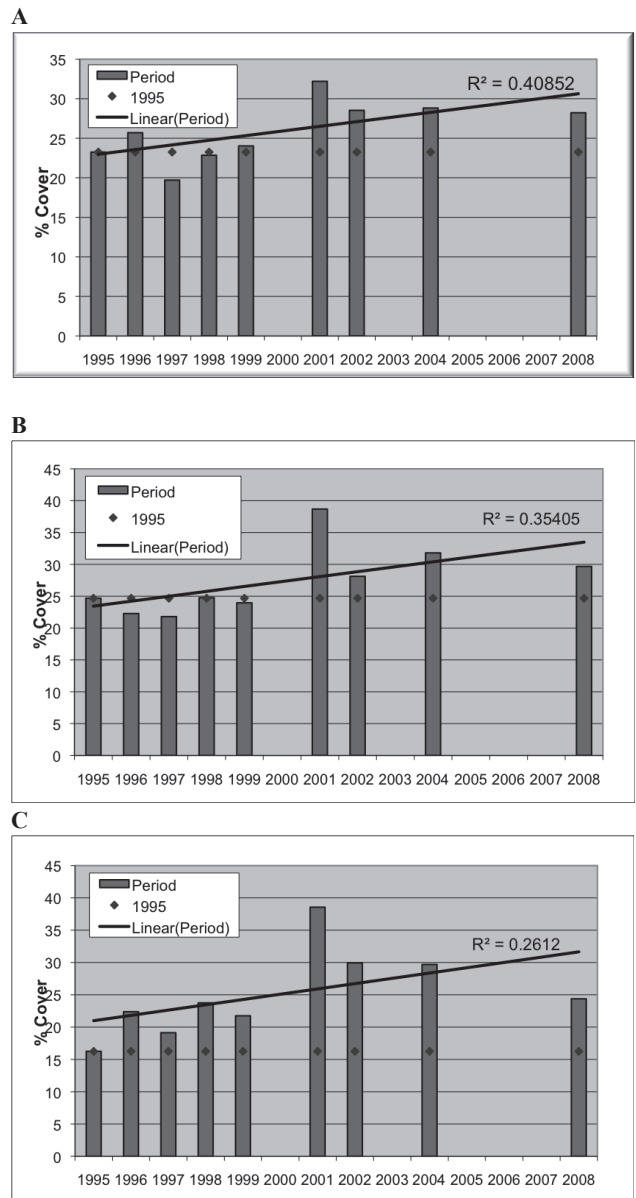
Figure 1: Comparison between % cover of Purple Moor-grass at the beginning of the 14-year term and that of intervening periods at A low, B middle and C high altitudes

2.3. Auditory Graph 2: A comparison of the percent cover of Purple Moor-grass across each altitude band for the 14-year period.

This auditory graph consists of a series of three-note melodies, one for each year, to allow the comparison of the percentage cover of Purple moor-grass across each altitude band. The graph in Figure 2 depicts this as bar height. Each note of the

melody is a different timbre representing each of the three altitude bands. Each melody is separated by a short pause and the years of no data are represented by a short, noise burst.
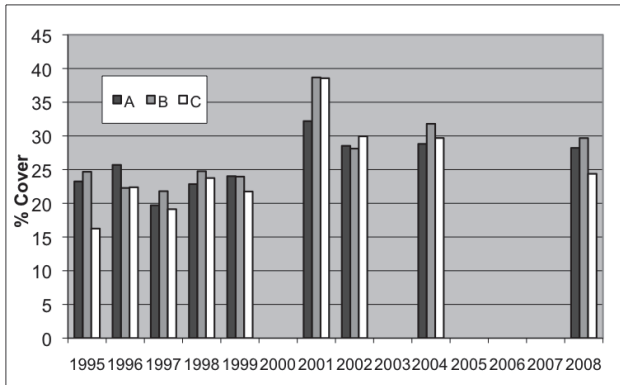

Figure 2: Variation in % cover of Purple Moor-grass over a 14-year period at A low, B medium and C high altitude

2.4. Auditory Graph 3: A comparison between the 14-year term difference and consecutive year differences in the percent cover of Purple Moor-grass at A low, B middle and C high altitudes.

