

DETECTION OF TEMPORAL BEHAVIOUR PATTERNS OF FREE-RANGING CATTLE BY MEANS OF DIVERSITY SPECTRA¹

J. M. DE MIGUEL*, M. A. RODRÍGUEZ** AND A. GÓMEZ SAL**

RESUMEN.- El objetivo del trabajo es identificar patrones temporales de comportamiento del ganado. El procedimiento utilizado, espectros de diversidad, permite apreciar, por un lado, el número de partes en que debe dividirse un transecto temporal para detectar la máxima segregación de las actividades del ganado y, por otro, el grado de definición con que se manifiesta dicha segregación.

En el caso estudiado (una dehesa del centro de España) la máxima segregación de las actividades fundamentales de comportamiento del ganado se produce al considerar el año dividido en dos periodos: primavera-verano y otoño-invierno. El comportamiento del ganado manifiesta un patrón anual de poco detalle, asociado principalmente a acciones de manejo y a la estacionalidad meteorológica propia del clima mediterráneo. Sin embargo, dentro de cada uno de los dos periodos anuales detectados, la máxima segregación se produce al considerar por separado los días de observación. Este patrón indica, dentro de cada estación, una cierta capacidad de respuesta a características de un ambiente fluctuante, que determina comportamientos muy distintos en días próximos.

En otoño-invierno el ganado muestra unas segregaciones estacional y diaria de sus actividades mejor definida que en primavera-verano. En el primero de estos periodos, la escasez de hierba, las condiciones climáticas más rigurosas y especialmente el manejo, parecen ser los factores que determinan una mayor organización temporal de las actividades.

ABSTRACT.- The aim of this paper is to detect temporal patterns of cattle behaviour. The method, diversity spectra, provides, on the one hand, the number of parts into which a temporary transect should be divided in order to understand the maximum segregation of cattle activities and, on the other, the clarity with which each segregation is defined.

¹ Received, October 1991.

* Departamento de Ecología. Facultad de Biología. Universidad Complutense. Ciudad Universitaria s/n. 28040 Madrid. Spain.

** Instituto Pirenaico de Ecología (CSIC). Ap. 202. 50080 Zaragoza. Spain.

In the case under study (a 'dehesa' pasture-land in central Spain) the maximum segregation of fundamental activities in cattle behaviour is reached by considering the year as divided into two periods: spring-summer and autumn-winter. Cattle behaviour shows an annual "coarse grain" pattern, which is associated with management activities and with the meteorological seasonality of the Mediterranean climate. However, within each of the two annual periods, maximum segregation is reached considering separately the days of observation. This "fine grain" pattern indicates within each season, a certain capacity for response to a fluctuating environment and determines very different behaviour on close days.

During autumn-winter period cattle show seasonal and daily activity segregations which are clearer than during spring-summer. In the former period, the lack of grass, more severe climatic conditions and management would seem to be determining factors of this temporal behaviour pattern.

RESUMÉ.-L'objectif de ce travail est l'identification de modèles temporels de comportement chez le bétail. La procédure utilisée, les spectres de diversité, permet d'apprécier d'une part le nombre de parties selon lesquelles un transect temporaire doit être divisé pour détecter la différenciation maximale des activités du bétail, et, d'autre part, le degré de définition selon lequel cette différenciation se manifeste.

Dans le cas que nous avons étudié (une dehesa du centre de l'Espagne), on obtient une différenciation maximale des activités fondamentales de comportement du bétail lorsque l'on divise l'année en deux périodes: printemps-été et automne-hiver. Le comportement du bétail suit un modèle annuel peu diversifié, associé principalement à la conduite et à la saisonnalité météorologique caractéristique du climat méditerranéen. Cependant, pour chacune des deux périodes annuelles détectées, on obtient une différenciation maximale lorsque l'on considère séparément les jours d'observation. Ce modèle nous indique, pour chaque saison, une certaine capacité de réponse aux caractéristiques d'un milieu fluctuant, qui détermine des comportements très différents pour des journées très proches les unes des autres.

En automne-hiver, le bétail montre une différenciation saisonnière et quotidienne de ses activités, qui est mieux définie qu'au printemps-été. Lors de la première de ces deux périodes, le manque d'herbage, les conditions climatiques plus rigoureuses et surtout la conduite semblent être les facteurs qui déterminent une plus grande organisation temporelle des activités.

Key words: *Cattle behaviour, Dehesa, diversity spectra, temporal pattern.*

Nomenclature: Tutin *et al.*, 1964.1980. Flora Europea.

Studies on temporary cattle behaviour patterns in extensive systems, and those concerned with domestic animal ecology, have been carried out mainly in countries with a highly developed livestock economy (see for example ARNOLD & DUDZINSKI, 1978; LOW *et al.*, 1981 a, b, c). In Spain, in spite of its territory being largely occupied by mountainous and fairly unfertile land, which is only suitable for livestock use, these studies are still scarce.

