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USE OF SINUOSITY INDEXES TO DESCRIBE FREE-RANGING COW PATHS[1]

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ABSTRACT.- An analysis of circular data was used to obtain vertical and horizontal sinuosity indexes of free-ranging cow paths. Focal sampling of cow displacements from 20 cows was translated from Cartesian co-ordinates (X,Y,Z) to rotation angles and the first order correlated random walk model developed by BOVET & BENHAMOU (1988) was used to calculate sinuosity indexes. Some of the statistical hypotheses were hard to accomplish in some samples. Nevertheless, the obtained indexes summarised well the complete path of grazing animals and so it could be used in order to detect differences in animal behaviour pattern.

Key words: Free-ranging cows, path analysis, sinuosity, circular statistics.

RÉSUMÉ.- Une analyse de données circulaires a été utilisée pour obtenir les index de sinuosité verticales et horizontales de parcours des vaches en libre pacage. Les observations visuelles des déplacements de 20 vaches ont été traduites de coordonnées cartésiennes (X,Y,Z) en angles rationnels et on a utilisé le modèle de premier ordre de parcours aléatoires correlés (correlated random walk), *développé par BOVET & BENHAMOU (1988) pour calculer les index de sinuosité. Certaines des hypothèses statistiques du modèle étaient difficiles á accomplir pour quelques échantillons. Néanmoins, les index obtenus ont bien résumé le parcours complet des animaux et par conséquent peuvent être utilisés pour détecter des différences dans le modèle de comportement animal.*

Mots clés: Vaches en pacage, analyse de parcours, sinuosité, statistique circulaire.

RESUMEN.- Se ha utilizado un análisis de datos circulares para obtener los índices de sinuosidad vertical y horizontal de vacas en pastoreo libre. Las

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observaciones visuales de los desplazamientos de 20 vacas se han traducido de coordenadas cartesianas (X,Y,Z) a ángulos rotacionales y se ha utilizado el modelo de primer orden de recorridos aleatorios correlacionados (correlated random walk), *desarrollado por BOVET & BENHAMOU (1988), para calcular los índices de sinuosidad. Algunas de las hipótesis estadísticas del modelo son difíciles de cumplir para ciertas muestras. Aun así, los índices obtenidos resumen bien el recorrido completo de los animales y por tanto pueden ser utilizados para detectar diferencias en las pautas de comportamiento animal.*

Palabras clave: Vacas en pastoreo, análisis de recorridos, sinuosidad, estadística circular.

1. Introduction

The management of suckler cattle in Pyrenees is based on free-ranging grazing in high mountain pastures from June to October. During this time animals remain alone in the range and are visited weekly by the cattle raisers. So cattle become range main users and use the space without restraint.

During range grazing animals move from one grazing zone to other. It will be useful the minimisation of those displacements due to its energy costs (especially high when slope is also high). Paths to cover primary requirements (feeding, watering and resting) are of particular interest. So, analysis of animal paths will be a useful tool to study cattle behaviour in free-ranging conditions and its economic implications in management improvement.

In some cases the variable used to describe animal path are rotation angles. Statistical analysis of this type of date can not be done by the usual statistical techniques. The use of rotation angles to describe the animal path implies the use of circular statistics and the adaptation of some non-parametric techniques to the data (BATSCHELET, 1981).

A way to study animal paths is the use of the first order correlated random walk model developed by Bovet and Benhamou (cf. BOVET & BENHAMOU, 1988; BENHAMOU & BOVET, 1991; SANUY & BOVET, 1997) with which it is possible to characterise each path with two independent indexes: its sinuosity and its speed. This works proposes a modification of that method in order to obtain also another index, the vertical sinuosity that should be important in analysis of animal movement in mountain conditions because it will be related with slope of animal paths.

