# An empirical method for the recognition of individual male Ring Ouzels *Turdus torquatus* from their song in the Rosedale area of the North York Moors using audio recordings and spectral analysis

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## Introduction

The recording of bird vocalization and their analysis by means of software packages specifically designed to display frequency and time features, has been the subject of a number of papers over the years.

In an article published in Ibis, *Recognition of individual European Nightjars Caprimulgus europaeus from their song* (Rebbeck et al. 2001), the analysis of nightjar vocalization using sonograms[1] to identify individual birds is described in some detail.

A paper in the journal of the International Zoo News, *Non-Invasive Sex Recognition in the Whitefaced Whistling Duck Dendrocygna viduata* (Ilya et al. 2003), described a non-invasive method using audio recordings and spectral analysis to measure temporal parameters for sexing individual birds.

In the book *Ring Ouzels of the Yorkshire Dales* (Appleyard 1994), the author mentions recording many hours of ring ouzel song[2] and that… "It is my belief that it is possible to identify individual male Ouzels [from their song]". Appleyard took this observation no further and made no mention as to how this could be achieved.

The late Dave Stemple in 2005 produced clear evidence from his considerable library of ring ouzel audio recordings that the ring ouzel simple[3] song was specific to a geographic area. His recordings are to be found on the Umass[4] web site. Stemple's observations clearly showed that the simple song of ring ouzels of the nominate race *T.t.torquatus* in Scotland, England and Norway were shared by all members of a local group and were not sung in other groups. In other words, a ring ouzel has a dialect that is specific to a geographical area and, moreover, can be used to determine an individual's natal site, such as a particular glen in Scotland. He describes how the dialect takes on a main or homologous form, labelled *Type 1*, that is sung by all birds in that area. Other song types, labelled *Type 2* etc., appear within the homologous repertoire to a lesser extent. This is explained in greater detail on the web site. The *Type 1* and *Type 2* forms of the Rosedale dialect are shown at Annex 2.

The study that this paper considers was carried out mainly in the Rosedale area of the North York Moors and formed part of a wider study of the ring ouzel that started in 1999. Rosedale was chosen as the core study area for the species chiefly for its ease of access but also because of the landowners' willingness to agree access to areas that were not open to the public prior to Open Access being introduced in 2005.

Finally, the work done by Dave Stemple stopped short of using the song to identify individual male ring ouzels, but it was his detailed and fascinating study that prompted the work that is described in this paper.

**Footnote**

1. The sonogram horizontal (X) axis displays time in seconds. The vertical (Y) axis shows frequency in Hertz; abbreviated to Hz. The strength of the sound is shown by the darkness of the elements in the sonogram; loud sounds being black while softer or weaker sounds are shown as varying shades of grey.
2. Most birds produce a range of vocalisations that are used in a variety of situations, in general terms these can be categorised as: Singing - to attract a mate or defend a territory; Calling - to contact others or sound an alarm. With the ring ouzel, singing is confined to the breeding season and is the way the male proclaims or defends its territory, attracts a mate or teaches its own young the local dialect.
3. Stemple described the ring ouzel as having two distinct forms of song: simple and complex. The simple song is the form used in this study and can be described as a whistle of a few seconds duration at a frequency of around 3 kHz. The complex song is a short pulse of sound that is explosive in nature and thus rich in harmonics that has a wide range of frequencies extending beyond 6 kHz. Stemple was of the view that the intricacy and diversity of the ring ouzel complex song pointed to it being improvised on the spot and to have no readily defined pattern or limit and as such was unusable for the purposes of his study.
4. University of Massachusetts web link http://people.cs.umass.edu/~stemple/RZ/RZdialects.html

# Methodology

One of the strokes of luck when it came to analysing the sonograms of male ring ouzels recorded in the Rosedale area, was to discover that the homologous form of the local dialect had clearly defined time sections that permitted the method of measurement detailed at Figure 2 below. A similar technique based on this approach appeared in a paper in the journal of the International Zoo News (Vol. 50, No. 3 (2003), pp. 160-167), which described in some detail a non-invasive method of sexing White-Faced Whistling Ducks (*Dendrocygna viduata*) using audio recordings and spectral analysis.

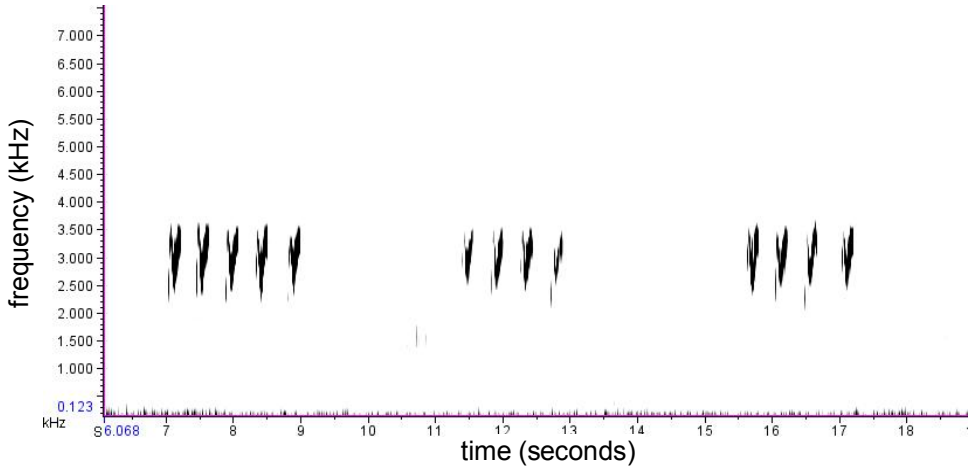


Figure 1: Sonogram of a typical ring ouzel simple song showing three distinct groups consisting of five and four notes. The number of notes sung in a group varies but often will be between two and four notes.

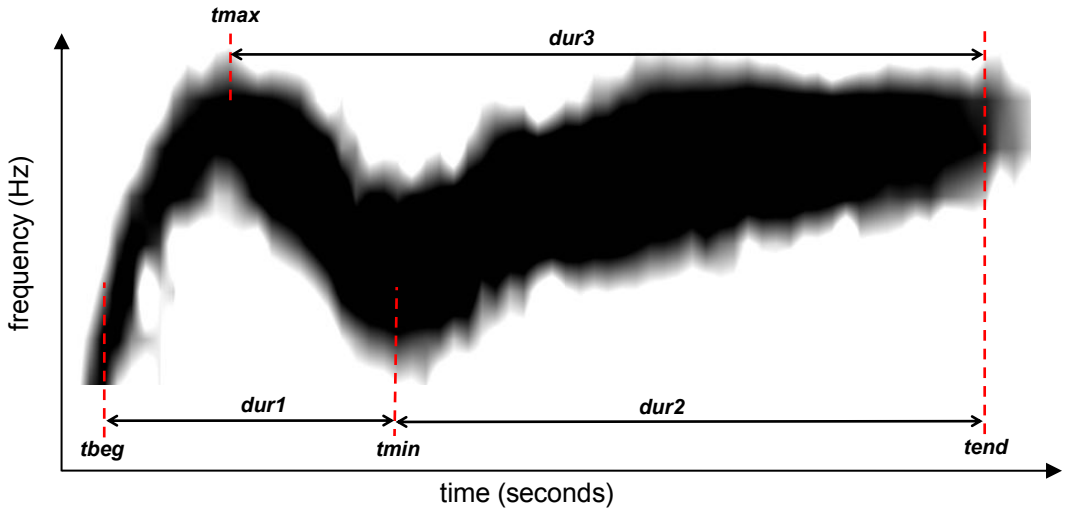


Figure 2: Sonogram of a typical time and frequency expanded single note of the Rosedale *Type 1* (homologous) ring ouzel simple song showing key measurement parameters.

**Comment**

Shown at Figure 2 are the points of measurement used for identifying individual Rosedale ring ouzels: beginning time *tbeg*, end time *tend*, maxima time *tmax* and minima time *tmin*. Also measurement of temporal parameters: durations of first and second sections *dur1* & *dur2* and duration between maxima time and end time *dur3*.

The analysis of the Rosedale *Type 1* song consisted of measuring the three temporal parameters - *dur1*, *dur2*, *dur3,* - for each note of the song. This was done for a minimum of 10 notes with the resulting mean and median tabulated - see Annex 1, Table 1.

From the outset the aim was to use a way of displaying the data that would be both visual and intuitive in its presentation and provide a relatively quick way of assessing the likely match, or not, of the recordings. As a first step the data from Annex 1, Table 1, is displayed using a three dimensional bubble chart with *dur1* on the *x* axis, *dur2* on the *y* axis and *dur3* the bubble area. Interpreting the bubble chart is then simply a matter of looking at the solid circles (bubbles) and seeing how close they are to each other. The closer they are the greater the confidence that the recordings are of the same bird - the logic being that when two recordings are made of the same bird then the bubbles should substantially overlap and appear as one. Conversely, non-overlapping and well separated bubbles are likely to be recordings of different birds while bubbles that are slightly separated could be the same bird, in this situation a statistical approach is used to confirm a match or otherwise. Figures 3a, 3b and 3c below show how the bubble charts would appear in situations when the bubbles are well-separated, close and overlapping.

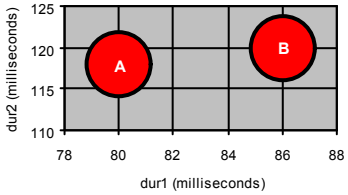


Fig. 3a: Recording 'bubbles' A & B are non-overlapping and well-separated, as such they are unlikely to be the same bird.

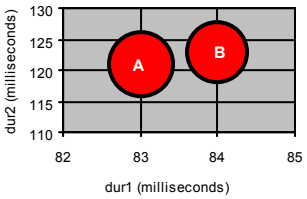


Fig. 3b: Recording 'bubbles' A & B are slightly separated indicating they may be same bird - further analysis using a statistical approach is used to test this assumption.

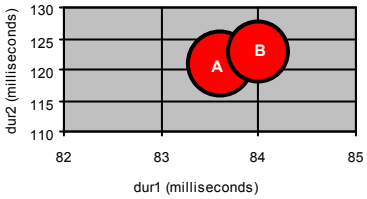


Fig. 3c: Recording 'bubbles' A & B are overlapping indicating they are most likely the same bird.

Composite bubble charts constructed from data at Annex 1, Table 1, are shown at Annex 4, Figures 1-3. Because of the cluttered nature of these charts, selected areas have been expanded in Figures 4-8 to permit more detailed analysis of individual recordings.

When bubbles are found to be non-overlapping and only slightly separated then two statistical tests are performed on the temporal data. One test uses a 'box and whisker' chart to show the amount of overlap (or not) between the two datasets, a second test uses the 'two-sample t-Test' to see whether or not the means of the two sets of data are equal or different. The t-Test is performed using the Data Analysis feature of Excel on *dur1*, *dur2* and *dur3* of each recording to test the null-hypothesis ($H_0$) that the means of the two recordings are equal. This is performed after first assessing if the variance of the data is equal or unequal using the F-Test feature of Excel and then selecting the t-Test for either equal or unequal variance. Examples of the application of the statistical tests are shown in the Observations, Analysis & Interpretation section below.

Where possible a selection of notes was picked from across the entire repertoire to give a sample of notes representative of the beginning, middle and end parts of the recording. For example, from a five-minute recording (typically containing 50 or more notes), four notes would be selected from within the first minute of the recording, four from around the three-minute mid-point and the remaining four from within the last minute. Not all notes would be sufficiently clear to be of use in which case, especially for short recordings, the best would be used for analysis. Experimentation suggested there was little to be gained from selecting more than 10 notes for analysis as the means were found to rapidly converge beyond this.

It is thought likely that the method described above for identifying individual male ring ouzels in Rosedale could readily be adapted to suit the dialect found in other geographic areas and thus allow direct comparison to be made with other male ring ouzels within an area's local group.

Finally, the recording equipment used consisted of a directional Shotgun Microphone (36cm long) with foam windshield (a 20cm parabolic dish was used from 2015) and a Roland RO-5 compact digital recorder. The software package for analysis of the sound recordings used Raven Lite v1.0 - a free sound analysis programme from Cornell Lab of Ornithology. All recordings were stored as WAV files - an uncompressed audio format that preserves frequency and dynamic range.

## Observations, Analysis & Interpretation

This section looks at a selection of audio recordings that have been made over the past 10 years. Observations 1 to 5 use just the bubble charts to interpret the recordings and draw conclusions, while Observations 6 to 8 show how a statistical approach can be used to reach a conclusion when interpretation of the bubble charts alone could prove inconclusive.

### 1 Male recorded in 2011 returning to same location in 2012

A recording made on the 16th May 2011 of a male (EF) singing in a tree in the dale bottom at Round Hill east (SE694968) - and which had a nest close by - was found to have good correlation with a recording made 11 months later on the 23rd April 2012 of a male (FD) singing in the same tree. This was the first time a male ring ouzel had been recorded whose sonogram displayed a similarity over consecutive years and may point to the suitability of audio recordings for tracking an individual bird's movements from one year to the next. Annex 4, Figure 5, shows bubbles for recordings EF and FD.