The present work comes under a general study of the livestock land-use (see DE MIGUEL *et al.*, 1988; DE MIGUEL, 1989; GÓMEZ-SAL & DE MIGUEL, 1989) in one of the most representative silvo-pastoral systems in Spain that is the

'dehesa' -open savannah-like holm oak (*Quercus rotundifolia*) woodland- (BALCELLS & GÓMEZ GUTIÉRREZ, 1975; GÓMEZ GUTIÉRREZ *et al.*, 1982 GARCÍA DORY & MARTÍNEZ VICENTE, 1988; UNESCO, 1989). Previous studies have highlighted the importance of grazing on the structure and dynamic of pastures in this type of ecosystem (DE MIGUEL, *et al.*, 1985; CASADO, *et al.*, 1985; GÓMEZ-SAL *et al.*, 1986; MONTALVO *et al.*, 1988). However a lack of knowledge exists on the temporal variability of cattle behaviour in the dehesas.

The present study aims to detect the main features of temporal behaviour patterns of free-ranging cattle in a 'dehesa' in central Spain. For this purpose a method based on diversity spectra (SHANNON & WEAVER, 1949; MARGALEF, 1957; PIELOU, 1975) was used. A similar procedure has been successfully used in the detection of both spatial patterns on pasture communities (PINEDA *et al.*, 1981, 1988), and temporal variation patterns on the structure of bird communities (SÁNCHEZ, 1985).

1. Material and methods

1.1. Study area

The study was carried out in a 3000 Ha estate, situated at the foothills of the Guadarrama range 20 km north of Madrid. The tree-population of the range consist mainly of fairly dispersed holm oak (*Quercus rotundifolia*) and to a lesser degree junipers (*Juniperus oxycedrus*). At the lower parts of the relief, near river-beds, there are often gall oaks (*Quercus faginea*) and ash trees (*Fraxinus augustifolia*). The most frequent shrubs are holm oak bushes, rock rose (*Cistus* spp.), broom (*Lygos sphaerocarpa*), thyme (*Thymus* spp.) and rosemary (*Rosmarinus officinalis*). Pastures, with a predominance of annual species, occupy a large area due to management (ploughing, cereal crops, oak-pruning, etc.) and to the wide variety of herbivores grazing on it (cattle, sheep and game). The lithological substrata are granitic and arkosic sediments which form an undulating relief at an altitude ranging from 610 m to 720 m. The climate is essentially of Continental-Mediterranean type with wide seasonal contrasts. Mean annual rainfall is 600 mm. The average minimum and maximum temperatures range from -7°C to 37°C respectively. Only three months are guaranteed frost free, while for five months frost are normal.

The economy of the estate -the traditional of the 'dehesa'- is based on complementing cattle raising with itinerant crops, hunting and timber. Management of the cattle (about 400 free-ranging cows and calves are grazed on the estate) is influenced by the strong seasonal contrast which are typical of a Continental-Mediterranean climate. High summer temperatures and drought, intense cold in winter mean a sharp decrease in grass production during these months making it necessary to provide fodder in order to complement the cattle's diet.

1.2. Sampling

Cattle behaviour was surveyed over 35 sampling days distributed evenly over one and a half years (1983-P4). Each day, the cattle behaviour was recorded at 10 minute intervals between sunrise and sunset. Before the first observation an animal was chosen at random to serve as a guide for the rest of the day. Only cattle within a 50 m radius of this animal were considered. A maximum of 10 animals were taken into account at each observation, which consisted of noting the number of animals involved in some basic activities: grazing, browsing, fodder consumption, ruminating and resting in both lain-down and upright positions, travelling, occasional movements and social conducts (HAFEZ & SCHEIN, 1969; ARNOLD & DUDZINSKI, 1978).

This sampling was not carried out during August as the animals were kept within the fields near to the estate so as to graze the fallow land.

1.3. Detection of temporary behaviour patterns

In order to analyze the annual behaviour patterns, 28 of the 35 sampling days were considered, making up a complete annual cycle. For each of these days the percentage of animals involved in the activity under consideration was calculated. With this data a matrix of 28 observations (sampling days) x 9 behavioural activities was made up (see Figure 1).