2. Materials and methods

Sample data

Data from an animal single day observation was used to check the technique. Site location was a mountain in the Catalan Prepyrenean. The potential vegetation was *Quecetum rotundifoliae* Br.-Bl. et O. Bolòs 1956 and the animals grazed on formerly arable lands occupied now by a *Thero-Brometalia* community Br.-Bl. 1936. Focal sampling observations were made on individuals using binoculars at some distance to avoid modification of animal behaviour. The animal position was recorded into a 1:5000 map during 7 h 30 min with 10 minutes between visual observations. Animal position was introduced into a digital map and co-ordinates X, Y and Z obtained.

Path analysis

Data was analysed separately for X and Y co-ordinates, horizontal path, and for horizontal displacement and Z co-ordinate, vertical path. The set of N points obtained was used to calculate a set of N-2 rotation angles between successive path steps both for horizontal and vertical path.

These data were tested using Kuiper's test (BATSCHELET, 1981) in order to check the normality of the angular distributions obtained. The acceptance of null hypothesis implies that the given circular distribution coincides with the Von Mises distribution (SHATKAY & KAELBLING, 1998).

In order to use the correlated random model (BOVET & BENHAMOU, 1988) successive rotation angles should be independent random variables. The Jupp-Mardia test (BATSCHELET, 1981) was used to check this late hypothesis.

Using the correlated random model the path, vertical and horizontal can be characterised in terms of a modified index of sinuosity based on index developed by BOVET & BENHAMOU (1988). This sinuosity index can be calculated both for horizontal path (Sh) and for vertical path (Sv):

$$Sh = \frac{1.18\sigma_h}{\sqrt{L_h}} \text{ and } Sv = \frac{1.18\sigma_v}{\sqrt{L_v}}$$

where σ_h and σ_v are standard deviation of the horizontal and vertical angular distribution, respectively and L_h and L_v the mean length of horizontal and vertical path steps, respectively. All calculations and tests were performed using a simple worksheet.