### 2 Male recorded in 2012 returning to same area in 2013

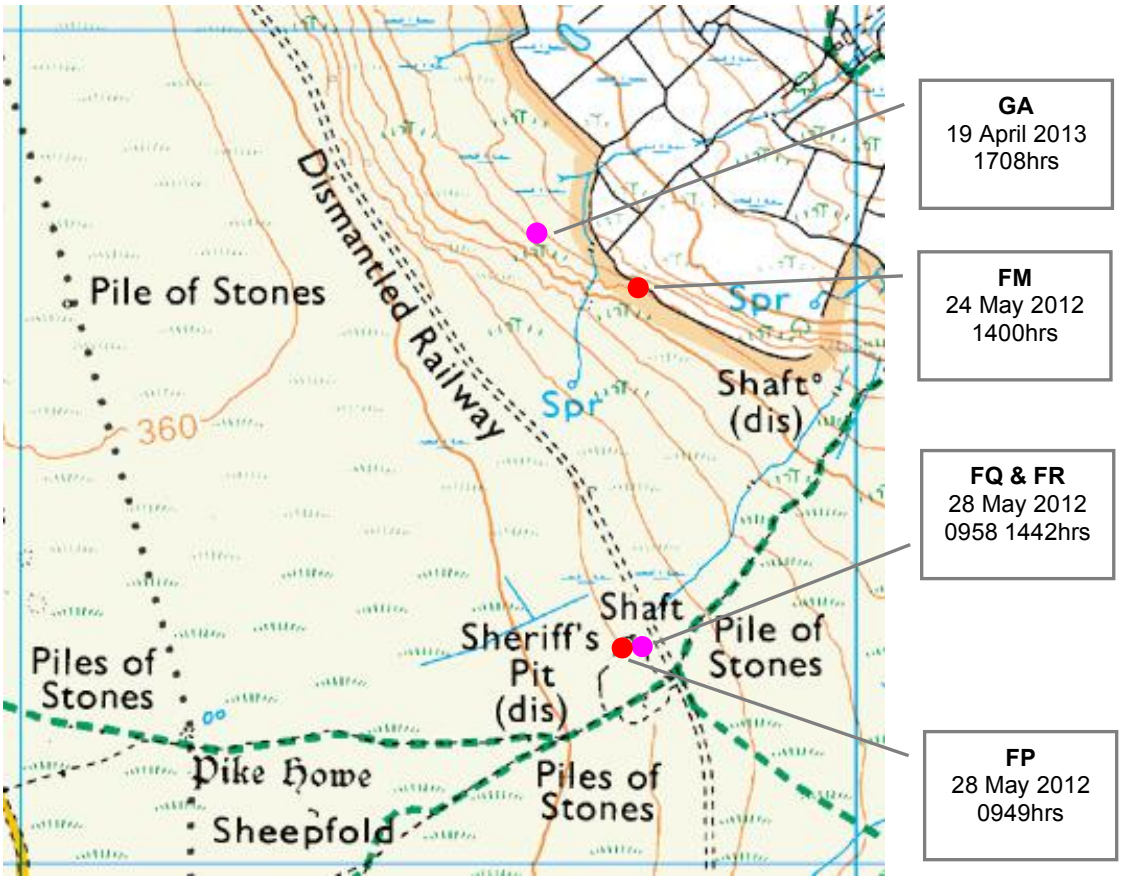


Figure 4: Map of Rosedale National Grid one kilometre square SE6996.

Recordings of a male (FQ/FR) singing on a fence post at Sheriff's Pit (SE697963) on the morning of 28th May 2012 at 0958hrs and again in the afternoon at 1442hrs (later shown by spectral analysis to be the same bird), showed good correlation with a male (GA) recorded 11 months later on 19th April 2013 in a tree at Round Hill south (SE694968). The positions of this male when the recordings were made are shown by a purple dot at Fig. 4, and as for Observation 1. above there seems to be a consistency in the bird's song from one year to the next - Annex 4, Figure 8, shows bubbles for recordings FQ, FR and GA.

## 3 Likely un-attached male moving around the area looking to attract a female - 1

On the 28th May 2012 a male (FP) was recorded singing on a fence post at Sheriff's Pit (SE697963) at 0949hrs - shown by red dot at Fig. 4. The bird flew off shortly after and was lost from view. Just nine minutes later at 0958hrs a male (FQ) - shown by a purple dot at Fig. 4 - was again recorded singing from a fence post at Sheriff's Pit. The bird recorded at 0958hrs was assumed to be the same male that was recorded nine minutes earlier. However, analysis of the sonograms of the two birds clearly showed that they were two different males and, furthermore, the bird recorded at 0949hrs was, from spectral analysis, the same male (FM) recorded four days earlier on the 24th May on the wall above the crags at Round Hill south (SE697967). The second male (purple dot) appeared to be the resident bird holding territory while the other male (red dot) was thought to be an unattached male looking to attract a female - Annex 4, Figure 7, shows recording bubbles FM & FP and Figure 8, bubble FQ.

## 4 Likely un-attached male moving around the area looking to attract a female - 2

A male was recorded in Matty Carr quarry (SE688984) on 26th May, 2014. The bird was in a tree near a nest that contained three pulli close to fledging. It was assumed that the male was associated with the nest. Two weeks later on 9th June 2014 a male was recorded singing in the quarry at Hob Crag (SE 714954). As with the Matty Carr quarry male, this bird was also singing for a long time and with gusto. The distance between the two locations was 4km. Analysis of the recordings showed a good match of the *Type 1* and *Type 2* forms, the later showing a distinct non-harmonic component at 4kHz – see Fig. 5a & 5b below.

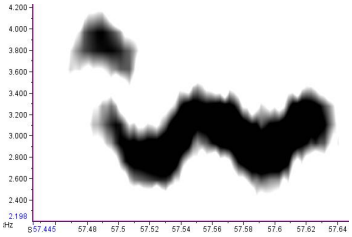

Figure 5a: *Type 2* Rosedale dialect recorded at Matty Carr quarry on 26 May 2014 showing distinct 4kHz non-harmonic component - compare with 5b.

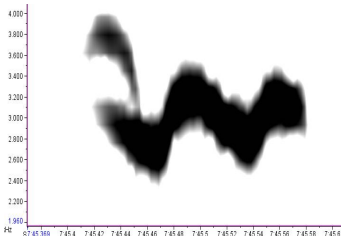

Figure 5b: *Type 2* Rosedale dialect recorded at Hob Crag quarry on 9 June 2014 showing distinct 4kHz non-harmonic component - compare with 5a.

Annex 4, Figure 3 & 7, show the bubbles for recordings HN and HQ. Annex 5 shows the sonogram for the Matty Carr recording with its associated *Type 1* and *Type 2* forms labelled.

## 5 Male recorded in 2014 recorded again in 2016 close to 2014 location

A male recorded on 24th April 2014 (HB) singing above Reeking Gill cutting (NZ689007) was found to have good correlation with two near identical recordings made in 2016 on the 15th April (JB) at Thorgill Bank west (SE702958) and three weeks later on 6th May (JH) at Reeking Gill (NZ691006); the later site with a female. The positions where the recordings were made are shown at Fig. 6 below. Annex 4, Figure 7, shows bubbles for recordings HB, JB and JH.

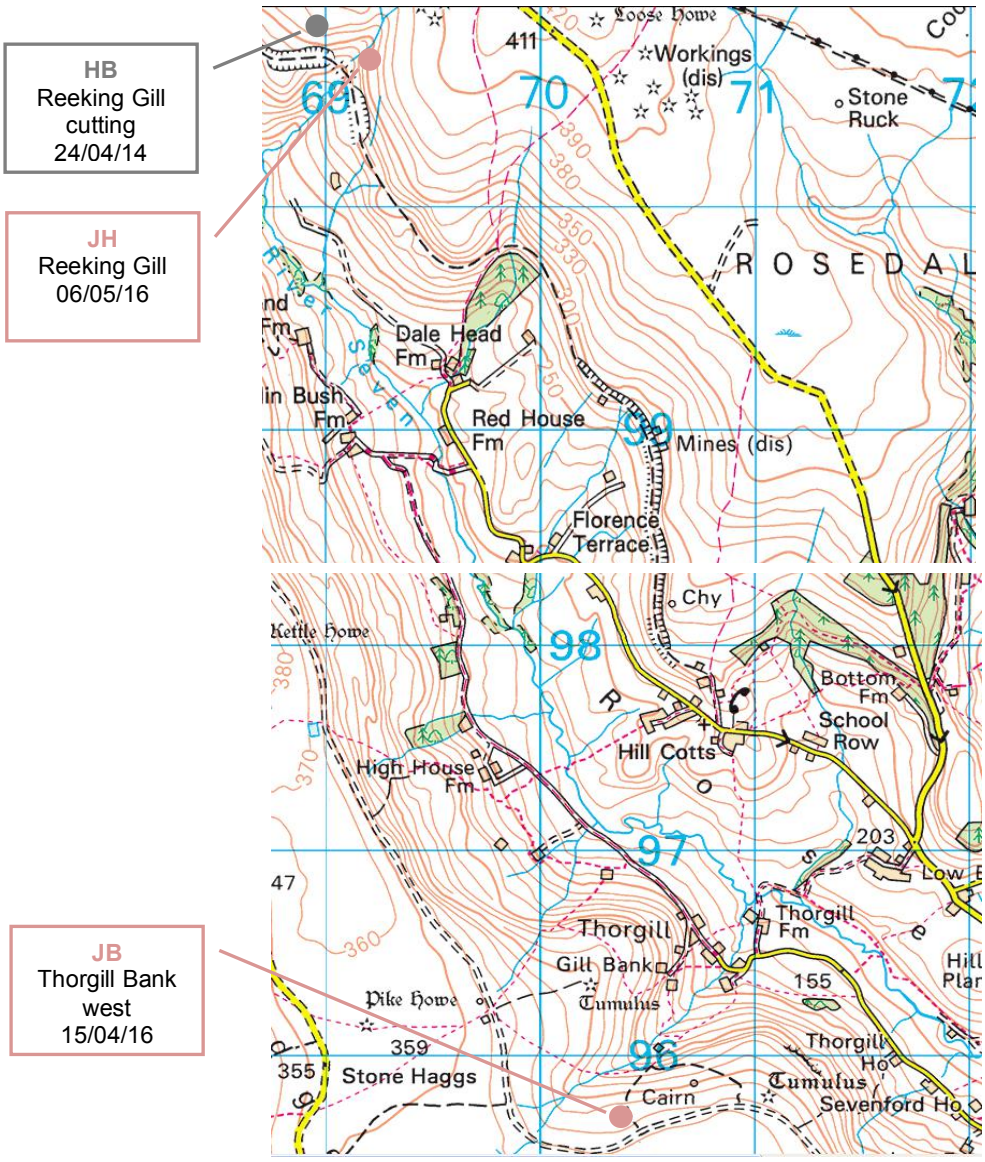


Figure 6: Map of north and central Rosedale showing location where recordings were made in 2014 and 2016.

# 6 Statistical analysis of two recordings confirming that they are likely the same bird

A male ring ouzel was seen singing in a tree just south of Sledge Shoe (SE691974) on 8th May 2014 and again in the same tree of 19th May 2014. First analysis of both recordings showed the three temporal parameters had a good match which suggested they were more than likely the same male, however, when plotting the results on a bubble chart the two bubbles were clearly separated giving rise to doubt as to whether or not it was the same bird - Annex 4, Figure 8, shows bubbles for recordings HL and HM. Further investigation using statistical analysis, detailed below, suggested both recordings were in fact the same male.

### a) Data analysis using 'box and whisker' presentation

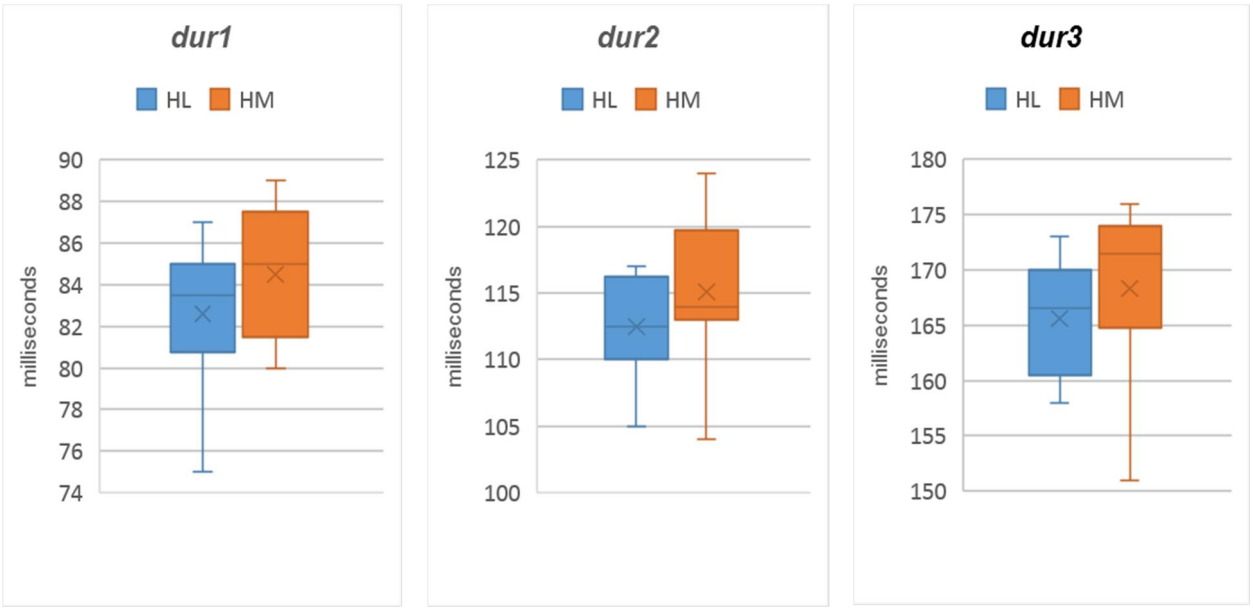


Figure 7: Temporal parameters *dur1, dur2, dur3* of recordings HL and HM. Horizontal line = median, X = mean, box = interquartile range (range between lower & upper quartile), vertical line = range from minimum to maximum value.

The interquartile range (IQR) is the range within which the middle 50% of the data are found. The IQR is a robust way of describing the dispersion of the data and, unlike classical statistical methods such as t-Test for comparing means and F-test for comparing variances, does not assume normal distributions or equal variance. Displaying the boxes side by side clearly shows if there are differences between the data sets and, what's more, can be applied without any statistical assumptions.

In Figure 7 above all three temporal parameters have a strong IQR overlap giving a high degree of confidence that recordings HL and HM are of the same bird.

### b) Data analysis using the 'two-sample t-Test' (t-Test)

The t-Test is performed to test the null-hypothesis ($H_0$) that the means of two recordings are equal and therefore the same. The null-hypothesis, which is assumed to be true until proven wrong, is that there is no difference between the two sets of data unless shown to be otherwise.