The data is graphed in Figure 3. Three separate auditory graphs were compiled: one for each altitude band. For each altitude band the difference between the percentage cover of consecutive years was calculated (e.g. 1996-1995; 1997-1996; 1998-1997 etc.). The difference between the percentage cover of the final and initial year (2008-1995) was also calculated. This illustrates how the percentage cover of Purple Moor-grass changed between consecutive years compared with the variation over the entire 14-year period. Each difference value was mapped to the pitch of the sound. In cases where the difference was negative (seen as the downward bars in the graph), vibrato was added to that sound in the sonification design. In each auditory graph, a series of melodic interval pairs were used to represent the comparison between the overall 14-year term difference (diamonds in the visual graphs) and each consecutive difference value (bar height). Silent gaps were used for years where no data was available.
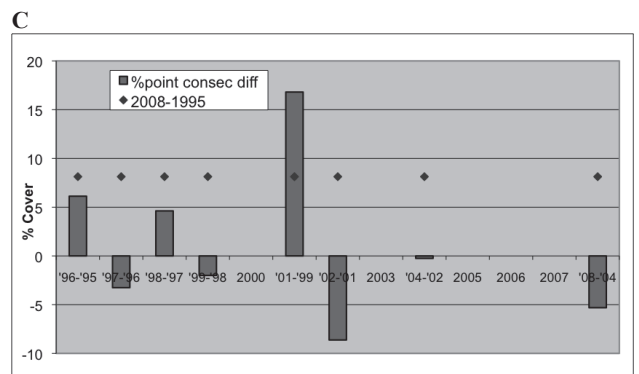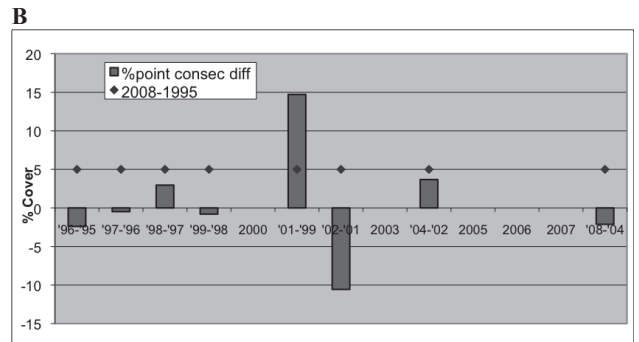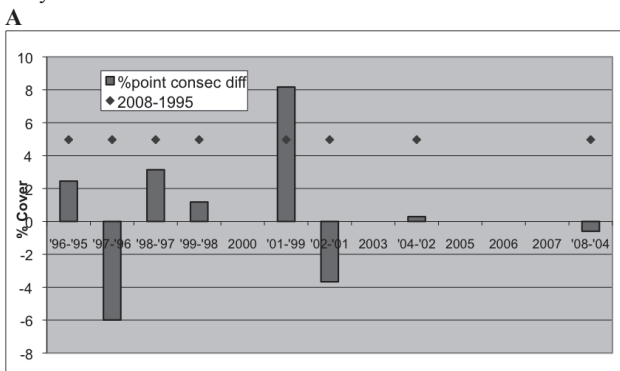
A

B

C

Figure 3: A comparison between the 14-year term difference and consecutive year differences in the % cover of Purple Moor-grass at A low, B middle and C high altitude

2.5. Auditory Graph 4: A comparison between the 14-year term difference and differences between intervening years and the base year (1995) in the percentage cover of Purple Moor-grass at A low, B middle and C high altitudes.