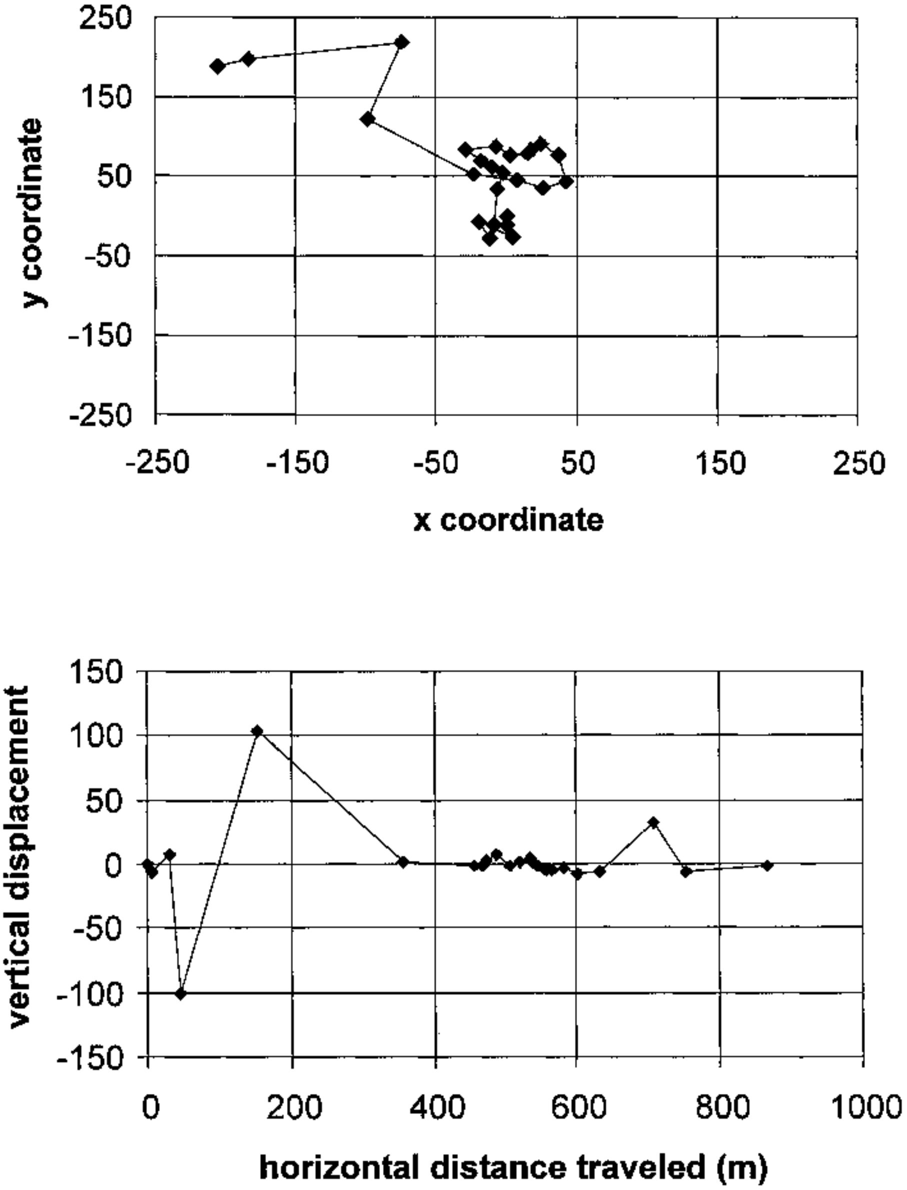
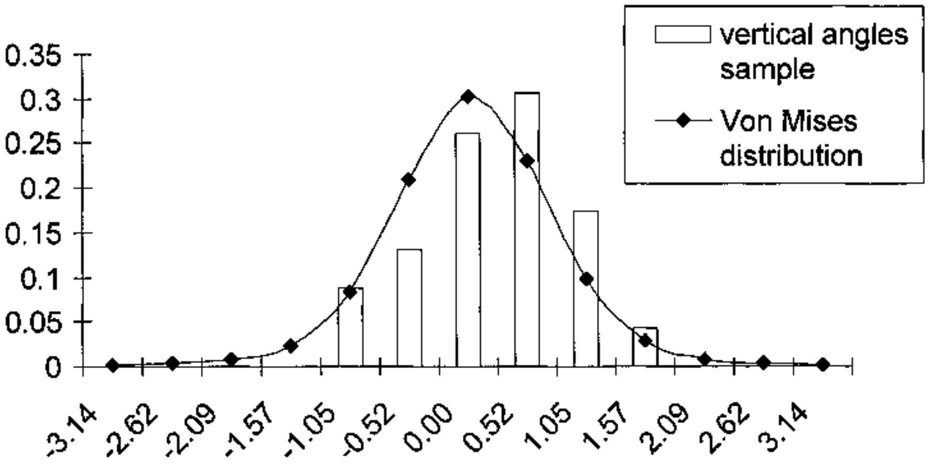


Figure 1. Horizontal and vertical paths observed.



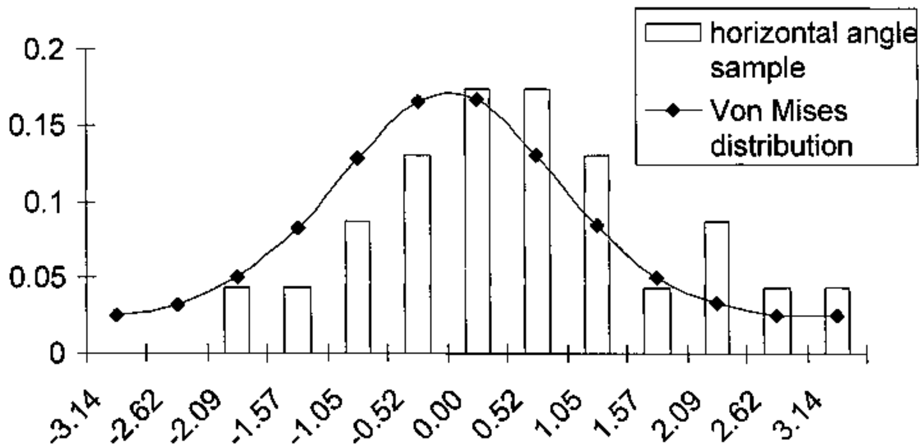


Figure 2. Sample rotation angle distribution (vertical and horizontal) and expected Von Mises distribution.