Using the Data Analysis feature of Excel, the t-Test is performed on *dur1*, *dur2* and *dur3* of recordings HL and HM - e.g. HL *dur1* and HM *dur1* are tested against the null-hypothesis, likewise *dur2* and *dur3*. Annex 5 shows the Excel calculations and the key parameters **t Stat** and **t Critical two-tail**. Applying these to the equation:

$$-t\ Critical\ two\text{-}tail(dur_n) < t\ Stat(dur_n) < t\ Critical\ two\text{-}tail(dur_n) \quad (n = 1, 2 \text{ or } 3)$$

it can be shown that the observed difference between the sample means of *dur1*, *dur2*, *dur3* of recordings HL and HM are **not significant** and therefore the null-hypothesis is satisfied and as such the recordings are considered to be that of the same bird.

## 7 Statistical analysis of two recordings confirming that they were unlikely the same bird and the conclusion that one was probably a singing female

A ring ouzel was observed at 1205hrs on 24th June 2013 perched on a fence post at the disused mine shaft at Sheriff's Pit (SE697963) singing a soft rendition of the simple song; the bird was seen with a beak full of worms at the time and was known to be feeding second-brood young in the pit shaft. After about a minute the bird dropped into the shaft and reappeared almost immediately without the worms and flew off out of sight. At 1248hrs a ring ouzel carrying worms appeared again on a fence post and sang softly for a minute or so before dropping into the shaft and reappearing around 30 seconds later without the worms and flying off. At the time it was assumed to be same male returning with food because of the similarity of the bird's plumage.

First analysis of the audio recordings and bubble-chart suggested they were different birds, the conclusion being that the nestlings were being fed by different males or that one of the birds was, in fact, a female; the plumage, particularly the gorget, of mature females can look similar to that of a male - Annex 4, Figure 3, shows bubbles for recordings GP and GQ.

Most authoritative books on ring ouzels make no mention of female song and Appleyard (1994) in his book, *Ring Ouzels of the Yorkshire Dales*, concluded that female ring ouzels do not sing. A short article by Gordon and Melling (2011) in British Birds, *Female Song in the Ring Ouzel*, provides conclusive evidence of the female ring ouzel singing. Recordings of two singing females at sites 3km apart - North Lees and Burbage Edge, Derbyshire - were made at the time both birds were feeding their second-brood young in the nest; a photo in the article clearly shows the female at Burbage Edge having a gorget of a similar whiteness to that of the male. A female ring ouzel was also observed at Spindle Thorn (SE713931), Rosedale, on 19th May 2014 singing within 5 metres of a first-nest that had four 9 day old chicks while the male was seen close by.

Analysis of recordings GP and GQ using a 'box and whisker' presentation is show below.

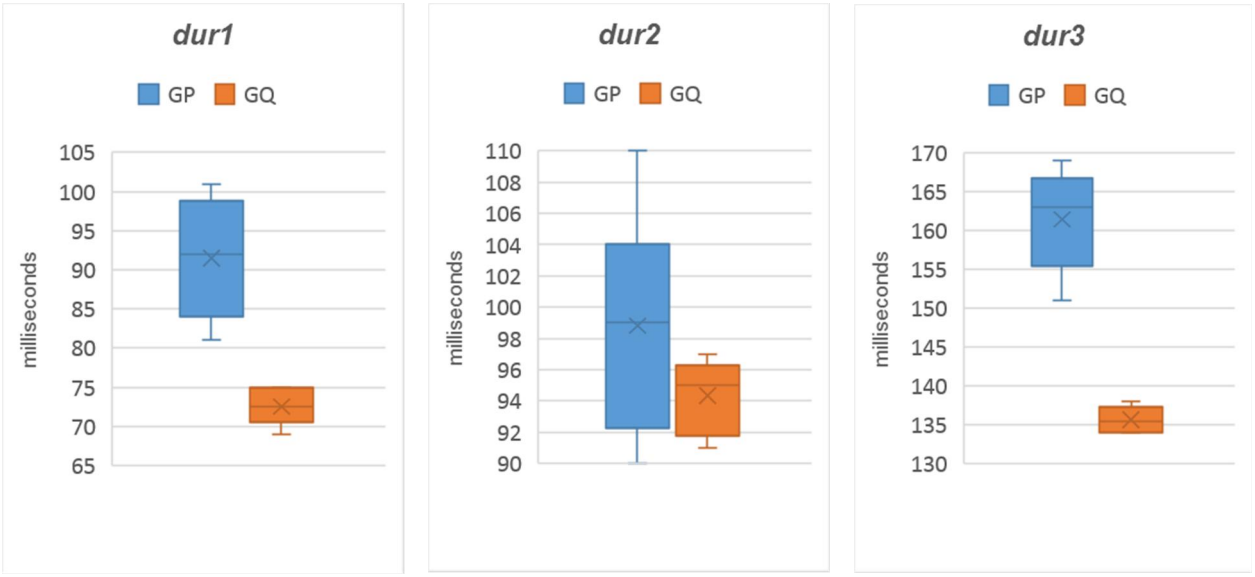


Figure 8: Temporal parameters *dur1, dur2, dur3* of recordings GP and GQ. Horizontal line = median, X = mean, box = interquartile range (range between lower & upper quartile), vertical line = range from minimum to maximum value.

In Figure 8 above temporal parameters *dur1 and dur3* have well separated IQRs while the IQR of GQ *dur2* overlaps only the lower quartile of GP IQR. The interpretation suggests recordings GP and GQ are most likely different birds and leads to the conclusion that one bird was in fact a mature female.

# 8 Statistical analysis of two recordings to determine the existence of either one or two territories

A ring ouzel was seen singing in a tree at Bank Top (SE720951) on 24th April 2015 at 1008hrs. Around 15mins later at 1023hrs a ring ouzel was seen singing on a wall just east of Hob Crag quarry (SE717952) approximately 400 metres from the Bank Top location. Recordings were made of both birds and analysed to see if they were the same male or whether or not they were different birds suggesting there could be two adjacent territories - Annex 4, Figure 7, shows bubbles for recordings IE and IF. An initial inspection of the bubble chart showed slightly overlapping bubbles. A more detailed analysis using a 'box and whisker' presentation (see Fig. 9 below) shows all IQRs to be overlapping with *dur1* almost totally.

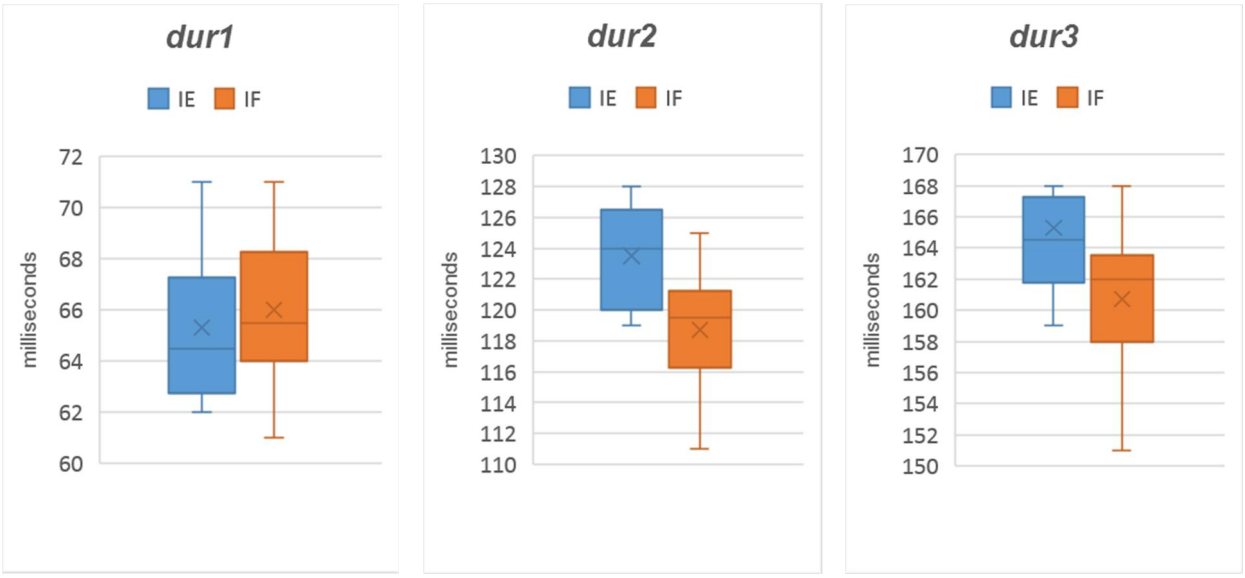


Figure 9: Temporal parameters *dur1, dur2, dur3* of recordings IE and IF. Horizontal line = median, X = mean, box = interquartile range (range between lower & upper quartile), vertical line = range from minimum to maximum value.

The conclusion drawn from Figure 9 is that recordings IE and IF were most likely the same male[1] singing from separate locations within its territory.

**Footnote**

1. Extensive observations of the bird's movements on 24th April revealed it had a nest on the moor plateau in the Bank Top area. The distance from the tree to the nest was 290 metres and from the wall to the nest 330 metres. This male was seen on other occasions over the following weeks singing from the same locations. The tree and the wall appeared to be the nearest features to the nest that could be used as song posts and were probably on the edge of its territory. These two song posts were adjacent to neighbouring territories at Bank Top east and Hob Crag quarry.

# Discussion

This is the first detailed study of ring ouzel song on the North York Moors (NYM) and the many recordings made in the Rosedale core study area confirm the predominance of a distinctive local dialect. It has also been interesting to note differences in the sonograms of NYM ring ouzels recorded in Northdale, Farndale and Bransdale. As expected one or two recordings have also indicated incomers or passage birds with other dialects.

The long established method of monitoring individual birds is the use of colour ringing and there are some excellent ring ouzel studies doing this notably in Scotland and elsewhere. There was no attempt to colour ring birds in Rosedale for the purposes of this study. Although it would have been instructive to combine colour ringing and sound recording, many pulli would need to be ringed given that fledgling mortality is high and first-year return rates are low and catching adults on the breeding grounds poses many problems. Locating returning colour ringed birds and then obtaining song recordings in sufficient numbers would also be fraught with difficulty.

The work done by Dave Stemple in the late 80s and early 90s made no attempt to use his audio recordings of male ring ouzels to identify individual birds, his sole aim being to show that the ring ouzel's dialect was specific to a geographic area. This study takes Stemple's work further by attempting to show that with more detailed analysis of an individual bird's song, it is possible to identify individuals and so track the bird's movements. The use of audio recordings to track individual ring ouzels is inevitably limited almost exclusively to males and to the breeding season and is not seen as an alternative method to colour ringing.

There were two questions that needed answering that are fundamental to using audio recordings to track individual birds. First, does the song stay the same throughout the season i.e. will a bird recorded in April display the same attributes when recorded again in June? Second, would those same attributes remain if the bird returns the following year? Without colour ringing individual birds, the answers to these questions will remain speculative. However, there is good evidence from the last 10 years of recordings to suggest that within the same season the key attributes remain unchanged and can be likened to the formant frequencies of the human voice where an individual person displays distinct vocal tract resonances regardless of age; even if they have a cold. Less clear is whether or not these individual attributes stay with the bird from one year to the next. Several recordings have been made where a good match of the bubble charts has been noted in successive years and that these recordings have been of birds territorial singing in the same place (one in the same tree). It is well known that male ring ouzels are site faithful and so the tentative conclusion is that these recordings were of males returning to their natal sites for a further breeding season.

There is much more to be done in analysing the song of ring ouzels. One area that needs further work is whether or not adult males pass on not only the dialect but also a 'carbon' copy of the key attributes of the song to their young; in effect producing male progeny whose song is an exact or near replica of the parent bird. If this was to be the case, then it could make identification of individual birds that more difficult and could explain why several charts show bubbles that are clustered in successive years. An outcome that could occur when parent and young return to the natal area to breed. On the other hand, beyond teaching the young the local dialect, it may be that individuals obtain their own distinctiveness in much the same way that humans pass on the dialect to their own young but who then have their own individual vocal traits. For the moment, however, it is assumed that these individual traits in ring ouzels, formed through resonances in the bird's syrinx, provide each bird with a unique 'voiceprint' that enables it to be readily identified by its song.

Analysis of the many recordings made over the last ten years has given confidence that the method described in this paper provides a relatively quick and reliable means of identifying individual male ring ouzels in the Rosedale area. The technique is considered to be sufficiently reliable to permit the identification of individual males and as such is a useful tool for monitoring movement within the dale and as a means by which a male's territory can be determined.

## Conclusion

The results to date are encouraging and suggest that spectral analysis of the song of male ring ouzels in the Rosedale area can provide the means to identify and track individual males.