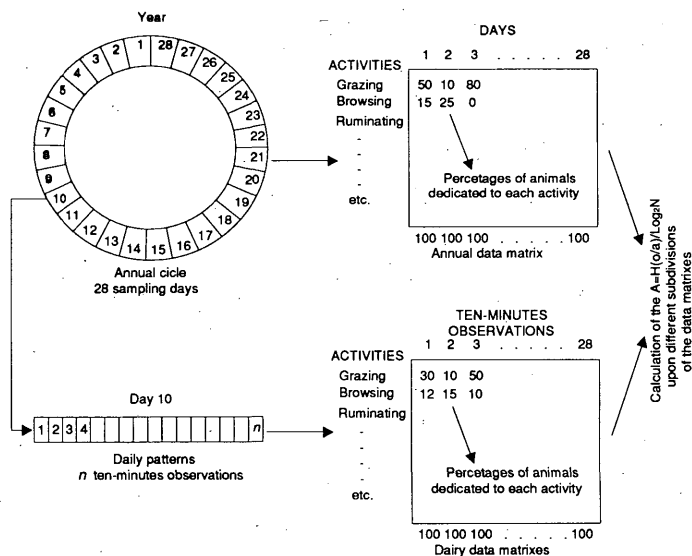


Figure 1: General methodological lay-out.

BEHAVIOUR PATTERNS OF FREE-RANGING CATTLE

In order to analyze daily behaviour patterns, a matrix of n observations of 10 minutes \times 9 behavioural activities was considered for each day. Percentages of animals undertaking each activity were calculated for each of the 10 minute observations (Figure 1).

The method used in the study of temporary data sets is based on the diversity concept which, taken in spectrum form, allows the detection of changes in the structure in a group of elements placed throughout a transect, which, in this case, are cattle activities. (MARGALEF, 1957; PINEDA *et al.*, 1988). The diversity index which was used is the conditioned entropy, one of the components of total entropy (PIELOU, 1975):

$$H(a.o) = H(a) + H(o/a)$$

$H(a.o)$ expresses total entropy, $H(a)$ expresses the entropy due to the behavioural activities, and $H(o/a)$ the entropy of temporary observations conditioned by activities (see Appendix).

The parameter $H(o/a)$ reaches a minimum value (zero) when each activity is only to be found in one temporary observation in the transect, and a maximum value when all the activities are equally distributed over all the observations (see Figure 2). This parameter can be used to find out into how

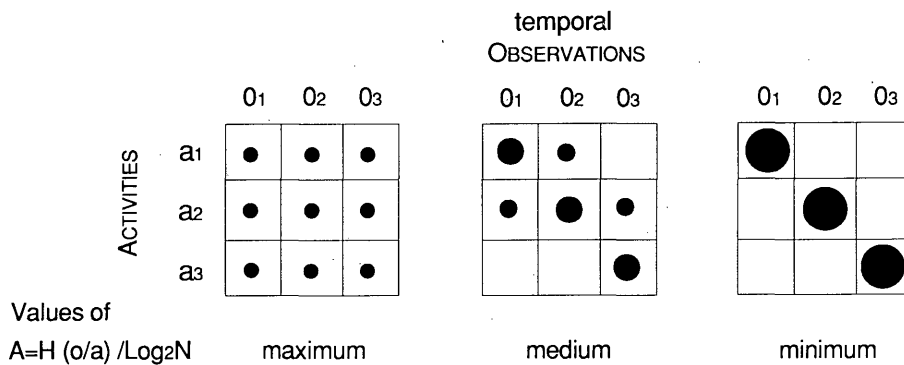


Figure 2: Three different segregation possibilities for cattle activities in a temporary transect of three observations ($N=3$). The size of the circles is in proportion to the percentage of animals undertaking each activity against the total recorded at each observation. Minimum A values are reached when segregation is maximum. The calculation of A over successive subdivisions of a transect with N observations, allows the detection of the transect subdivision that has best picked up the maximum activity segregation.

many parts each transect should be divided in order to pick up the maximum segregation of activities (PINEDA *et al.*, 1981, 1988). This segregation should correspond to the transect division reached by the lowest $H(o/a) / \text{Log}_2 N$ value (the standardization by the number of transect subdivisions $-\text{Log}_2 N$ makes up comparable the $H(o/a)$ values).

The standardized parameter $H(o/a)$ could be considered as a measure "A" of the niche width (PINEDA *et al.*, 1981). In this case, the niche width of the activities in the temporal transect:

$$A = H(o/a) / \text{Log}_2 N$$

In this study the parameter A has been calculated from various transects and different subdivisions of the transects. This allows to find out the detail which the temporary behaviour pattern is shown; i.e. the number of subdivisions reached by the lowest A values. By taking into account absolute minimum values, independently of the number of subdivisions which best produces the adjustment, it is possible to see the clarity -strong or weak- with which each segregation is defined.

2. Results and discussion

2.1. Annual and seasonal behavioural patterns

Given the fact that the 28 observation days are distributed evenly throughout the year, their sequence may be taken as an annual cycle. Methodologically, as many options as days in the cycle may be analyzed, as each transect could begin, rotatively, on any of the 28 sampling days if the sequential order is maintained. The lowest A value should be reached in a subdivision of one of the 28 transects.