In order to show the utility of the presented indexes, vertical and horizontal sinuosity was calculated from data of 20 paths obtained from cows that grazed the same area that sample data.

3. Results and discussion

Figure 1 shows the horizontal and vertical path of the analysed animal. The estimated distribution parameters of path angles are show in Table 1, both horizontal and vertical path angles follow a Von Mises Distribution according to the Kuipper's test. Figure 2 shows the expected Von Mises distribution and the sample distribution.

The successive horizontal rotation angles obtained can be considered not correlated according to the Jupp-Mardia test. So the correlated random model can be used to without restrictions to calculate the sinuosity index (Sh= 0.225).

The rotation angles generated by the vertical path analysed are not independent ($p<0.01$) and so the correlated random model can not be applied directly. BOVET & BENHAMOU (1988) proposed the rediscretization technique to overcome this problem. We had use and adaptation of this technique to our data, grouping path steps with short length (e. g. vertical path steps between 450 and 650 m of horizontal distance travelled showed in Figure 1), and new rotation angles are then independent ($p>0.01$). So the vertical sinuosity index can be calculated and it was lower than the horizontal (Sv=0.120).

When the sinuosity index was calculated for a set of observed paths, there were some problems, because in some vertical paths the angles did not accomplish the hypothesis of no correlation (Table 2) or did not follow a Von Mises distribution. Nonetheless, only two horizontal paths angles had that type of problems.

Differences in sinuosity index were found and Figure 3 shows two extreme paths for horizontal and vertical sinuosity index. Clearly sinuosity indexes are a good summary of the type of travel path. Paths observed came from observations at morning (6:00 to 11:00 a.m) and evening (16:00 to 21:00). Although horizontal and vertical sinuosity indexes were higher at morning (0.129 vs 0.098 and 0.036 vs 0.022, for Sh and Sv respectively) no statistical differences were found between sinuosity indexes ($p=0.12$ and $p=0.17$ for Sh and Sv respectively).

4. Conclusion

Some of the hypotheses of the path angles needed to calculate properly those indexes were hard to accomplish for vertical paths. Besides, the calculation of sinuosity indexes implies that all the observations without movement were not take into account and so sinuosity indexes does not take into account some parts of grazing behaviour. Nevertheless, calculated sinuosity index showed the possibility to summarise the complete path of grazing animals and so it could be used in order to detect differences in animal behaviour pattern under different conditions.

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Table 1. Rotation angle, horizontal and vertical, for each path step and estimated parameters.

Sample parameters		
	Horizontal rotation angle[1]	*Vertical rotation angle*[2]
ϕ (mean angle)	-0.253	0.039
r (length of mean vector)	0.438	0.757
σ (angular standard deviation)	1.060	0.697

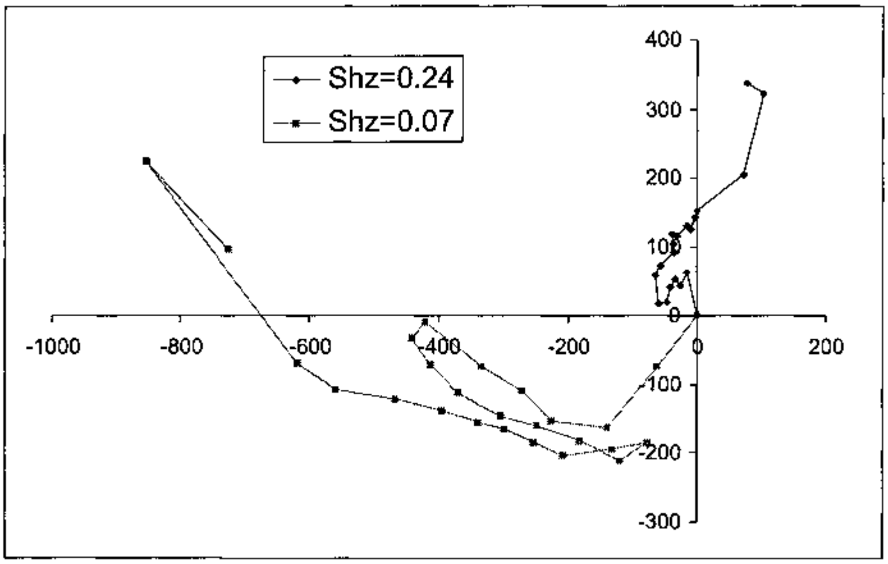
1 horizontal angles between -p and p radians.