# Further Reading


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# Annex 1 - Table of Sonogram Parameters of Rosedale Ring Ouzels

Table 1: Mean and median values of duration parameters *dur1*, *dur2*, *dur3* measured from sonograms of sound recordings taken at various locations in Rosedale, North York Moors, in years 2003 and 2008 to 2016.

| ID | Year | Date | Location | N.G.R. | ***dur1*** milliseconds mean (median) | ***dur2*** milliseconds mean (median) | ***dur3*** milliseconds mean (median) | Sample Size | Remarks |
|---|---|---|---|---|---|---|---|---|---|
| AA | 2003 | 22 April | Blakey Bank | SE684989 | 74 (75) | 142 (140) | 184.5 (186) | 10 | |
| AB | 2003 | 23 April | Bank Top near kilns | SE721948 | 54 (52) | 100 (99) | 130 (129.5) | 10 | |
| AC | 2003 | 23 April | Bank Top near cottages | SE720951 | 89 (88) | 103 (103.5) | 157 (159.5) | 10 | |
| BA | 2008 | 5 June | Dalehead north | NZ679010 | 62 (59) | 135.5 (134) | 173 (170.5) | 4 | |
| BB | 2008 | 5 June | Nab Scar (below) | NZ692002 | 75 (76) | 137 (137) | 180 (181) | 10 | |
| BC | 2008 | 15 May | Reeking Gill | NZ692006 | 74 (72.5) | 137 (137) | 180 (178) | 10 | |
| BD | 2008 | 29 May | Round Hill | SE694970 | 85 (83.5) | 63 (64.5) | 125 (124) | 6 | |
| BE | 2008 | 29 May | Round Hill south | SE697966 | 65 (66) | 137 (135) | 174 (175) | 10 | |
| CA | 2009 | 6 April | Round Hill | SE694970 | 79 (82) | 107 (105) | 166 (165) | 15 | |
| CB | 2009 | 14 April | Matty Carr quarry | SE688983 | 75 (75) | 134 (136.5) | 183 (184.5) | 20 | |
| CC | 2009 | 16 April | Nab Scar (mid) | NZ694000 | 70 (67.5) | 133 (137) | 179 (182.5) | 12 | |
| CD | 2009 | 27 April | Dalehead west | NZ680010 | 89 (92) | 115 (115) | 182 (184) | 15 | |
| CE | 2009 | 30 April | Hob Crag | SE714953 | 81 (82) | 59 (54) | 118 (116) | 15 | |
| CF | 2009 | 14 May | Sturdy Bank 1 - SE side of gill | SE699998 | 95 (98) | 114 (114) | 176 (179) | 17 | |
| CG | 2009 | 14 May | Sturdy Bank 2 - S of track in trees | SE699996 | 73 (73) | 131 (131) | 183 (184 | 13 | |
| CH | 2009 | 19 May | 250m south of Matty Carr | SE689981 | 68 (65) | 146 (153) | 193 (195) | 15 | |
| CI | 2009 | 21 May | 220m south Blakey Swang sth 1010hrs | SE687991 | 64 (63.5) | 130 (130) | 173 (176.5) | 8 | |
| CJ | 2009 | 21 May | 250m sth. Blakey Swang sth 0945hrs<br>300m nth. Matty Carr 0912hrs (same RZ) | SE687991<br>SE688987 | 73 (70.5) | 120 (122) | 173 (171.5) | 10 | |
| CK | 2009 | 21 May | 240m south Blakey Swang sth 0956hrs | SE687991 | 71 (72.5) | 129 (127.5) | 184 (184) | 14 | |
| CL | 2009 | 28 May | Reeking Gill sth of gill below track | NZ691005 | 70 (69) | 144 (147) | 187 (189.5) | 16 | |
| CM | 2009 | 28 May | Reeking Gill west | NZ689006 | 70 (73.5) | 118 (120.5) | 164 (163) | 14 | |
| DA | 2010 | 8 April | Blakey Swang south | SE686995 | 78 (79) | 147 (150) | 205 (205) | 15 | |
| DB | 2010 | 19 April | 400m sth Reeking Gill below track | NZ691002 | 94 (94) | 95 (95.5) | 153 (153) | 2 | |
| DC | 2010 | 19 April | Reeking Gill below track in pine tree | NZ690006 | 73 (75) | 118 (112) | 156 (159) | 7 | |
| DE | 2010 | 22 April | 500 north Matty Carr on wall. | SE688988 | 83 (82) | 133 (137) | 185 (187) | 13 | |
| DF | 2010 | 26 April | 300 north Matty Carr in tree. | SE687987 | 81 (82) | 133 (134) | 182 (190) | 9 | |
| DG | 2010 | 26 April | Round Hill south in tree. | SE694968 | 84 (86) | 107 (107) | 160 (159) | 6 | |
| DH | 2010 | 6 May | Round Hill south. | SE694968 | 84 (86.5) | 97 (99.5) | 153 (153.5) | 18 | |
| DI | 2010 | 6 May | Round Hill | SE694970 | 73 (74) | 114 (114) | 158 (156) | 13 | |
| DJ | 2010 | 13 May | Round Hill south | SE694968 | 73 (72.5) | 127 (127) | 168 (167.5) | 10 | |
| DK | 2010 | 20 May | Round Hill nest bird @ RH south. | SE694968 | 84 (83) | 103 ((99.5) | 157 (156) | 9 | |
| DL | 2010 | 3 June | Dalehead east quarry at 0940hrs. | NZ683007 | 80 (73) | 101 (101) | 148 (138) | 11 | |
| DM | 2010 | 3 June | Dalhead east quarry at 1345hrs. | NZ683007 | 74 (72) | 166 (173) | 203 (207) | 11 | |
| DO | 2010 | 6 June | Sheriff's Pit | SE697963 | 79 (80) | 101 (98) | 153 (153.5) | 10 | |
| DP | 2010 | 14 June | Reeking Gill small gill on west side | NZ691008 | 78 (75) | 126 (125) | 179 (180) | 15 | |
| EA | 2011 | 14 April | Reeking Gill west side in tree below track | NZ690006 | 78 (76.5) | 119 (114.0) | 180 (176.0) | 8 | |
| EB | 2011 | 18 April | Hob Crag | SE715954 | 82 (83.0) | 113 (117.0) | 166 (166.5) | 10 | |
| EC | 2011 | 18 April | Bank Top east | SE724947 | 69 (70.0) | 90 (90.5) | 129 (131.0) | 10 | |
| ED | 2011 | 21 April | Nab Scar south | SE696998 | 91 (93.5) | 94 (98.5) | 163 (163.0) | 10 | |
| EE | 2011 | 12 May | Reeking Gill west side in tree below track | NZ690006 | 84 (85.0) | 113 (115.0) | 163 (163.5) | 10 | |
| EF | 2011 | 16 May | Round Hill east, in tree towards R.H. sth. | SE694968 | 74 (72.5) | 113 (114.5) | 154 (156.0) | 8 | |
| EG | 2011 | 19 May | Sledge Shoe | SE691976 | 78 (77.5) | 123 (124.0) | 179 (179.5) | 10 | |
| EH | 2011 | 23 May | Round Hill east, in tree towards R.H. sth. | SE694968 | 71 (70.0) | 114 (115.0) | 152 (154.0) | 10 | |
| EI | 2011 | 31 May | Round Hill east, in tree near 1st nest. | SE694970 | 77 (78.5) | 125 (126.5) | 176 (174.0) | 12 | |
| EJ | 2011 | 9 June | Matty Carr north | SE687987 | 87 (86.5) | 101 (101.0) | 156 (157.0) | 10 | |
| EK | 2011 | 9 June | Matty Carr quarry | SE688983 | 86 (86.5) | 103 (101.0) | 156 (157.5) | 10 | |
| EM | 2011 | 2 June | Farndale - Round Crags | SE675995 | 75 (72.5) | 125 (124.0) | 173 (171.5) | 10 | |
| FA | 2012 | 10 April | Round Hill in tree towards Round Hill sth. | SE694968 | 77 (77.5) | 117 (117) | 164 (165.5) | 12 | |
| FB | 2012 | 12 April | Hob Crag in tree 150m south of quarry. | SE715954 | 69 (67.5) | 113 (111.5) | 154 (154) | 12 | |
| FC | 2012 | 12 April | Bank Top east | SE724947 | - | - | - | - | Too few notes & poor quality recording. |
| FD | 2012 | 23 April | Round Hill east. | SE694970 | 74 (73.5) | 112 (110.5) | 157 (156) | 12 | |
| FE | 2012 | 23 April | Bank Top - in tree next to cottages, | SE720951 | - | - | - | - | Non-Rosedale dialect, not analysed. |
| FF | 2012 | 26 April | Round Hill west | SE692971 | - | - | - | - | Non-Rosedale dialect, not analysed. |
| FG | 2012 | 7 May | Hob Crag in 'stone/tree'. 0755hrs | SE715954 | 75 (75) | 110 (108.5) | 155 (154.5) | 12 | |
| FH | 2012 | 7 May | Hob Crag in 'stone/tree'. 1359hrs | SE715954 | 81 (82.5) | 118 (119) | 165 (165) | 12 | |
| FU | 2012 | 10 May | Matty Carr - at north end. 0952hrs | SE688983 | 70 (69.5) | 114 (113) | 155 (152) | 12 | |
| FI | 2012 | 10 May | Matty Carr - in tree at south end. 1038hrs | SE688983 | 84 (94.5) | 117 (117) | 173 (177) | 12 | |
| FJ | 2012 | 10 May | Sheriff's Pit - on pit fence post. | SE697963 | 70 (70) | 73 (73) | 115 (116) | 10 | |
| FK | 2012 | 14 May | Hob Crag in 'stone/tree' area. 0920hrs | SE715954 | 91 (89.5) | 121 (124) | 182 (182.5) | 12 | |
| FL | 2012 | 24 May | Matty Carr - 20 metres south of quarry. | SE688982 | - | - | - | - | Only one note, not measurable. |
| FM | 2012 | 24 May | Round Hill south - on wall above crags. | SE697967 | 70 (67.5) | 120 (120.5) | 162 (161.5) | 12 | |
| FN | 2012 | 24 May | Sheriff's Pit - on noticeboard post. | SE697963 | 71 (70) | 128 (127) | 174 (173) | 12 | |
| FO | 2012 | 24 May | Spindle Thorn | SE717931 | - | - | - | - | Poor quality. Batteries died after 1 min. |
| FP | 2012 | 28 May | Sheriff's Pit - on pit fence post. 0949hrs | SE697963 | 70 (68.5) | 123 (125) | 165 (167) | 12 | |
| FQ | 2012 | 28 May | Sheriff's Pit - on pit fence post. 0958hrs | SE697963 | 82 (81) | 122 (123.5) | 175 (177) | 12 | |
| FR | 2012 | 28 May | Sheriff's Pit - on pit fence post. 1442hrs | SE697963 | 82 (83) | 121 (120.5) | 179 (179.5) | 12 | |
| FS | 2012 | 19 June | Sledge Shoe | SE691976 | 81 (81) | 98 (97) | 145 (145.5) | 12 | |
| FT | 2012 | 19 June | Matty Carr - below south end of quarry. | SE688983 | - | - | - | - | Poor quality therefore not usable. |
| GA | 2013 | 19 April | Round Hill south - in tree in dalebottom. | SE694968 | 82 (81) | 124 (123) | 172 (171) | 10 | |
| GB | 2013 | 16 May | Hob Crag - in dalebottom north of quarry. | SE714955 | 120 (118.5) | 103 (102.5) | 194 (193.5) | 12 | |
| GC | 2013 | 16 May | Sheriff's Pit - on fence post singing softly. | SE697962 | - | - | - | - | Weak recording therefore not usable. |
| GD | 2013 | 16 May | Sledge Shoe - at south end below track. | SE691975 | - | - | - | - | Weak recording therefore not usable. |
| GE | 2013 | 27 May | Round Hill south - near nest & meadow. | SE697967 | - | - | - | - | Non-Rosedale dialect, not analysed. |
| GF | 2013 | 02 May | Sledge Shoe - in tree towards dalebottom | SE691976 | - | - | - | - | Poor quality therefore not usable. |
| GG | 2013 | 03 June | Sheriff's Pit - on fence post. | SE697962 | 94 (94.5) | 104 (106.5) | 173 (176) | 10 | |
| GH | 2013 | 06 June | Blakey Swang north - in tree at nth end. | SE684998 | 77 (77.5) | 112 (108) | 163 (163.5) | 10 | |
| GI | 2013 | 06 June | Reeking Gill south - in tree. 1536hrs | NZ692004 | 73 (74) | 123 (123.5) | 167 (169) | 10 | |
| GJ | 2013 | 06 June | Reeking Gill quarry - on rock. 1432hrs | NZ692005 | 83 (82.5) | 118 (119) | 168 (170) | 10 | |
| GK | 2013 | 10 June | Round Hill south - in tree above meadow<br>then flew to tree at Round Hill east. | SE696967<br>SE694969 | - | - | - | - | Non-Rosedale dialect, not analysed.<br>N.B. Dialect different to that of 27/05. |
| GL | 2013 | 13 June | Round Hill south - on daleside of track . | SE695967 | 91 (91) | 107 (108) | 167 (166.5) | 10 | |
| GM | 2013 | 13 June | Round Hill south - above meadow. | SE696967 | - | - | - | - | Non-Rosedale dialect, not analysed. |
| GN | 2013 | 17 June | Round Hill south - on wall above crags. | SE699966 | 93 (93.5) | 109 (110) | 173 (174.5) | 10 | |
| GO | 2013 | 17 June | Round Hill south - on wall above crags. | SE698967 | - | - | - | - | Non-Rosedale dialect, not analysed. |
| GP | 2013 | 24 June | Sheriff's Pit - on fence post. 1248hrs. | SE697962 | 92 (92) | 99 (99) | 162 (163) | 6 | |
| GQ | 2013 | 24 June | Sheriff's Pit - on fence post. 1205hrs. | SE697962 | 73 (72.5) | 94 (95) | 136 (135.5) | 6 | |