Figure 3 shows the A values obtained by dividing the 28 annual transects into 2, 4, 7, 14 and 28 parts. The minimum A value is obtained by dividing the transect beginning on day 14 or day 28 into two equal parts (see Figure 4). This subdivision is mainly related to climatic seasonality and to the differing importance of fodder distribution on each day of each group. The group of days from 13 to 28 consist of the spring and early summer period, with abundant grass and little fodder distribution (on only 3 of the sampled days in summer fodder was distributed). The other group of days consists of the autumn-winter period, with little grass in the estate when fodder is used to supplement the cattle's feeding. The need of cattle to be at the fodder distribution points every day and the time spent waiting or feeding there, conditions the cattle behaviour during this period.

The previous result indicates that there is an annual pattern with little detail (coarse grain) in cattle behaviour and that it responds basically to seasonal factors related to food availability. This type of factor is, on this scale, more important than other meteorological ones (rain, wind, clouds, etc.) which may change from day to day.

The percentages of animals found to be carrying out the various activities during both periods are shown in Table 1. In spring-summer grazing, rumination and resting in a lying-down position are undertaken for more intensely than in autumn-winter when browsing, resting in upright position, travelling and occasional movement are more intense. Other activities, such as rumination in upright position or social conducts do not show up significant differences.

BEHAVIOUR PATTERNS OF FREE-RANGING CATTLE

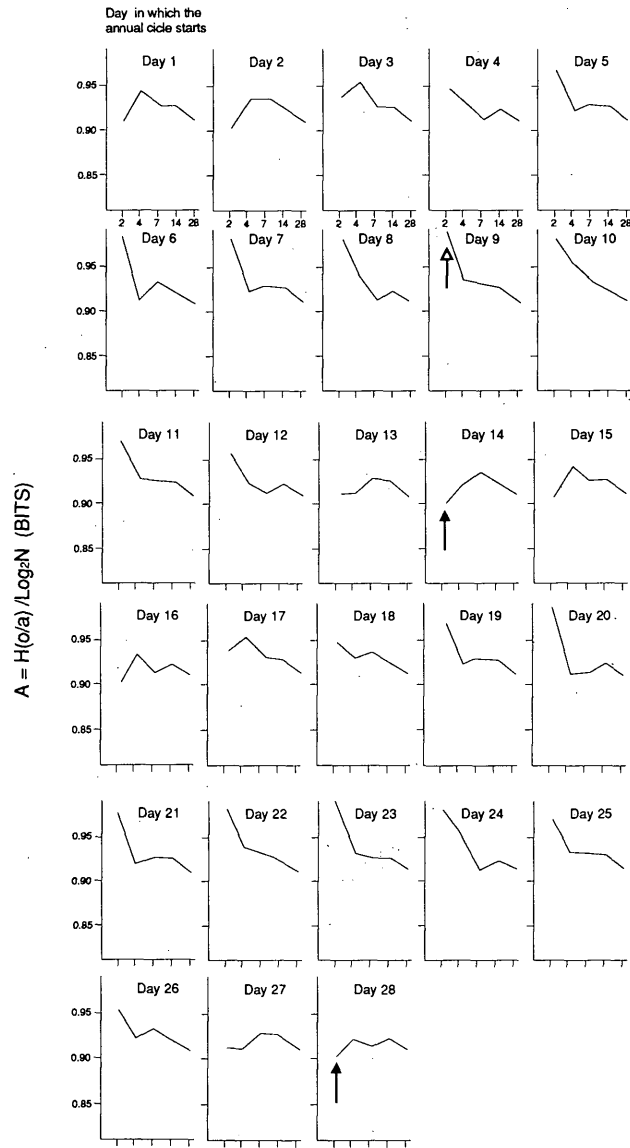


Figure 3: Niche-width (A) value spectra corresponding to each of the 28 transects under consideration in the annual cycle, beginning on a different day rotatively. In each case, A values are those arrived at by dividing the transect into 2, 4, 7, 14 and 28 equal parts. Maximum activity segregation (minimum A values) is produced when the annual cycle is divided into two parts from day 14 or 28. This subdivision separates spring-summer days from autumn-winter days.

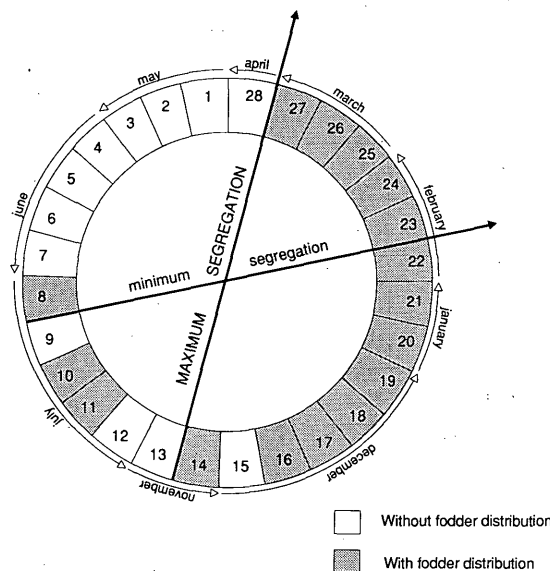


Figure 4: Subdivisions of the studied annual cycle (28 days) on which maximum and minimum cattle activity segregation are produced (lowest and highest niche width -A- values respectively). Maximum activity segregation mainly coincides with the spring-summer and autumn-winter periods, in which the fodder distribution frequencies are very different.