The data is graphed in Figure 4. Three separate auditory graphs were created: one for each altitude band. Each presents the difference between each year and the base year (indicated by the bar height in the visual graph) alongside the overall 14-year term difference (indicated by the diamonds in the visual graph), as melodic interval pairs (e.g. 2008-1995 and 1996-1995; 2008-1995 and 1997-1995 etc.).   The overall term difference is always presented as the first note in the interval. So if the overall term difference is greater than the difference between a particular year and the base year the interval falls and if it is less, the interval rises. In cases where the difference was negative (seen as the downward bars in the graph), vibrato was added to that sound in the sonification design. Where the differences were positive as in altitude band C (bottom graph), vibrato sounds do not occur.
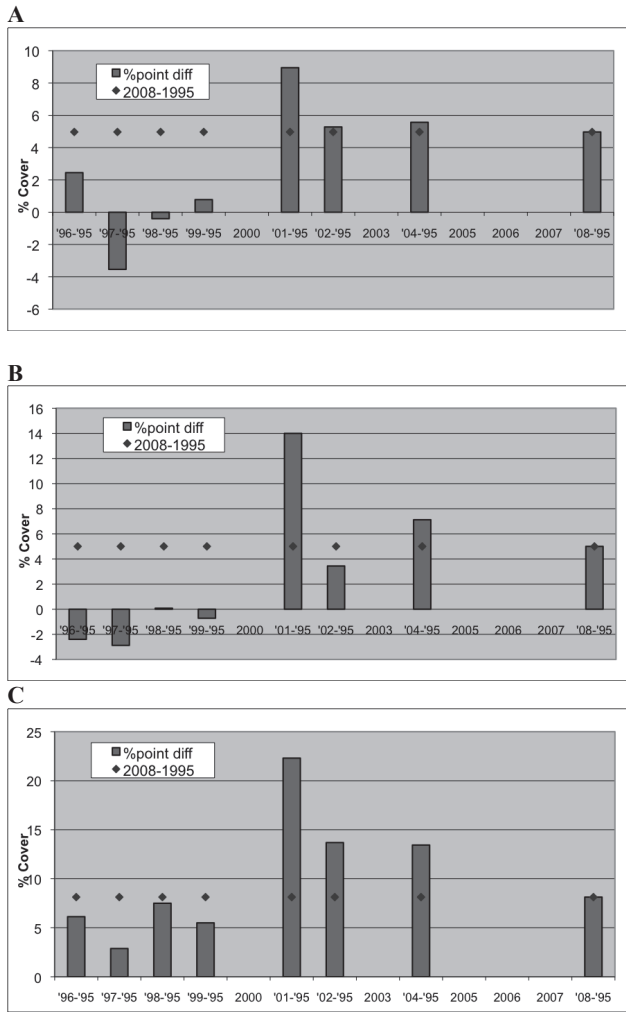
105

A

B

C

Figure 4: A comparison between the 14-year term difference and the differences between intervening years and the base year in the % cover of Purple Moor-grass at A low, B middle and C high altitude.

2.6. Auditory Graph 5: A comparison between the percentage cover of all vegetation and that of Purple Moor-grass over the 14-year term at A low, B middle and C high altitudes.

The data is graphed in Figure 5. Three auditory graphs were designed to compare the percentage cover of all vegetation with that of Purple Moor-grass over the 14–year period at each altitude band. The timbres used for Purple Moor-grass at each altitude band are as before. A different timbre was designed to represent the percentage cover of the overall vegetation. The percentage cover is mapped to the pitch of both sounds. In these sonification designs the percentage cover of overall vegetation and that of Purple Moor-grass are spatially separated, one to each ear. The spatial and timbral separation allows the ear to follow both streams with relative ease, or one can choose to focus on the percentage cover 14-year trend of either Purple Moor-grass or that of overall vegetation. A silent gap is used to represent the years where no data was collected.
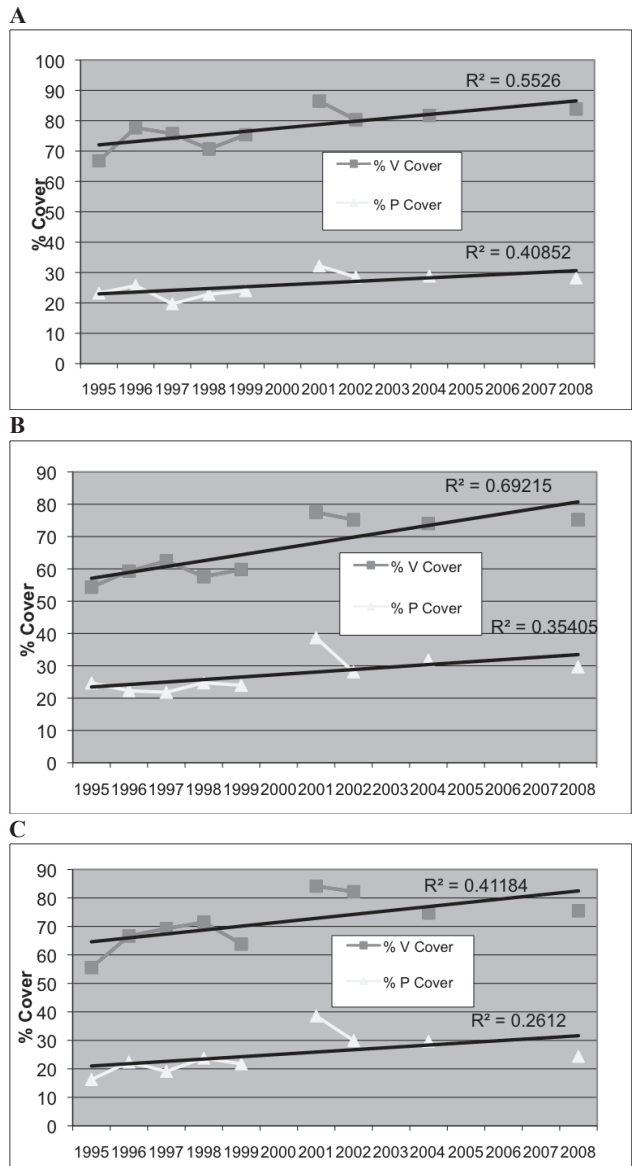
A