**Table 1 continued.**

| ID | Year | Date | Location | N.G.R. | *dur1* milliseconds mean (median) | *dur2* milliseconds mean (median) | *dur3* milliseconds mean (median) | Sample Size | Remarks |
|---|---|---|---|---|---|---|---|---|---|
| HA | 2014 | 24 April | Nab Scar north at 1157 in tree | NZ693001 | | | | | |
| HB | 2014 | 24 April | Reeking Gill cutting at 0958 high on moor | NZ689007 | 72 (72) | 107 (106.5) | 151 (151) | 6 | Short recording, only six notes. |
| HC | 2014 | 24April | Reeking Gill 1110 on fence below bank | NZ690006 | - | - | - | - | Too few notes & poor quality recording. |
| HD | 2014 | 24April | Reeking Gill at 1121 near HC rec. | NZ690006 | - | - | - | - | Too few notes & poor quality recording. |
| HE | 2014 | 24April | Reeking Gill at 1409 in tree below bank | NZ690006 | - | - | - | - | Too few notes. |
| HF | 2014 | 24April | Reeking Gill quarry 1350 in tree by track | NZ692005 | 86 (86.5) | 106 (106.5) | 165 (164) | 10 | |
| HG | 2014 | 24April | Reeking Gill south 1003 in tree by track | NZ692004 | 78 (73.5) | 116 (117) | 163 164) | 10 | |
| HH | 2014 | 24April | Reeking Gill sth 1326 in tree above track | NZ692004 | 81 (82) | 109 (110) | 159 (159.5) | 10 | |
| HI | 2014 | 24April | Reeking Gill south 1340 same as HH rec, | NZ692004 | 82 (82.5) | 108 (108.5) | 159 (159) | 6 | |
| HJ | 2014 | 28 April | Round Hill east 1212 in dalebottom tree | SE694968 | 84 (85) | 102 (101.5) | 157 (156) | 10 | |
| HK | 2014 | 05 May | Round Hill east 1249 in tree below track | SE694968 | - | - | - | - | Short recording, only three notes |
| HL | 2014 | 08 May | Sledge Shoe 1015 in tree at south end | SE691974 | 83 (83.5) | 112.5 (112.5) | 166 (166.5) | 10 | |
| HM | 2014 | 19 May | Sledge Shoe 0959 in tree at south end | SE691974 | 84 (85) | 115 (114) | 168 (171.5) | 10 | |
| HN | 2014 | 26 May | Matty Carr quarry 1359 in tree south end | SE688983 | 67 (67.5) | 118 (118.5) | 159 158.5) | 10 | |
| HO | 2014 | 26 May | Round Hill south 1111hrs. | SE696967 | - | - | - | - | Too few notes & poor quality recording. |
| HP | 2014 | 02 June | Round Hill west 1226hrs below 1st nest. | SE693971 | 71 (71.5) | 110 (110) | 160 (160.5) | 10 | |
| HQ | 2014 | 09 June | Hob Crag quarry 1303hrs top quarry wall | SE714954 | 67.5 (68.5) | 116 (115.5) | 159 (159.5) | 10 | |
| IA | 2015 | 07 April | Sledge Shoe 1055hrs south end in tree. | SE691974 | 67 (67) | 117.5 (118) | 158 (154.5) | 10 | |
| IB | 2015 | 07 April | Round Hill south at 1213hrs. | SE696967 | 65 (65.5) | 100 (101.5) | 139 (138.5) | 10 | |
| IC | 2015 | 10 April | Hob Crag quarry in tree at 0818hrs | SE714954 | 88 (85) | 120 (121) | 176.5 (176.5) | 10 | |
| ID | 2015 | 17 April | Hob Crag area on wall 200m sth. quarry. | SE716953 | 71 (71.5) | 120 (120.5) | 164 (164.5) | 10 | |
| IE | 2015 | 24 April | Bank Top in tree near cottages. | SE720951 | 65 (64.5) | 124 (124) | 165 (164.5) | 10 | |
| IF | 2015 | 24 April | Hob Crag area 250m sth. quarry on moor | SE717952 | 66 (65.5) | 119 (119.5) | 161 (162) | 10 | |
| IG | 2015 | 4 May | Matty Carr quarry in tree dalebottom. | SE694971 | 63 (62.5) | 128 (127) | 168 (168.5) | 10 | |
| IH | 2015 | 8 May | Hob Crag area 250m sth. quarry on moor | SE717952 | 67 (67) | 119 (119.5) | 165 (163) | 10 | |
| JA | 2016 | 15 April | Round Hill south from RH east at 1145 | SE696968 | 75 (75.5) | 92 (91.5) | 139 (139.5) | 8 | |
| JB | 2016 | 15 April | Thorgill Bank west in tree NW sheepfold | SE702958 | 72 (71.5) | 106 (108) | 153 (154) | 10 | |
| JC | 2016 | 19 April | Round Hill south from RH east | SE696968 | - | - | - | - | Weak recording, not usable. |
| JD | 2016 | 22 April | Thorgill Bank quarry in tree below cairn | SE707959 | 79 (77.5) | 112 (110.5) | 160 (159) | 10 | |
| JE | 2016 | 03 May | Loskey Beck in hollytree below ford 0842 | SE713933 | 67 (67) | 96 (95) | 141 (140.5) | 10 | |
| JF | 2016 | 03 May | Hob Crag in wood 50m sth of qurry 1041 | SE715953 | 64 (64.5) | 106 (107.5) | 148 (147) | 10 | |
| JG | 2016 | 03 May | Spindle Thorn in tree W side of rd. 0815 | SE716931 | 66 (66.5) | 99 (99.5) | 138 (137) | 10 | |
| JH | 2016 | 06 May | Reeking Gill at 1003 | NZ691006 | 72 (71.5) | 109 (109.5) | 152 (150) | 10 | |
| JI | 2016 | 10 May | Loskey Beck in hollytree below ford 0851 | SE713934 | 69 (66.5) | 87 (89.5) | 133 (139) | 8 | Recorded on Edirol micraphone. |
| JJ | 2016 | 10 May | Round Hill Crags above crags at 1331 | SE697967 | 66 (66.5) | 122 (121) | 161 (161) | 10 | |
| JK | 2016 | 10 May | Thorgill Bank west on sheepfold wall | SE705957 | 63 (61.5) | 97 (97.5) | 138 (137.5) | 10 | |
| JL | 2016 | 7 June | Round Hill south on bank by track 1057 | SE695967 | 63 (63.5) | 95 (99) | 132 (133) | 10 | |
| JM | 2016 | 7 June | Round Hill south in tree dalebottom 1113 | SE696968 | - | - | - | - | Too few notes & poor quality recording. |
| JN | 2016 | 7 June | Sledge Shoe in tree at north end at 1013 | SE691979 | 69 (70) | 127 (127) | 168 (169) | 10 | |
| JO | 2016 | 21 June | Round Hill west in tree below 2015 nest | SE693971 | 69 (68.5) | 110 (109.5) | 148 (147.5) | 10 | |
| JP | 2016 | 21 June | Sledge Shoe in tree dalebottom 1004 | SE691976 | 63 (64) | 92 (95) | 127 (129.5) | 8 | |

Note: Sample Size is the number of notes of the song used to determine the mean/median value of the three temporal parameters *dur1*, *dur2* and *dur3*.

## Annex 2 - Sonograms of Rosedale Dialect Male Ring Ouzels

## Type 1 and 2 Dialects

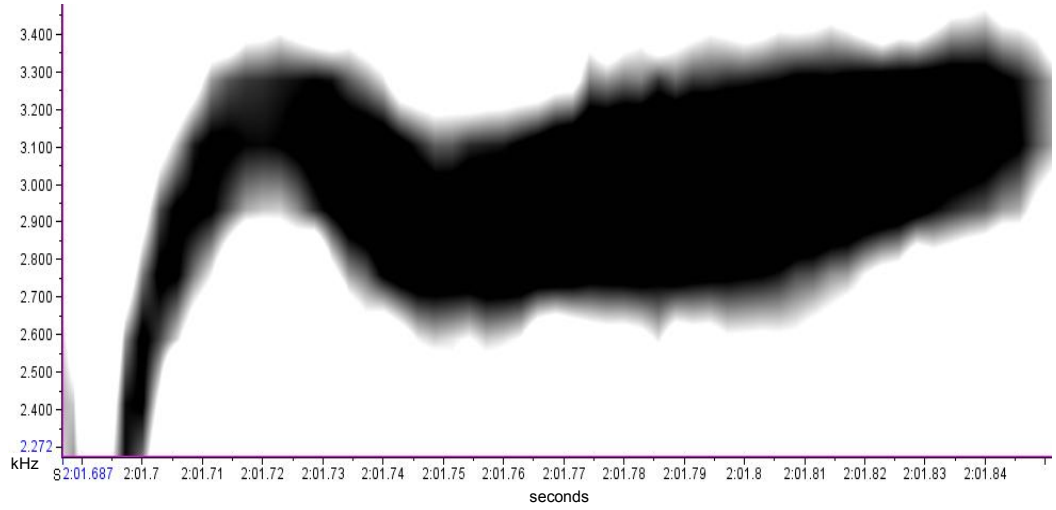



Figure 1: Sonogram of a single note of the Rosedale *Type 1* dialect in the un-modulated form. (Bank Top 23 April 2003)

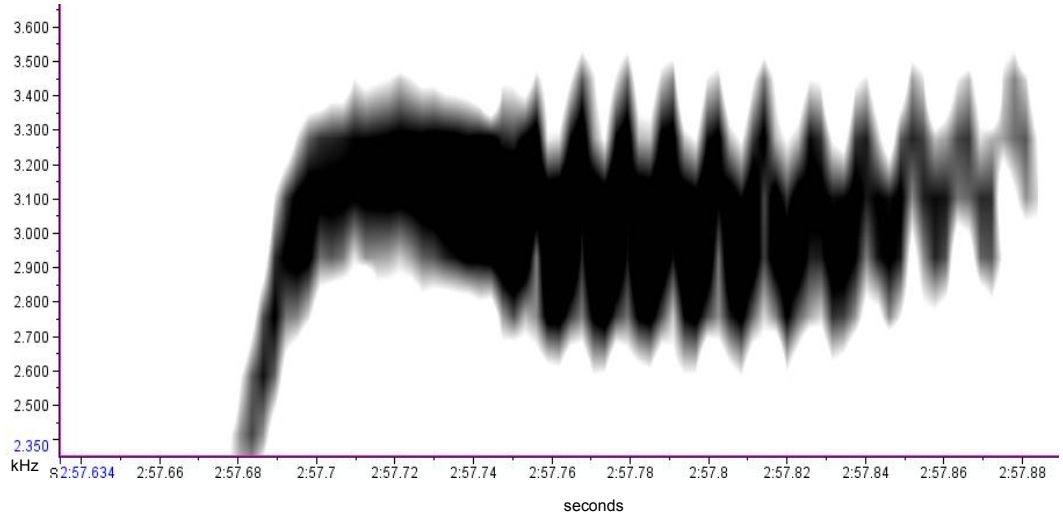



Figure 2: Sonogram of a single note of the Rosedale *Type 1* dialect in the modulated form having a modulation frequency of 80 Hz. (Bank Top 23 April 2003)

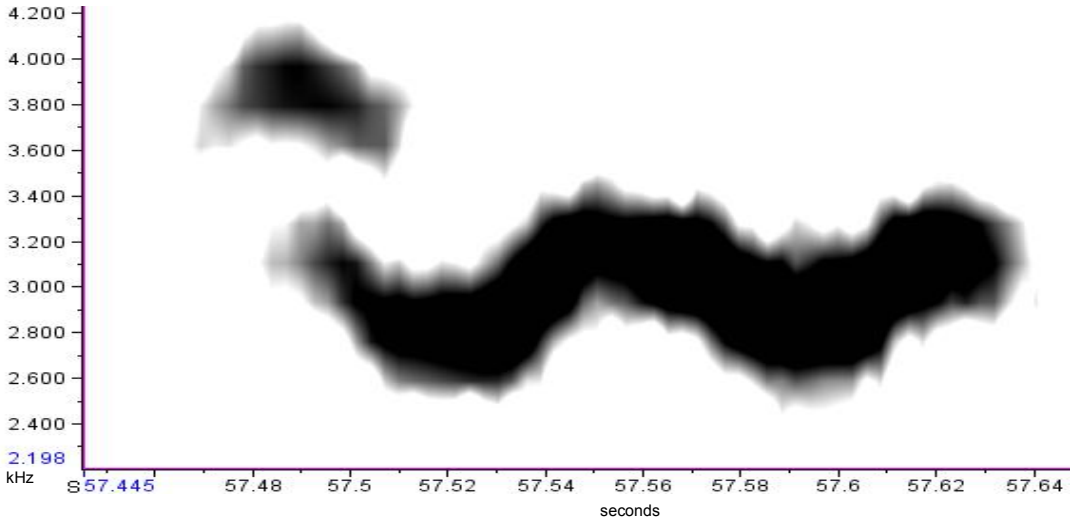



Figure 3: Sonogram of a single note of a Rosedale *Type 2* dialect. (e.g. Sledge Shoe Bent, 19/6/12; Hob Crag quarry, 16/5/13; Blakey Swang north, 6/6/13; Reeking Gill south, 6/6/13 & 24/4/14; Matty Carr quarry, 26/5/14)

The *Type 1* dialect, shown in Figures 1 and 2 above, seems to be the homologous form for Rosedale ring ouzels and appears to be the main song sung by males fledged in the dale. Both the un-modulated and modulated *Type 1* forms are sung in the repertoire, often in equal measure. In a few males a *Type 2* form, shown at Figure 3, occasionally appears in the repertoire and consists of just a few notes interspersed with the *Type 1* song. Of interest in the Rosedale *Type 2* form is the appearance of a non-harmonic component around 4kHz at the beginning of the note. This has been seen in most Rosedale *Type 2* recordings and clearly shows the bird singing a duet[1] at this point in its song.

Annex 6 shows the sonograms of a male ring ouzel mixing all three of the above forms in his repertoire - recorded at Matty Carr quarry on 26 May 2014.

**Footnote**

[1.] Don Stapp's book, Bird Song, describes how birds have two voice boxes and as a consequence are able to sing a duet. Studies conducted in the mid-1950s on the Wood Thrush showed the thrush's song contained harmonically unrelated notes that overlapped in time. In other words, they included frequencies that were not multiples of each other as they would be if they came from the same source. Research into the way a bird's syrinx produced sound and the way a bird can control the two halves of the syrinx independently to enable it to sing two notes at the same time, is described in greater detail in the book.