TABLE 1:
Average percentage values of animals found carrying out the various behavioural activities in spring-summer and autumn-winter. The differences between both annual periods are compared by means of T of Student (* P<0.05, ** P<0.01, *** P<0.001).

	SPRING-SUMMER without fodder Days 13-28	AUTUMN-WINTER with fodder Days 14-27	F Snedecor (d.f. 13 x 13)	T Student (d.f. 26)
ACTIVITIES				
Grazing	36.9 ***	15.1	0.77	-3.03
Browsing	4.8	19.9 ***	0.09	3.31
Ruminating in upright position	7.4	8.3	1.02	0.44
Ruminating in lain-down position	7.2 *	3.1	2.10	-2.44
Resting in upright position	8.9	18.3 ***	0.43	4.15
Resting in lain-down position	14.2 *	7.3	2.14	-2.44
Travelling	9.6	14.9 *	0.66	2.25
Occasional displacement	5.1	7.7 *	1.04	2.38
Social activities	5.5	4.8	0.98	-0.69

BEHAVIOUR PATTERNS OF FREE-RANGING CATTLE

On a territory climatologically resembleable to that under study here, ARNOLD (1981) also found a winter decrease in grazing activity among various livestock types. However, in environments where pasture availability does not vary much from season to season, grazing would seem to show similar intensities during spring and winter (GONYOU & STRICKLIN, 1984). According to RUTTER (1968) and ARNOLD & DUDZINSKI (1978) an increase in browsing during grass scarcity, and in the lying-down position during periods of little rain-fall, seem to be frequent tendencies among livestock.

In order to find out the temporary behaviour patterns within the spring-summer and autumn-winter periods, the value A was calculated for various subdivisions (in groups of 2, 7, 14 days). In both periods the maximum segregations of cattle activities (minimum A values) was reached when they were divided into as many parts as the days contained within: 14 in each case (see Figure 5). Cattle behaviour adjusted itself to a detailed -"fine grain"-pattern, indicating a response to environmental factors which may change over short periods of time -from one observation day to the next one- such as meteorological factors. At this degree of detail, the cattle recognize long periods of time or groups of days with similar meteorological, management or grass-availability characteristics.

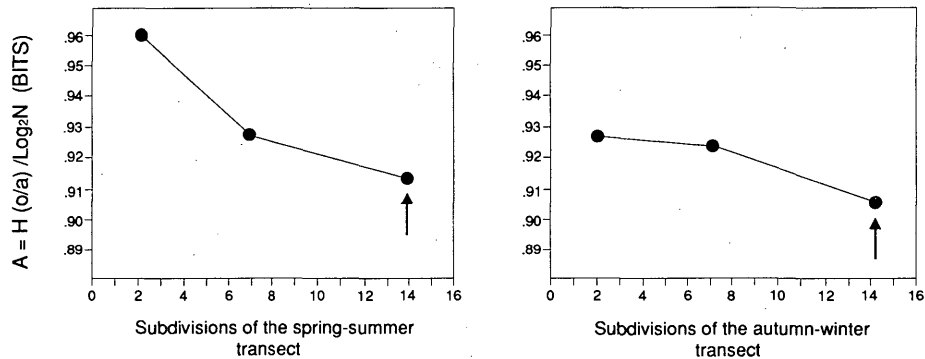


Figure 5: Niche-width (A) value spectra, obtained by subdividing the spring-summer and autumn-winter periods into 2, 7, and 14 equal groups of days. The lowest A values are obtained in both periods when they are divided into as many days as they contain (14 days), indicating a seasonal "fine grain" behavioural pattern. In the autumn-winter period, the minimum A value is less than in spring-summer, which indicates a greater clarity in the behavioural pattern during that period.

The lowest value of A obtained in the autumn-winter period (Figure 5) indicates that at this period, behavioural activities are more predictable than in spring. This is probably related to the differences in limitations to subsistence encountered by the cattle during both periods. In autumn-winter the animals seem to have fewer opportunities for selection of their daily activity, whereas in spring-summer the quantity of grass in the range allows the animals a wider choice of activity, less conditioned by external factors.