2 vertical angles between -p/2 and p/2 radians.

Table 2. Horizontal and vertical sinuosity indexes of 20 observed cow paths.

Path number	*Horizontal*	*Vertical*	*Day period*	*Observations*
P1	0.082	0.025	Evening	2
P2	0.094	0.030	Evening	1
P3	0.063	0.030	Morning	2
P4	0.161	0.032	Evening	2
P5	0.076	0.040	Evening	
P6	0.083	0.029	Evening	
P7	0.209	0.051	Evening	
P8	0.168	0.117	Morning	2,3
P9	0.074	0.015	Evening	1
P10	0.074	0.017	Evening	1
P11	0.106	0.034	Morning	
P12	0.122	0.024	Morning	
P13	0.094	0.012	Evening	1
P14	0.134	0.012	Evening	
P15	0.243	0.044	Morning	1
P16	0.114	0.020	Morning	1,3
P17	0.107	0.012	Evening	1
P18	0.108	0.021	Evening	1
P19	0.131	0.014	Morning	
P20	0.091	0.015	Morning	4

1. Vertical Path angles do not accomplished the no correlation hypothesis and do not follows Von Mises distribution.
2. Vertical Path angles do not accomplished the no correlation hypothesis
3. Horizontal Path angles do not accomplished the no correlation hypothesis
4. Vertical Path angles does not follows Von Mises distribution.



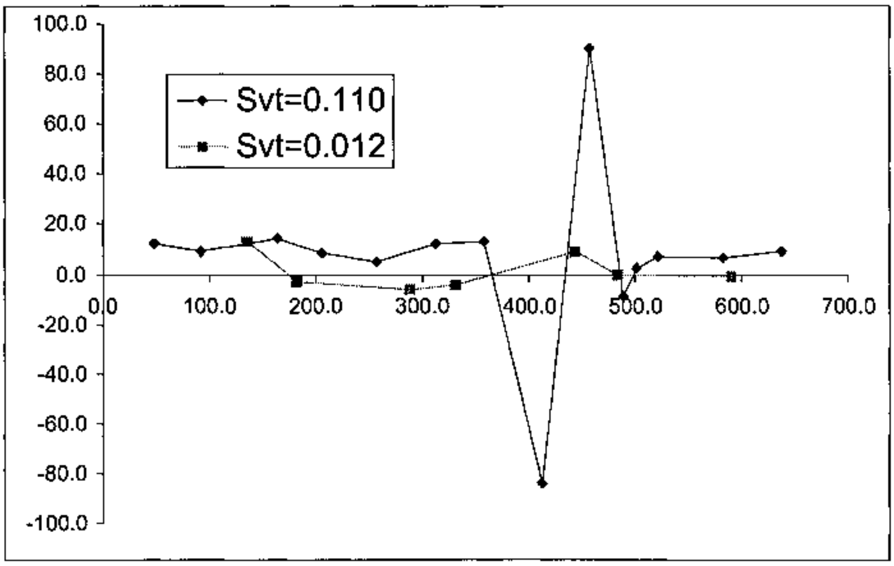


Figure 3. Extreme paths for horizontal (a) and vertical (b) sinuosity.