## Annex 3 - Sonograms of Non-Rosedale Dialect Male Ring Ouzels

### Recordings made in Rosedale

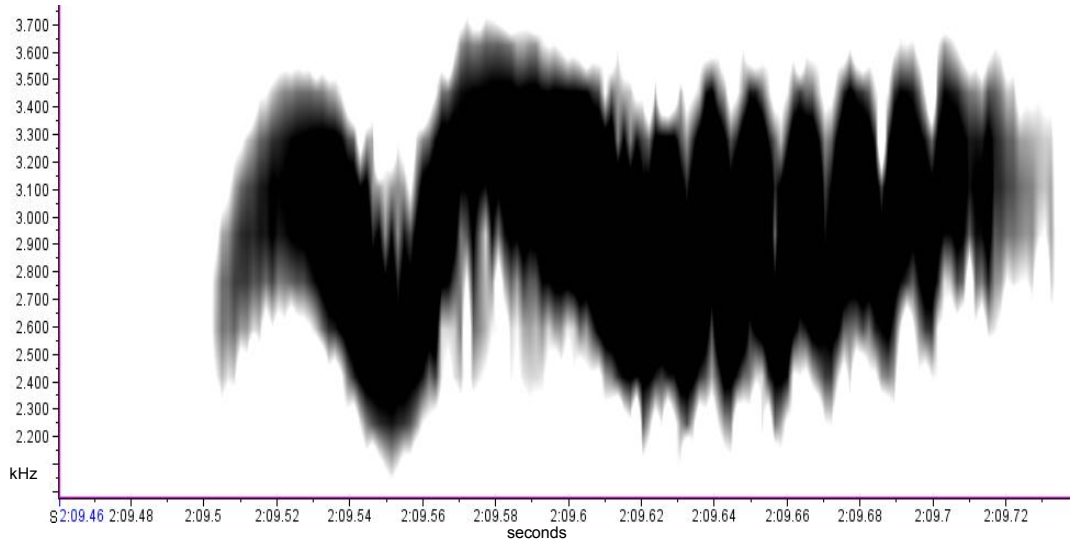



Figure 1: Sonogram of a single note of an un-identified dialect recorded at Bank Top, Rosedale, on 23 April 2012.

**Comment**

There is just a hint of the Rosedale *Type 1* (modulated) and *Type 2* dialects in this male's song.

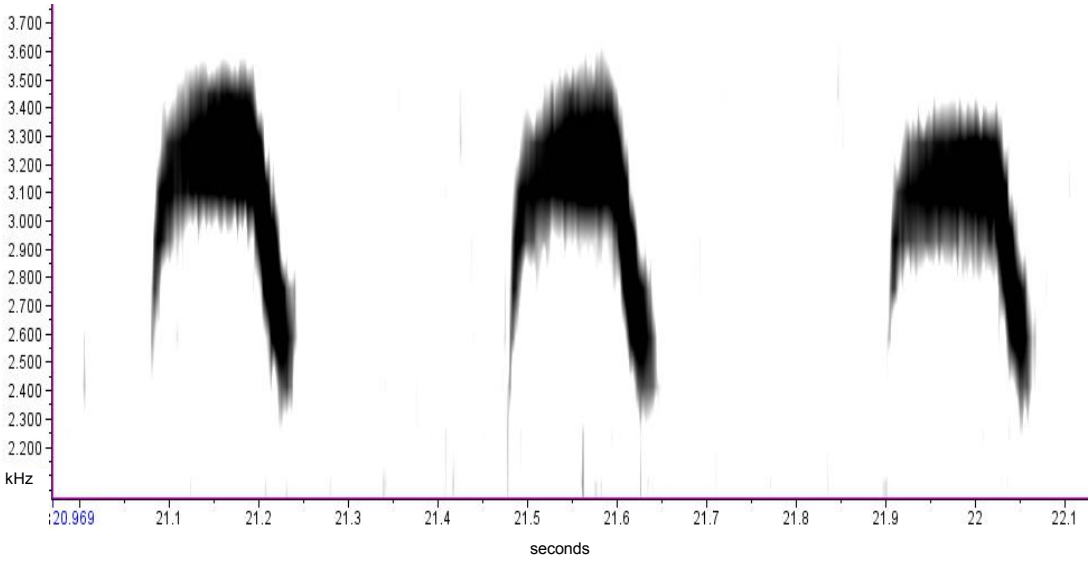



Figure 2: Sonogram of three notes of an un-identified dialect recorded at Sledge Shoe, Rosedale, on 26 April 2012.

**Comment**

A similar sonogram was recorded at Dalehead quarry, Rosedale, on 3 June 2010 which was comparable to one recorded a year earlier at Gill Wath, Farndale, on 30 April 2009 (the distance between Gill Wath and Dalehead quarry is about 1.5 km.) and may point to this being the same male - the bird recorded at Gill Wath also possessed a Rosedale *Type 2* dialect.

## Recordings made in other areas of the North York Moors

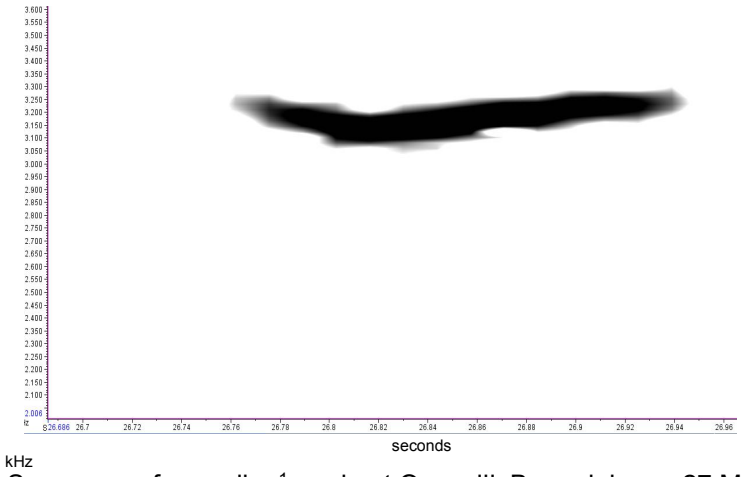



Figure 3: Sonogram of recording[1] made at Ousegill, Bransdale, on 27 May 2010.

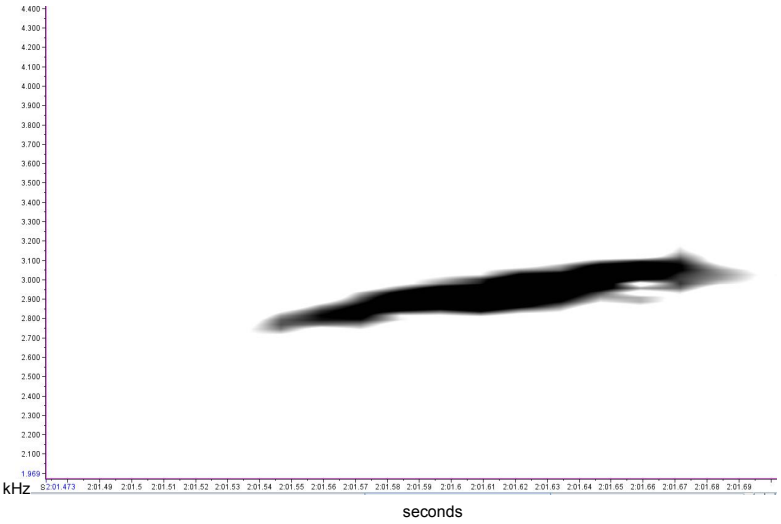



Figure 4: Sonogram of recording made at Cinderhill Wath[2], Bransdale, on 17 April 2016.

Recorded by Chris Tyas.

### Footnote

1. Several birds were recorded in the Ousegill area in 2009/10 and one in 2014. All had a similar dialect suggesting this could be the homologous *Type 1* form of the Bransdale dialect. One bird's repertoire also had a distinct *Type 2* dialect that was similar to the Rosedale *Type 1* dialect which may suggest a Rosedale connection - the distance between the two sites is around 6km. Note the rising frequency component over the main part of the note in both the Ousegill and Cinderhill Wath recordings.

2. Cinderhill Wath is situated on the west side of Bransdale, around 3km from Ousegill on the east side.

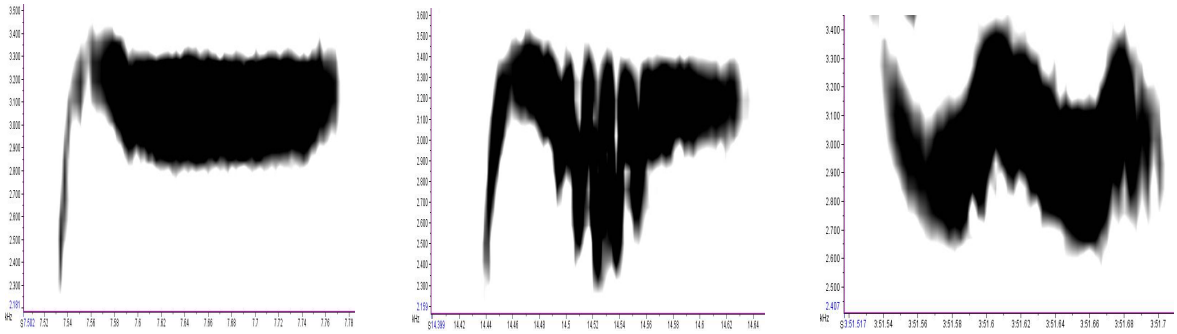


Figure 5: Sonograms of recording made at Esklets Crags, Westerdale, (NZ662015) on 14 May 2015. Note: this bird's dialect is similar to the Rosedale *Type 1* dialect in un-modulated form, left, and modulated form, centre, and has a distinct Rosedale *Type 2* dialect, right - the distance between Rosedale dalehead and Esklets Crags is just two kilometres.

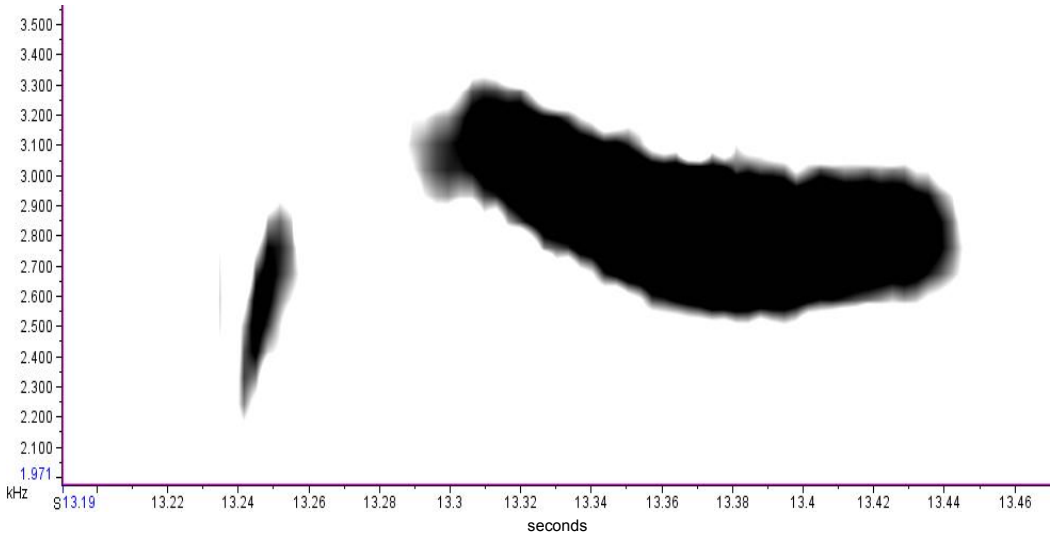



Figure 6: Sonogram of recording made at Esklets Crags, Westerdale, (NZ657015) on 14 May 2015. Note: this is not the same bird as shown at Fig.5, though both recordings were made at the southern end of the crags just 10 minutes apart - the song has a hint of a Rosedale *Type 1* dialect.

## Annex 4 - Bubble Charts of Rosedale Dialect Temporal Parameters

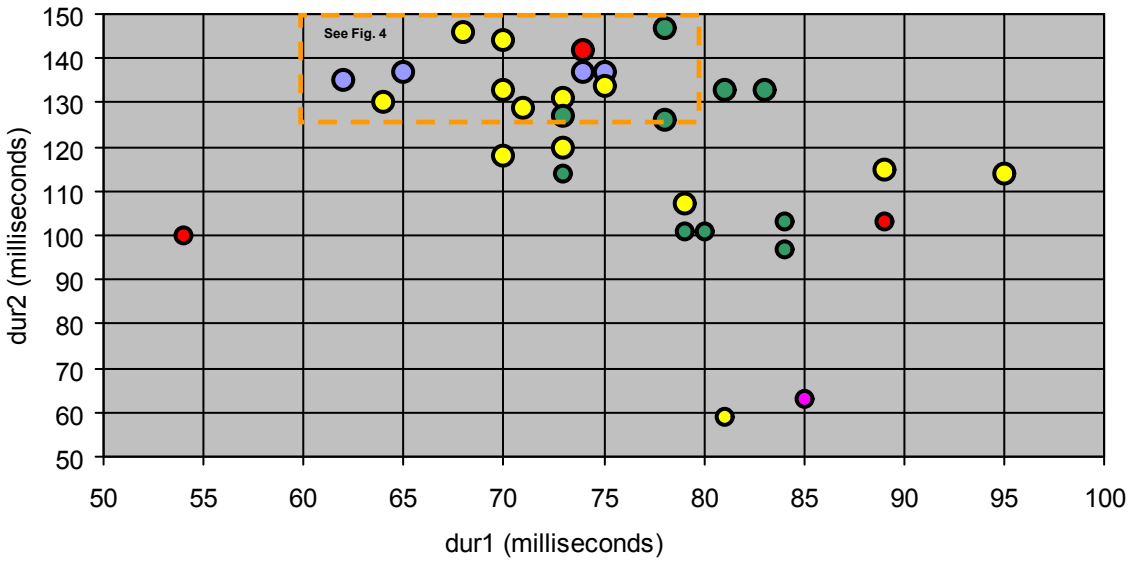



Figure 1: Bubble chart of mean temporal parameters *dur1*, *dur2* & *dur3* (circle area) taken from Annex 1, Table 1, for years 2003 & 2008-10. (*dur3* area reduced to 15% of true value for greater clarity)