2.2. Daily behavioural patterns

Minimum A values obtained for each of the 35 days analyzed are shown in Figure 6a. The number of subdivisions which each day reach these values are shown in Figure 6b. In this case the possible subdivisions change from day to day due to the difference in length (i.e. short in winter, long in summer).

The differences observed in the minimum A values show the greater or lesser clarity (degree of definition) of the daily behavioural patterns independently of the "grain" type (number of subdivisions) to which the pattern adjust. Autumn-winter days tend to show up lower minimum A values than in spring-summer days, and also fewer fluctuations and a similar behaviour between the two sampled years. This indicates that on autumn-winter days cattle have a clearer behavioural pattern. Fodder distribution which is carried out on almost every day during this period, at practically the same time of day and at the same few places, could be the cause of such a result. The need of cattle to assemble at these places at a certain time means greater organization of other activities during the rest of the day. Management, therefore, can have considerable impact on the cattle activity rhythm, making the temporary behaviour patterns more regular.

As for the parts of the day when maximum segregation occurs (Figure 6b), a clear regularity throughout the year has not been observed, nor significant differences between the two season under consideration. This result indicates that, although the cattle segregate their activities more clearly during autumn-winter days, they do so in a different way each day. There are days when behavioural changes are continuous (the day is arranged into short-spell units) while on other days the cattle carry out preferred specific activities for longer periods.

3. Conclusions

In the silvo-pastoral system studied in this paper, maximum segregation of behavioural activities is achieved by dividing the year into two periods which correspond to spring-summer, with abundant grass on the range, and autumn-winter, with a lack of grass and frequent provision of fodder. Thus it can be confirmed that cattle show a "coarse grain" annual behavioural pattern, associated with management impact (fodder distribution) and with Mediterranean climate seasonality.

Within each of the two periods cattle behaviour reaches maximum segregation when isolated days are considered. This kind of pattern seems to respond to not very persistent environmental features, possibly meteorological (rain, wind, clouds etc), which may undergo sudden changes within short periods and which may cause different behaviour in close days. Nevertheless, cattle show a greater organization of their activities in autumn-

BEHAVIOUR PATTERNS OF FREE-RANGING CATTLE

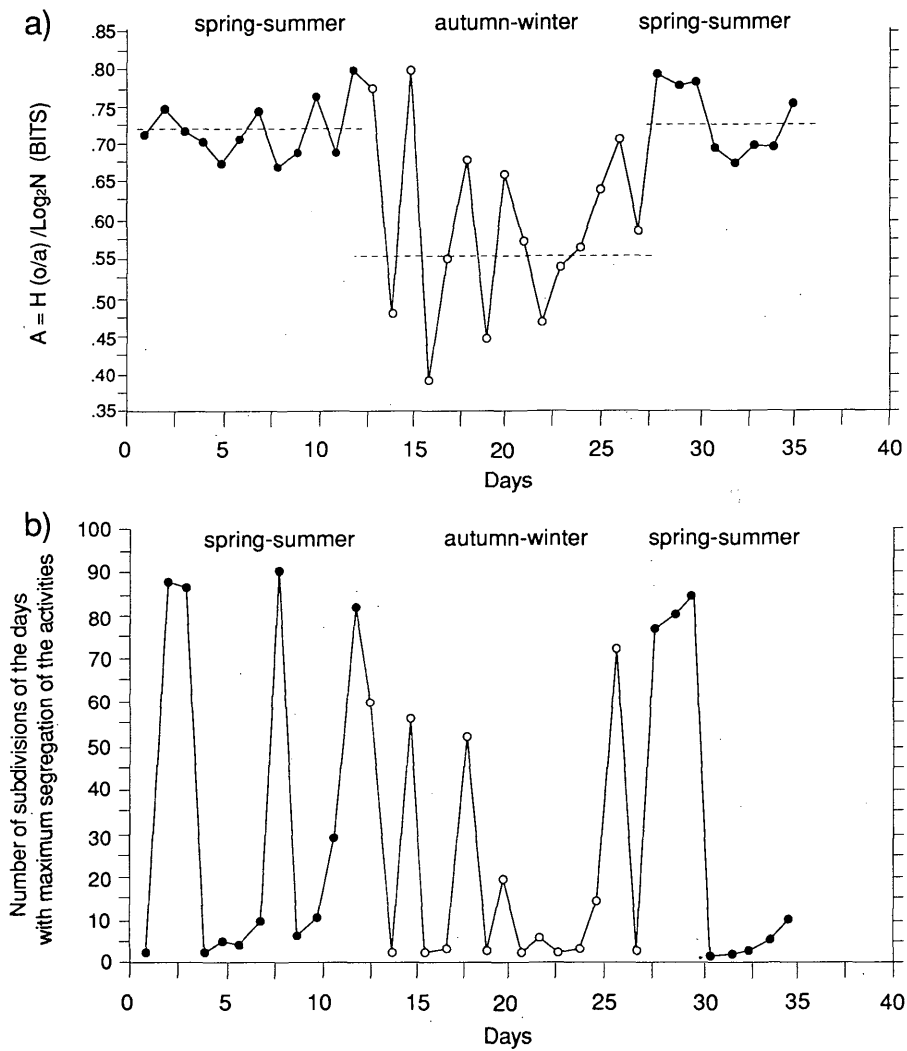


Figure 6: a) Minimum niche-width (A) values obtained on the 35 analyzed days . b) Number of subdivisions in which each day the minimum A value is reached. In autumn-winter minimum A values are less than in spring-summer, indicating a clearer behavioural pattern in the former case.

