Automated Monitoring of Foraging Behaviour in Free Ranging Sheep Grazing a Bio-diverse Pasture using Audio and Video Information

J. Sneddon
School of Natural Sciences and Psychology
Liverpool John Moores University
Liverpool, UK.
J.C.Sneddon@ljmu.ac.uk

A. Mason
School of Built Environment
Liverpool John Moores University
Liverpool, UK.
A.Mason1@ljmu.ac.uk

Abstract— **Non-invasive methods for monitoring foraging choice in free ranging grazing animals are largely limited to accelerometers and video calibration. Acoustic data from a wireless microphone attached to the skull has been used to distinguish between resting and feeding bouts in free ranging cattle, sheep and goats. Similar data has been reported in restrained sheep presented with forage of differing dry matter content. We take these approaches further by using a small video camera attached to a halter in free range sheep, and software developed specifically for the analysis of animal sounds. Combined biting and mastication sounds allowed us to distinguish between foraged grasses and browsing activity, and non-foraging chewing activity in four sheep of differing body size and breed in the height of a UK summer for up to 8 hours.**

Keywords-automated foraging livestock monitor; browsing activity; audio and video analysis.

I. Introduction

Grass covers 60% of the agricultural land mass in the UK, and uplands make up 60% of the total land mass. Upland pastures in particular, and the habitats they sustain, are characterised by bio-diverse plant species that are largely maintained by grazing sheep [1]. In order to understand the processes governing the maintenance of the uplands by sheep, methods need developing to quantify what sheep are actually choosing to eat. In addition, there is an economic argument for better quality meat from animals grazing on bio-diverse pastures, so quantification of plant types in the diet holds further relevance [2]. Current drivers in the British Society for Animal Science, and the English Beef and Lamb Executive (a branch of the Agriculture and Horticulture Levy Board) are encouraging UK livestock production professionals to enhance and optimise lower input grass based farming systems [1,2].

In order to optimise contribution to the diet from forage, behavioural influences on forage selection have to be understood using technology that won't interfere with the grazing behaviour of free ranging animals feeding on mixed plant communities. The focus for this study was not on forage intake, which is often of concern [3-6], but whether acoustic analysis could be used to determine foraging choices in free ranging animals. We focussed on the use of acoustic analysis for determining foraging behaviours over realistic grazing time spans (several hours). This project ran in tandem with the development of a wireless sensor network system integrated with movement sensors for positioning sheep and describing grazing events, a system which was initially described by the authors in 2013 [7] and has since progressed substantially toward a commercial application. Forage intake parameters will thus be the subject of a future paper, and it is anticipated that the findings here will facilitate integration of on-animal audio monitoring over extended periods (weeks, months or even years).

Other authors working in this area have considered bite event frequency, bite duration and a bite power derivative, all of which have been correlated with sward height [5]. It was demonstrated that this could be correlated with dry matter intake, but no differentiation between foraged plant types could be gained from this data. Other work has looked at acoustic modelling for automated event recognition of sound signals including biting and chewing. This was developed particularly for homogeneous feed types presented to restrained sheep. Segmentation and subsequent automated classification of wave forms for ingestive events was described separately in terms of frequency and relative amplitude for either orchard grass or alfalfa *(Medicago sativa)*, and for sward height. The work described forage type with 67% accuracy and foraging event with 82% accuracy [6].

This paper therefore goes beyond the current state of the art in demonstrating that, using audio and video analysis, it is possible to determine the grazing behaviour of free-ranging sheep given a bio-diverse pasture. Furthermore, the work demonstrates that, with further calibration, it would be possible to provide real-time information regarding the grazing habits of free-ranging animals through sound analysis alone. This will be a major step change in current analysis, which often relies upon time-consuming human observation. Obviously this method cannot be conducted continuously over grazing seasons, thus limiting the available information regarding the eating habits of free-ranging animals.

II. Methodology

A. *Experimental Setup*

Four mature ewes were supplied: A Texel (~70 kg), two Hebrideans , and a Welsh Balwen (all approx. 30 kg).