B

C

Figure 5: A comparison between the % cover of all vegetation with that of Purple Moor-grass over the 14-year term at A low, B middle and C high altitudes

3. OBSERVATIONS AND CONCLUSIONS

Data representing a number of aspects of the percentage cover of a dominant species of semi-natural hill vegetation in western Ireland under a known grazing system are presented both visually and sonically. The complexity of the information on the vegetation cover especially where various differences between specific groups of data are compared may be daunting to even the most attentive audiences. This exercise represents an initial application of sonification to the percentage cover and changes therein of a particular vegetation species over time by altitude. The change in the percentage cover was mapped to the pitch of the sound, the altitude band was mapped to timbre and

vibrato was used to represent negative values, which arose during a comparison of some of the differences. It is hoped that evaluation will help identify which of the above set of auditory graphs are most effective in conveying the contrasting changes in this environment under a particular land use system. In the final sonification design, which compared the percentage cover of Purple Moor-grass with that of overall vegetation, spatial separation and timbre in addition to pitch were used as mapping parameters. The use of spatial and timbral separation, to differentiate between the Purple Moor-grass and overall vegetation percentage cover, minimized unwanted grouping and should allow the listener to follow and compare these parameters with relative ease. Silent gaps and, in one case, noise bursts were used to represent years where no data was available, allowing the listener to clearly identify where data was missing.

The listener, in all the auditory graphs, is required to interpret from the direction of the pitch change whether there was an increase or decrease in the percentage cover, for a particular year. Neuhoff *et al.* [12] demonstrated that musical training is important in sonification designs especially when the listener is required to recognize the direction of pitch change. They showed that non-musicians had difficulty in perceiving the direction of pitch change especially for small intervals. This highlights the importance of training in the perception and interpretation of auditory graphs. Of equal importance is the ability for the user to experiment with different ways of representing the data that allows the best interpretation for them, in a similar fashion to how we work with visual graphs. However, in the cases here, we feel that an appropriate introduction together with brief explanatory comments, as presented above, would not only enhance perception and interpretation but also increase the retention time-span of complex changes that are displayed in graphical form. This will be tested in an evaluation of the graphs, which is the focus of future work.

4.   FUTURE WORK

Future work will include an evaluation of the auditory graphs presented. This is to determine the most effective mapping and presentation (e.g. tempo/playback speed) parameters, and will involve studies designed to investigate listener perception and comprehension and whether or not there are requirements for learning and training.

Additional parameters could be included in the sonification design e.g. auditory cues could be added to identify individual years (i.e. the equivalent of the x-axis tick marks) and statistical significance.

5.   ACKNOWLEDGMENTS

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