winter; this is probably related to the fewer opportunities for choice during this period, conditioned by lack of grass and more severe meteorological conditions.

Daily behavioural patterns are as well clearer during autumn-winter days when the cattle show a more sharply defined segregation throughout the day. This would seem to be related to greater management control. Fodder distribution, carried out on most days in this period, acts as a behavioural organizer and the cattle adapt their activities to the timing and placing of these provisions. This produces a clearer segregation of activities throughout the day and therefore, a more predictable behaviour.

Acknowledgments

This study is part of the project PB87-0451 financed by Spanish CAICYT, and formerly by a grant of the "Caja de Ahorros de Madrid". We are grateful to the owner of the field sites (J. M. Urquijo, GESTINCO Company) for the facilities offered for the study.

Appendix

From a matrix with "c" columns (temporary observations) and "r" rows (behavioural activities):

U_{11}	U_{12}	U_{13}	.	.	.	U_{1c}	$U_{.1}$
U_{21}	U_{22}	U_{23}	.	.	.	U_{2c}	$U_{.2}$
U_{31}	U_{32}	U_{33}	.	.	.	U_{3c}	$U_{.3}$
.
.
U_{r1}	U_{r2}	U_{r3}	.	.	.	U_{rc}	$U_{.r}$
$U_{.1}$	$U_{.2}$	$U_{.3}$.	.	.	$U_{.c}$	

the following expressions are used with the Shannon-Weaver formula for the U_{ij} values ($i=1,2,3, \dots r$; $j=1,2,3, \dots c$):

$$H(a) = - \sum_{i=1} p_i \log_2 p_i = - \sum_{i=1} \frac{U_{.i}}{\sum_{i,j} U_{ij}} \log_2 \frac{U_{.i}}{\sum_{i,j} U_{ij}}$$

which may be expressed as follows (see Pineda et al., 1988):

$$H(a) = - \sum_{i=1} (\sum_{j=1} p_{ij}) \log_2 (\sum_{j=1} p_{ij})$$

BEHAVIOUR PATTERNS OF FREE-RANGING CATTLE

and equally,

$$H(a.o) = - \sum_{ij} p_{ij} \log_2 p_{ij}$$

$$H(o/a) = \sum_{i=1} [- \sum_{j=1} p_{ij} \log_2 (p_{ij} / p_{i.})]$$

References

- ARNOLD, G. W. & DUDZINSKI, M. L. (1978).- *Ethology of free-ranging domestic animals*. Elsevier Scien. Publ. Company. New York.
- ARNOLD, G. W. (1981). Grazing behaviour. In (F.H.W. Morley Ed.)- *Grazing animals*. 79-103. Amsterdam.
- BALCELLS, E. & GÓMEZ, J. M. (Eds.) (1975).- *Estudio integrado y multidisciplinario de la dehesa salmantina*. Fasc 1-4. Proyecto 506. MaB. Unesco.
- CASADO, M. A.; DE MIGUEL, J. M.; STERLING, A.; GALIANO, E. F. & PINEDA, F. D. (1985).- Production and spatial structure of mediterranean pastures in a different stages of ecological succession. *Vegetatio*, 64: 75-86.
- DE MIGUEL, J. M. (1989).- *Estructura de un sistema silvopastoral de dehesa*. Tesis doctoral. Universidad Complutense. Madrid.
- DE MIGUEL, J. M.; CASADO, M. A.; GÓMEZ-SAL, A. & PINEDA, F. D. (1985).- Herbivorous influence on the quality and structural evolution of "dehesa" pastures in Central Spain. In *11th General Meeting of European Grassland Federation*. Setubal (Portugal), Abstracts: 33.
- DE MIGUEL, J. M.; RODRÍGUEZ, M. A. & GÓMEZ SAL, A. (1988).- Selección de habitat y distribución territorial de un grupo de vacas en ambiente de dehesa. *Options Méditerranéennes*, 3: 299-303.
- GARCÍA DORY M. A. & MARTÍN VICENTE S. (1988).- *La ganadería en España*. Alianza Editorial. España.
- GÓMEZ GUTIÉRREZ, J. M. et al. (1982).- Descripción de una dehesa tipo. En: Unesco (Ed). *Estudio integrado y multidisciplinario de la dehesa salmantina*. Fascículo n.º 4: 5-83. MaB. España.
- GÓMEZ GUTIÉRREZ, J.M. (1978).- Utilización. In UNESCO (Ed.): *Estudio integrado y multidisciplinario de la dehesa salmantina*. Fasc. 2.: 205-223 MaB.
- GÓMEZ-SAL, A. & DE MIGUEL, J. M. (1989).- Implications ecologiques du comportement du bétail dans l'exploitation et la gestion des dehesas. In Unesco (Ed.): *Seminarie sur dehesas et systemes Agro-sylvo-pastorales similaires*. 98-99. España.
- GÓMEZ-SAL, A.; DE MIGUEL, J. M.; CASADO, M. A. & PINEDA, F. D. (1986).- Successional changes in the morphology and ecological responses of a grazed pasture ecosystem in Central Spain. *Vegetatio*, 67: 33-44.
- GONYOU, H. W. & STRICKLIN W. R. (1984).- Diurnal behaviour patterns of feedlot bulls during winter and spring in northern latitudes. *J. of Anim. Sci.*, 58: 1075-1083.
- HAFEZ, E. S. E. (Ed.) (1975).- *The behaviour of domestic animals*. Bailliere, Tindall & Cassell. London (3th edition).
- LOW, W. A.; TWEEDIE, R. L.; EDWARDS, C. B. H.; HODDER, R. M.; MALAFANT, W. J. & CUNNINGHAM, R. B. (1981a).- The influence of environment on daily maintenance behaviour of free-ranging shorthorn cows in Central Australia. I. General introduction and descriptive analysis of day-long activities. *Appl. Anim. Ethol.*, 7: 11-22.