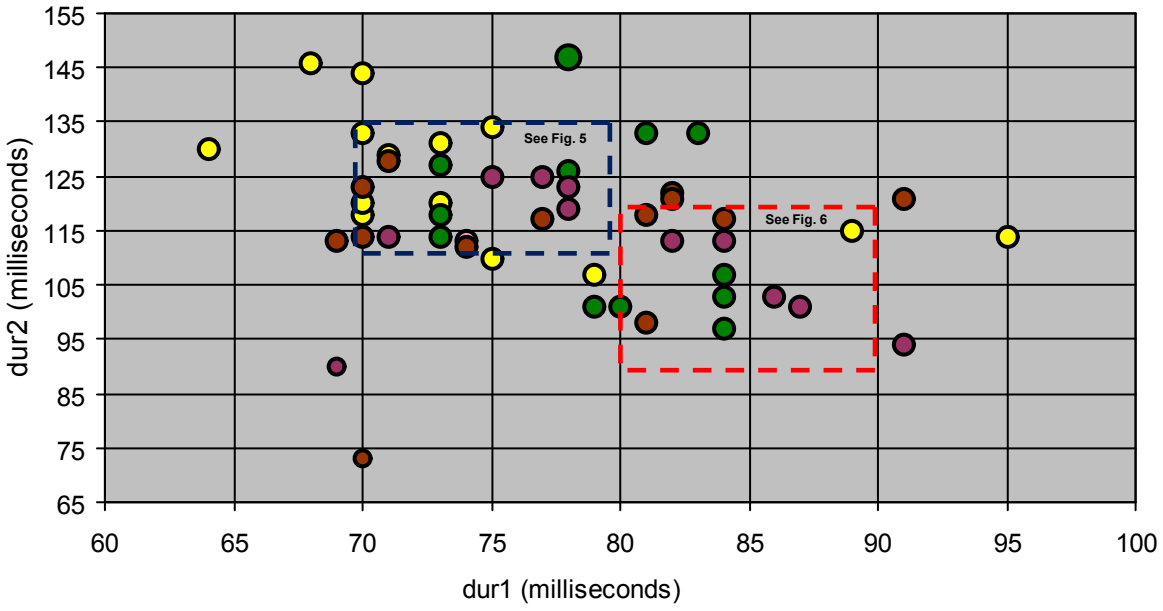



Figure 2: Bubble chart of mean temporal parameters *dur1*, *dur2* & *dur3* taken from Annex 1, Table 1, for years 2009-12. (*dur3* area reduced to 15% of true value for greater clarity)

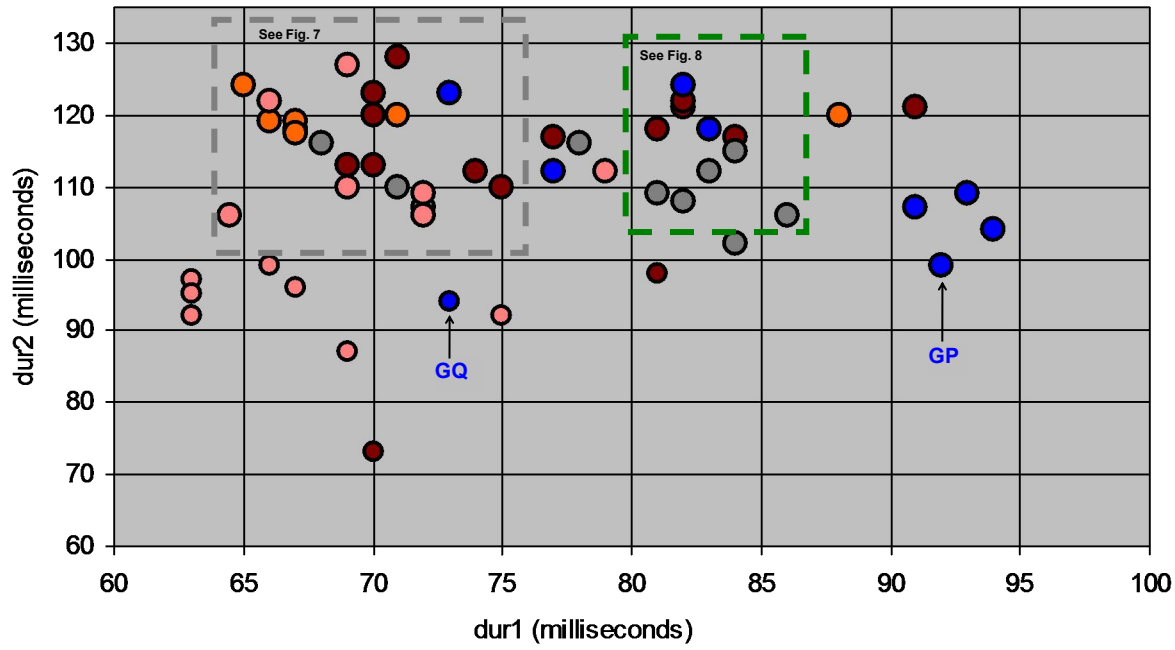



Figure 3: Bubble chart of mean temporal parameters *dur1*, *dur2* & *dur3* taken from Annex 1, Table 1, for years 2012-16. (*dur3* area reduced to 15% of true value for greater clarity)

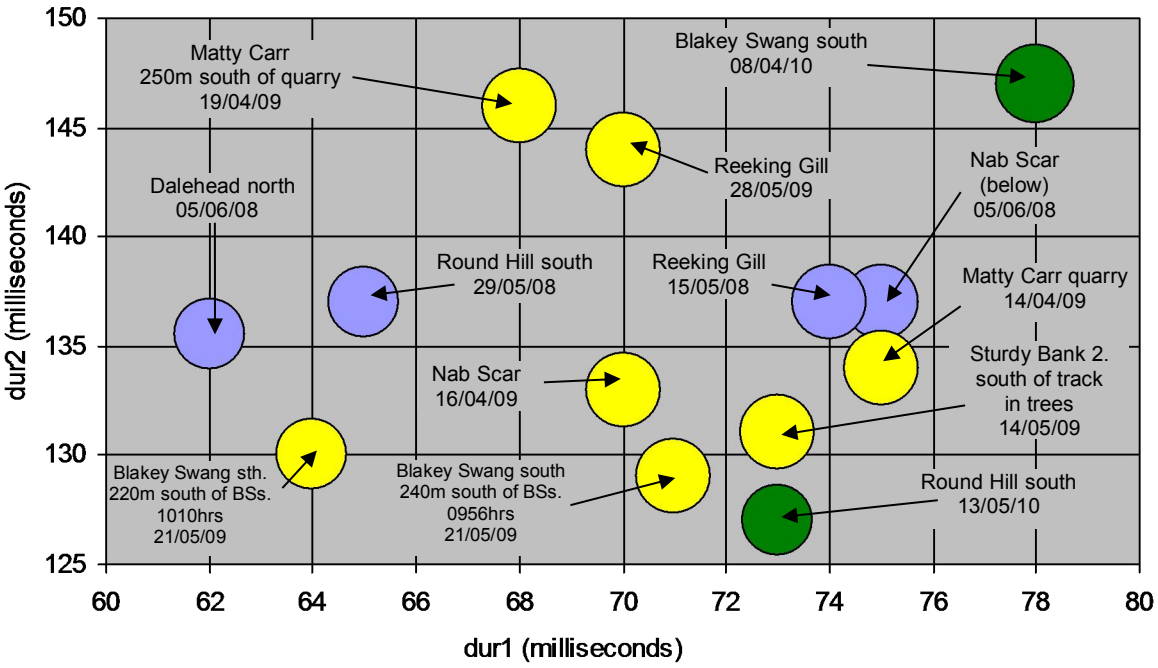



Figure 4: Expanded bubble chart showing detail in the **orange** hatched area at the top of Figure 1 for mean temporal parameters *dur1*, *dur2* & *dur3* for years 2008-10.

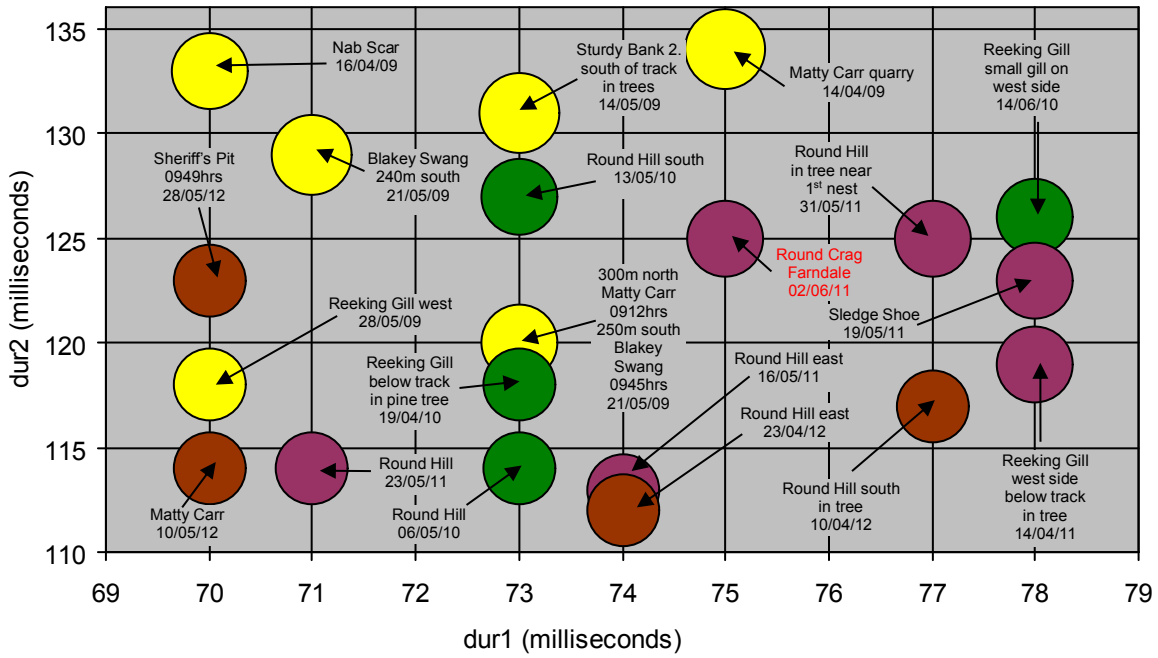



Figure 5: Expanded bubble chart showing detail in the blue hatched area at the top of Figure 2 for mean temporal parameters *dur1*, *dur2* & *dur3* for years 2009-12.

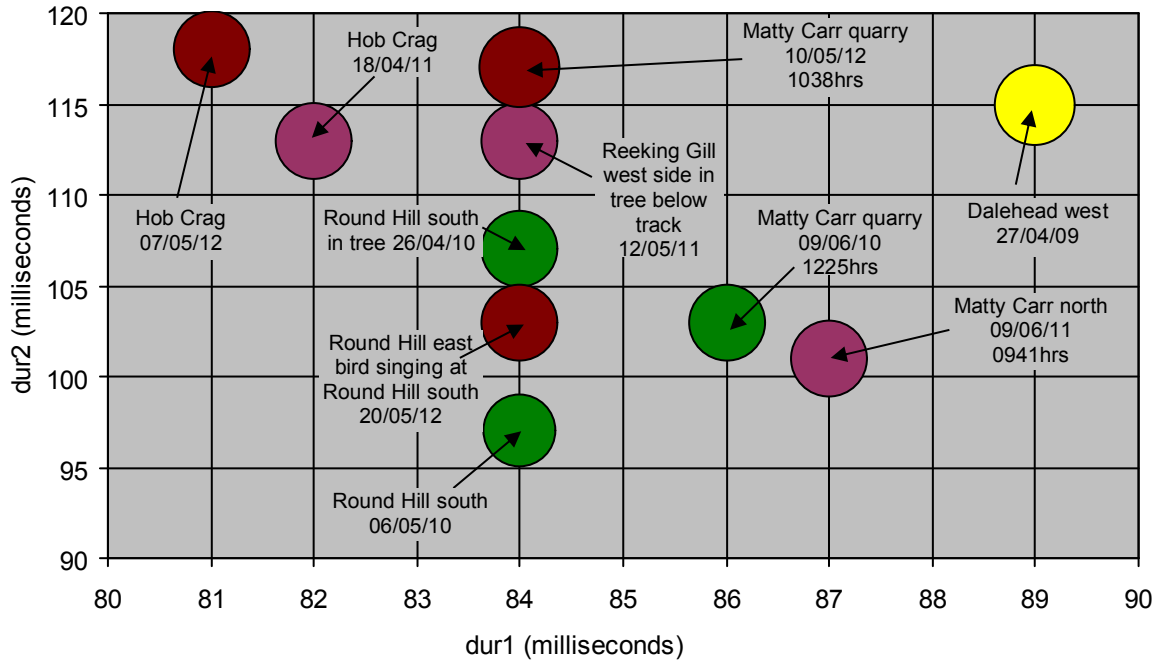



Figure 6: Expanded bubble chart showing detail in the red hatched area at the top of Figure 2 for mean temporal parameters *dur1*, *dur2* & *dur3* for years 2009-12.