Each sheep was fitted with a chromium tanned leather halter (Kamer Ltd®) to which was attached a small video camera with a 120° wide angle lens. These are illustrated in Figure 1.The experiments were carried out at OS location 333781,371970 Shotwick, Cheshire UK.

Figure 2 shows an overview of the testing site. The two fields (outlined in yellow, each 20 × 60 metres) had not received artificial fertiliser for at least 20 years and had been lightly grazed by sheep (n=3 or 4) for the last 11 years. Field 2 (Section 4-6) contained 5 fruit trees.

Plant diversity in paddocks (% occurrence) was examined on this bio-diverse mature pasture during June 2013 when seed heads on grasses made plant identification easier [7,8]. The fields were equally sectioned into three as outlined in

Figure 2 and 20 × 1 m^2 quadrats were measured in each field section. The diversity is indicated in

Table 1, with the area being found to contain clover-rye grass, with additional red fescue, Yorkshire fog, timothy, and meadow grass mixtures.

(a)

(b)

Figure 1. Illustrating (a) the car key fob micro video camera with 32GB memory and 120° wide angle lens, and (b) the mode of attachment to a Texel ewe via a halter.

Figure 2. Aerial view of test site which consists of two fields (Field 1 is denoted by Sections 1-3, Field 2 by Sections 4-6), with each section numbered arbitrarily. Measurements of plant species were conducted in June 2013 and these measurements are provided in

Table 1.

B. *Sound and Video Analysis*

SoundAnalysis Pro 2011 was utilised for analysis of audio sounds from animals; the software has been specifically designed for this purpose and offers a wide range of audio analysis capability. This was combined with the video data recorded to identify what animals were eating at the time of each sound, thus allowing appropriate categorisation and subsequent calibration.

Table 1. Quantification of plant species growing at test site during June 2013, measured immediately prior to monitoring of animal grazing. Figures are shown as percentages for each section of the test side, with sections labelled in Figure 2. Plant species classified at "Other" included: Groundsel *(Senecio vulgaris)*, Ladies Shepherds Purse *(Cpasella bursa-pastoris)*, Sweet Vernal *(Anthoxanthum odoratum)*, Daisy *(Bellis perennis)*, Dock *(Ramus obtusifolus)*, Nettle *(Urtica diocia)*, Chickweed *(Stellaria media)* and Cocksfoot *(Dactylis glomerata)*.

Field Section # (see Figure 2)	**Meadow Grass** *(Poa spp)*	**Rye Grass** *(Lolium perenne)*	**Clover** *(Trifolium repens)*	**Thistle** *(Urtica dioica)*	**Y Fog** *(Holcus lanatus)*	**Common Mouse Ear** *(Cerastium fontanum)*	**Red Fescue** *(Festuca rubra)*	**Buttercup** *(Ranunculus repens)*	**Timothy** *(Phleum pratense)*	**Other**
1	2	17	13	17	9	3	12	13	12	1
2	10	22	21	17	6	2	8	11	2	1
3	14	25	19	9	10	6	9	7	0	5
4	21	29	29	0	1	6	1	6	0	14
5	21	21	16	0	0	9	0	10	0	16
6	21	21	16	0	0	9	0	10	0	16

The SoundAnalysis Pro 2011 manual [9] reviews globally recognised descriptors of animal sounds based on pitch, goodness of pitch, amplitude modulation, frequency modulation and Wiener entropy. Wiener entropy corresponds with the degree of dynamic change of the energy in a sound. SoundAnalysis Pro 2011 has been reviewed with other free ware in terms of its capability for separation of broadband sounds characteristic of animal sounds and has been found to be relatively immune to background disturbance [10].

All animals were videoed foraging during July 1-21 2013 on three or four occasions for up to 8h at a time. Audio files were processed in the following fashion:

1. Conversion to WAV format for ease of processing using FormatFactory[1] freeware application;
2. Segmented into 10 second clips using Audacity [2] freeware application;
3. Imported into SoundAnalysis Pro 2011 for data acquisition in respect of globally recognised sound descriptors;
4. Exported to SPSS 21® for discriminate function analysis and one-way ANOVA.

The globally recognised sound descriptors considered particularly were: frequency modulation; amplitude modulation; pitch; goodness of pitch; and Wiener entropy. Up to 12 selections of foraging activity or category were randomly chosen in order to give appropriate confidence in the reported findings.