- LOW, W. A.; TWEEDIE, R. L.; EDWARDS, C. B. H.; HODDER, R. M.; MALAFANT, W. J. & CUNNINGHAM, R. B. (1981 b).- The influence of environment on daily maintenance behaviour of free-ranging shorthorn cows in Central Australia. II. Multivariate analysis of duration and incidence of activities. *Appl. Anim. Ethol.*, 7: 27-38.
- LOW, W. A.; TWEEDIE, R. L.; EDWARDS, C. B. H.; HODDER, R. M.; MALAFANT, W. J. & CUNNINGHAM, R. B. (1981 c).- The influence of environment on daily maintenance behaviour of free-ranging shorthorn cows in Central Australia. III. Detailed analysis of sequential behaviour patterns and integrated discussion. *Appl. Anim. Ethol.*, 7: 39-56.
- MARGALEF, R. (1957).- La teoría de la información en Ecología. *Mem. R. Acad. Ciencias Barcelona*, 32 (13): 373-449.
- MONTALVO, J.; DE MIGUEL, J. M.; SCHMITZ, M. F.; GARCÍA-CRIADO, B. & PINEDA, F. D. (1988).- Calidad de la hierba y sucesión secundaria en un pastizal mediterráneo. *Monogr. Inst. Pirenaico de Ecología*, 4: 837-845.
- PIELOU, E. C. (1975).- *Ecological diversity*. Wiley Interscience. London.
- PINEDA, F. D. & PECO, B. (1988).- Los pastizales adehesados del área de El Pardo. *Mundo Científico*, 79: 386-395.
- PINEDA, F. D.; DE PABLO, C. L.; CASADO, M. A. & DE MIGUEL, J. M. (1988).- Ecological structures recognized by means of entropy analysis: assessment of differences between entropy values. *J. Theor. Biol.* 135: 283-293.
- PINEDA, F. D.; NICOLÁS, J. P.; RUIZ, M.; PECO, B. & BERNÁLDEZ, F. G. (1981).- Succession, diversité et amplitude de niche dans les paturages du Centre de la Peninsule Iberique. *Vegetatio*, 47: 267-277.
- RUTTER, N. (1968).- Time lapse photographic studies of livestock behaviour outdoors on the College Farm Aberystwyth. *J. Agric. Sci. Camb.* 71: 257-265.
- TUTIN, T. G.; HEYWOOD, V. H.; BURGUES, N. A.; VALENTINE, D. H.; WALTERS, S. M. & WEBB, D. A. (1964).- *Flora Europaea*. Cambridge at the University Press.
- SHANNON, C. & WEAVER, W. (1949).- *The mathematical theory of communication*. Univ. Illinois Press. Urbana.
- SÁNCHEZ, F. (1985).- *Análisis de ordenación espacio-temporal de la avifauna de un soto del río Duero*. Tesis Doctoral. Universidad Autónoma. Madrid.
- UNESCO (Ed.) (1989).- *Seminarie sur dehesas et systemes Agro-sylvo-pastoraux similaires*. MaB. España.