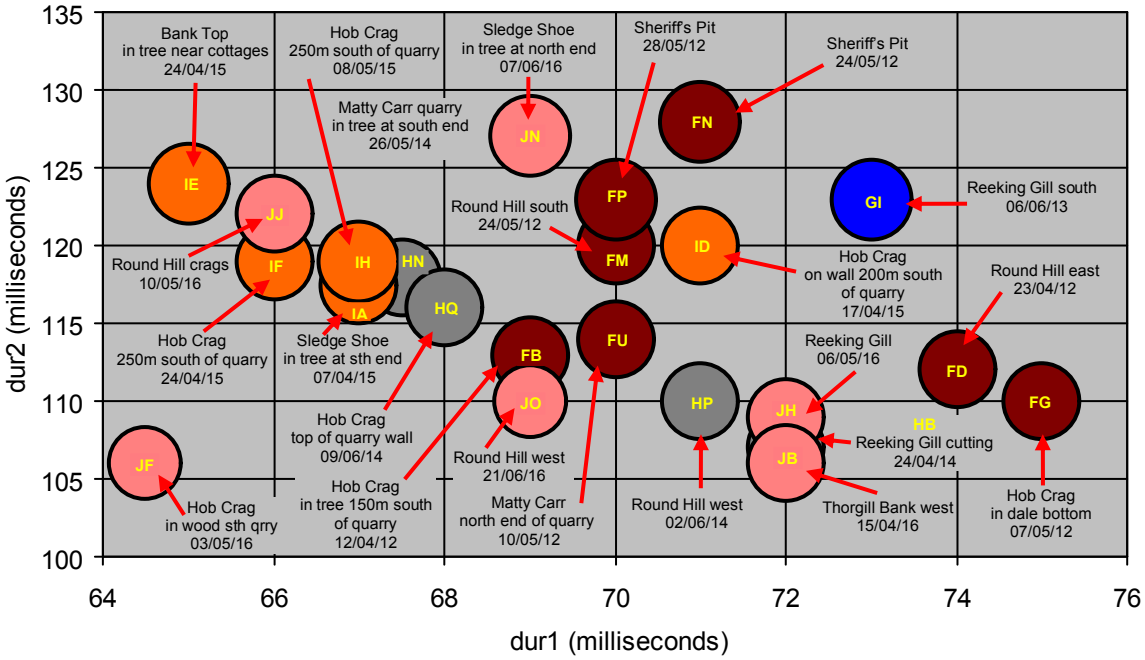



Figure 7: Expanded bubble chart showing detail in the grey hatched area at the top of Figure 3 for mean temporal parameters *dur1*, *dur2* & *dur3* for years 2012-16.

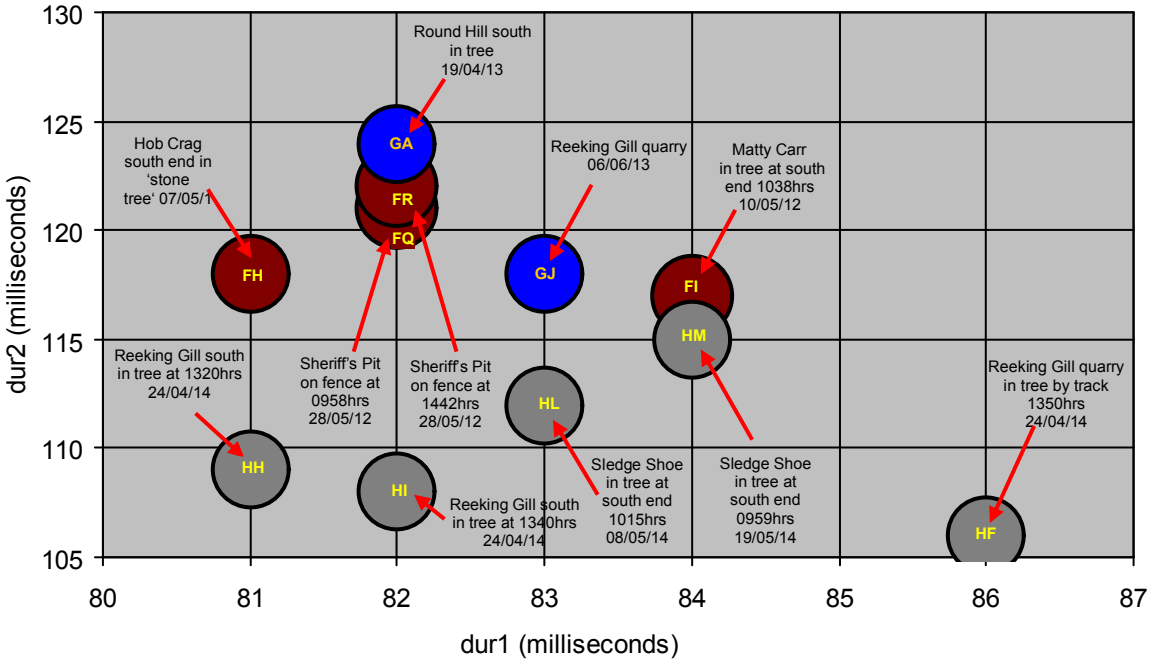
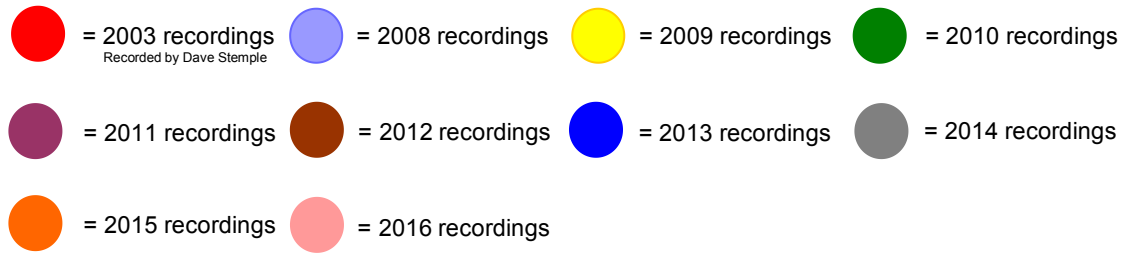



Figure 8: Expanded bubble chart showing detail in the **green** hatched area at the top of Figure 3 for mean temporal parameters *dur1*, *dur2* & *dur3* for years 2012-14.



## Annex 5 – Example of the use of EXCEL to perform an F-Test and t-Test on recordings HM and HL

| HM *d1* | HL *d1* | HM *d2* | HL *d2* | HM *d3* | HL *d3* |
|---|---|---|---|---|---|
| 89 | 81 | 116 | 117 | 176 | 170 |
| 82 | 80 | 114 | 110 | 168 | 159 |
| 89 | 85 | 114 | 116 | 172 | 170 |
| 82 | 75 | 104 | 117 | 155 | 167 |
| 84 | 85 | 124 | 115 | 174 | 166 |
| 86 | 81 | 114 | 105 | 170 | 161 |
| 80 | 85 | 122 | 110 | 172 | 158 |
| 86 | 87 | 119 | 110 | 171 | 169 |
| 87 | 82 | 114 | 113 | 174 | 173 |
| 80 | 85 | 110 | 112 | 151 | 163 |

As **t Stat** (*d1/d2/d3)* are > **-t Critical two-tail** (d1/d2/d3) & < **t Critical two-tail** (d1/d2/d3), the observed difference between the sample means *d1* , *d2, d3* of recordings HL and HM are not significant and as such are considered to be recordings of the same bird.

t-Test: Two-Sample Assuming Equal Variances

| | HM *d1* | HL *d1* |
|---|---|---|
| Mean | 84.5 | 82.6 |
| Variance | 11.61 | 12.49 |
| Observations | 10.00 | 10.00 |
| Pooled Variance | 12.05 | |
| Hypothesized Mean Difference | 0.00 | |
| df | 18.00 | |
| t Stat | 1.22 | |
| P(T<=t) one-tail | 0.12 | |
| t Critical one-tail | 1.73 | |
| P(T<=t) two-tail | 0.24 | |
| t Critical two-tail | 2.10 | |

F-Test Two-Sample for Variances

| | HL *d1* | HM *d1* |
|---|---|---|
| Mean | 82.6 | 84.5 |
| Variance | 12.49 | 11.61 |
| Observations | 10.00 | 10.00 |
| df | 9.00 | 9.00 |
| F | 1.08 | |
| P(F<=f) one-tail | 0.46 | |
| F Critical one-tail | 3.18 | |

As **F** < **F Critical one-tail** the variances of *d* 1 HL and HM are considered equal.

t-Test: Two-Sample Assuming Equal Variances

| | HM *d2* | HL *d2* |
|---|---|---|
| Mean | 115.1 | 112.5 |
| Variance | 32.99 | 14.94 |
| Observations | 10.00 | 10.00 |
| Pooled Variance | 23.97 | |
| Hypothesized Mean Difference | 0.00 | |
| df | 18.00 | |
| t Stat | 1.19 | |
| P(T<=t) one-tail | 0.13 | |
| t Critical one-tail | 1.73 | |
| P(T<=t) two-tail | 0.25 | |
| t Critical two-tail | 2.10 | |

F-Test Two-Sample for Variances

| | *HM d2* | *HL d2* |
|---|---|---|
| Mean | 115.1 | 112.5 |
| Variance | 32.99 | 14.94 |
| Observations | 10.00 | 10.00 |
| df | 9.00 | 9.00 |
| F | 2.21 | |
| P(F<=f) one-tail | 0.13 | |
| F Critical one-tail | 3.18 | |

As **F** < **F Critical one-tail** the variances of *d* 2 HL and HM are considered equal.

t-Test: Two-Sample Assuming Equal Variances

| | HM *d3* | HL *d3* |
|---|---|---|
| Mean | 168.3 | 165.6 |
| Variance | 70.90 | 26.27 |
| Observations | 10.00 | 10.00 |
| Pooled Variance | 48.58 | |
| Hypothesized Mean Difference | 0.00 | |
| df | 18.00 | |
| t Stat | 0.87 | |
| P(T<=t) one-tail | 0.20 | |
| t Critical one-tail | 1.73 | |
| P(T<=t) two-tail | 0.40 | |
| t Critical two-tail | 2.10 | |

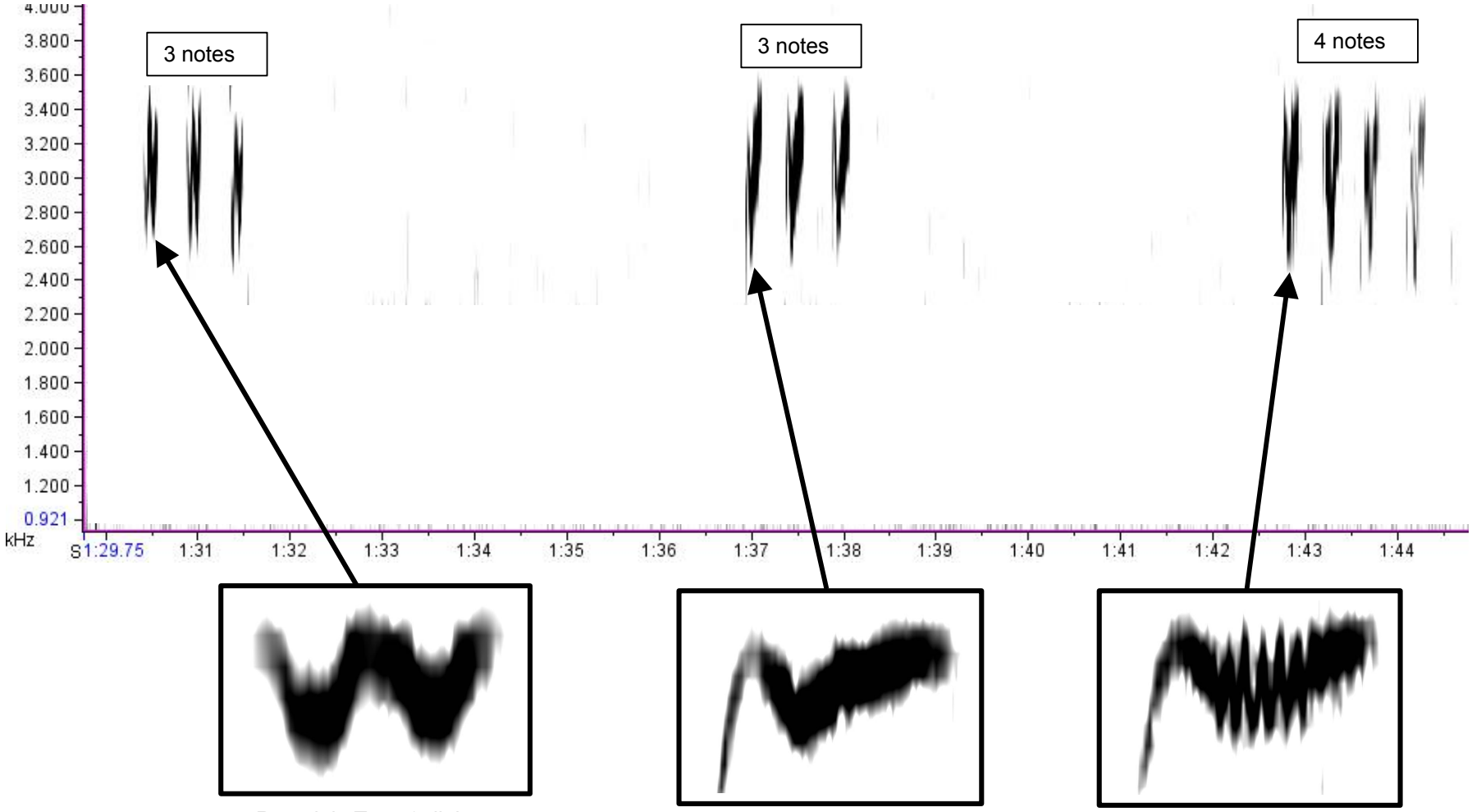
F-Test Two-Sample for Variances

| | *HM d3* | *HL d3* |
|---|---|---|
| Mean | 168.3 | 165.6 |
| Variance | 70.90 | 26.27 |
| Observations | 10.00 | 10.00 |
| df | 9.00 | 9.00 |
| F | 2.70 | |
| P(F<=f) one-tail | 0.08 | |
| F Critical one-tail | 3.18 | |

As **F** < **F Critical one-tail** the variances of *d* 3 HL and HM are considered equal.

## Annex 6 - Sonogram of a Rosedale ring ouzel mixing Type 1 and Type 2 forms of simple song

The three forms of simple song were mixed together in equal measure throughout the repertoire. All forms sound different to the human ear.




Rosedale Type 2 dialect

The Type 2 form appears in about 20% of Rosedale birds' rendition.

Rosedale Type 1 dialect un-modulated

This is the Type 1 or homologous form and is the basic dialect which all ring ouzels sing in Rosedale.

Rosedale Type 1 dialect modulated

Most Rosedale ring ouzels will add the modulated Type 1 form to their rendition.