III. RESULTS AND DISCUSSION

The paddocks were very bio diverse in both grasses and meadow plants, as demonstrated in

Table 1, and were thus well suited to this study. The sound descriptor variables were heavily asymmetric, and so they were normalised using a $\log_{10}$ transformation based on pitch and goodness of pitch data [9]. All variables were further normalised via calculating variation from the median. Discriminate function analysis was performed on the five sound descriptors, classifying by foraging category [9,10]. The first derived component described 94% of the variation in the data, dominated by Wiener entropy.

Resting or background noise and vocalisation were discriminated from foraging categories with 100% and 94% accuracy, but the foraging categories were discriminated from each other with only 47% accuracy. Discriminate function analysis was not able to differentiate between browsing and grazing foraging categories, as shown in Figure 3.

The effect of foraging category on mean values for the sound descriptors frequency modulation, amplitude modulation, pitch, goodness of pitch and Wiener entropy were therefore examined with a one way ANOVA. Post-hoc testing was performed with a least significant difference test ($p< 0.05$).

[1] Available at http://www.pcfreetime.com/.
[2] Available at http://audacity.sourceforge.net/.

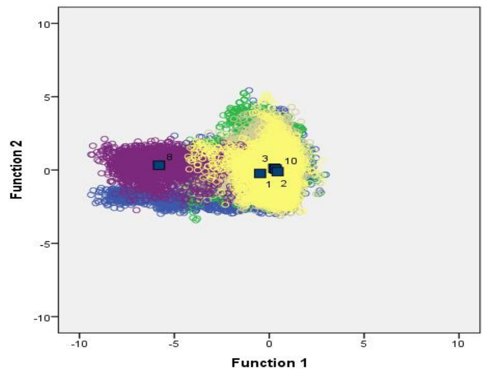


Figure 3. Discriminate function analysis on normalised sound descriptors for a Hebridean ewe indicating differentiation of vocalisation (purple) from foraging activity (other colours), but no differentiation between different categories of foraging.

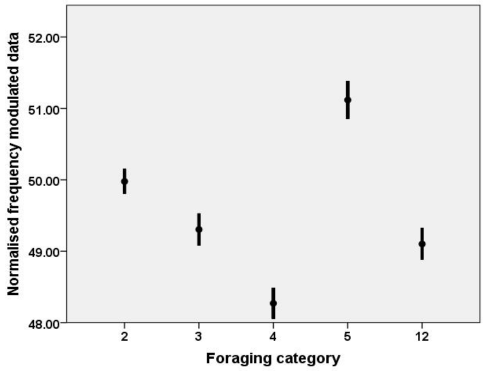
Four sound descriptors effectively discriminated between foraging categories and sample data for frequency; examples for two sheep are presented in Figure 4. Mean amplitude modulation showed discriminating capability between foraging categories.

The globally recognised sound descriptors pitch, goodness of pitch, frequency modulation and Wiener entropy all proved useful at distinguishing between the foraging categories in all sheep. Differences between mean data across foraging categories were significant ($p < 0.001$). Patterns of change across foraging categories were also similar. Background chewing had lower values for pitch and frequency than those for other foraging categories. Dryer forage (browsed versus grazed forage) produced higher frequency and pitch of biting and mastication. Grazing on lush clover or rye grass dominated sward in general produced lower frequency and pitch values.

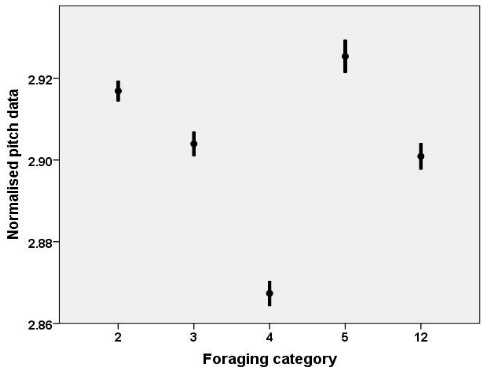
Dry matter content of forage has been inferred from presented homogeneous forage material [3]. This agrees with previous research where higher dry matter material received more chews per bite [8].

The smaller sheep (Hebrideans and Welsh Balwen) had higher values for normalised frequency data (range 40-50) and normalised pitch data (range 2.26 to 3.10) than the Texel (ranges 0-10; -0.13 to -0.03). This may have related to the resonance qualities of smaller or larger skulls during biting and mastication. This indicates that data would have to be calibrated for larger or smaller animals in the case of a flock of unequal sizes. In general this is not the case and breeding flocks tend to be of uniform size. It may only be necessary to place equipment on a limited number of animals in a flock to gain insight into forage use and impact of grazing on the habitat.

Wiener entropy describes the dynamic change in sound energy and this is also said to be primarily influenced by the amount of dry matter in forage material [6]. Mean values produced a particularly strong differentiation across foraging categories as can be seen in Figure 5. It is not associated with amplitude *per se* which is perhaps borne out by the strong impact of Wiener entropy on the data, and not amplitude.



(a)



(b)

Figure 4. Mean (a) frequency modulation and (b) pitch data across foraging categories in a Hebridean ewe n=4-12 clips of 10s sound trace per foraging category taken between July 1-21st 2013. Foraging categories: (2) clover dominated sward; (3) rye grass dominated sward; (4) dry fruit tree leaf; (5) fescue seed heads; (6) background chewing and (12) pure clover sward.

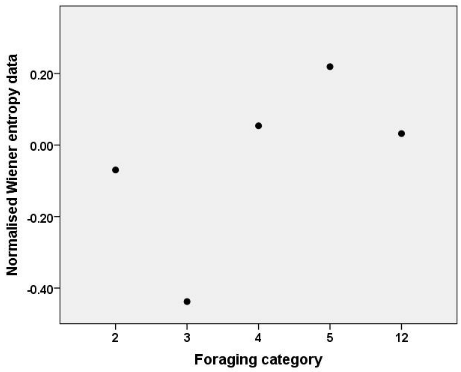


Figure 5. *Mean Wiener entropy values across foraging categories for a Hebridean ewe.* Foraging categories: (2) clover dominated sward; (3) rye grass dominated sward; (4) dry fruit tree leaf; (5) fescue seed heads; (6) background chewing and (12) pure clover sward.

IV CONCLUSION

Differentiation of foraging categories in terms of the plant community eaten from sounds transmitted via the mouth parts and associated with biting and mastication was possible in all sheep grazing on mixed swards. Forages with higher dry matter content produced higher pitch and frequency data. Individual ‘calibration’ of animals seems in order based on resonance qualities of skull size. These data will compliment technologies to be used in an impending wider study, where free ranging sheep will be located and their foraging movements followed with an accelerometer, in real time and over seasonal timescales. These technologies will provide a useful management tool for monitoring the impact of free ranging animals on mixed swards. The data will be of interest to land managers in bio diverse habitats with sensitive areas that require careful grazing.

ACKNOWLEDGMENT

The authors would like to thank both EBLEX and Natural Resources Wales for their help and support in developing the underlying tools for this and future research in the area of livestock grazing behaviours.

REFERENCES

[1] Environment Food and Rural Affairs Committee, Farming in the Uplands (HC556), London, The Stationary Office, 2011.

[2] H. Buller, Eating Biodiversity: An Investigation of the Links between Quality Food Production and Biodiversity Protection, Swindon, ESRC, 2007.

[3] D.H. Milone, et al., Computers and Electronics in Agriculture 65 (2009) 228-237.

[4] E.D. Ungar, et al., Applied Animal Behaviour Science 98 (2006) 11-27.

5] S. Navon, et al., Biosystems Engineering 114 (2013) 474-483.

[6] J.R. Galli, et al., Livestock Science 140 (2011) 32-41.

[7] A. Mason, et al., Automated monitoring of foraging behaviour in free ranging sheep grazing a biodiverse pasture, 2013, 46-51.

[8] Field Studies Council, Guide to Grassland Plants, 2002.

[9] O. Tchernichovski, SoundAnalysis Pro 2011 User Manual, 2011.

[10] M.C. Baker, et al., Ethology 109 (2003) 223-242.