Applied Animal Behaviour Science, 28 (1990) 221–232
Elsevier Science Publishers B.V., Amsterdam

Distance traveled by free-ranging supplemented and non-supplemented lactating and non-lactating cows*

R.R. Rouda[1], D.M. Anderson[2], L.W. Murray[3] and J.N. Smith[2]

[1]*Department of Animal and Range Sciences, New Mexico State University, Las Cruces, NM 88003-0003 (U.S.A.)*
[2]*Jornada Experimental Range, Agricultural Research, U.S. Department of Agriculture, Box 30003, New Mexico State University, Dept. 3JER, Las Cruces, NM 88003-0003 (U.S.A.)*
[3]*Department of Experimental Statistics, New Mexico State University, Las Cruces, NM 88003-0003 (U.S.A.)*

(Accepted for publication 25 June 1990)

ABSTRACT

Rouda, R.R., Anderson, D.M., Murray, L.W. and Smith, J.N., 1990. Distance traveled by free-ranging supplemented and non-supplemented lactating and non-lactating cows. *Appl. Anim. Behav. Sci.*, 28: 221–232.

Daily travel of protein supplemented and non-supplemented lactating and non-lactating mature (>4 years of age) Santa Gertrudis×Hereford and Hereford×Santa Gertrudis crossbred cows was estimated between 29 May and 18 August 1986. The study was conducted on semidesert rangeland in south-central New Mexico. Ambient air temperatures ranged between 7 and 38°C. Relative humidity ranged between 15 and 91%, with precipitation 49% above the long-term January–August mean of 147 mm. Four lactating and 4 non-lactating cows were fed an average of 1.4 kg per head day^{-1} of a 41% crude protein cottonseed supplement every 3.5 days. Ten similar non-supplemented cows, 5 lactating and 5 non-lactating, were grazed with the supplemented animals in paddocks averaging >2000 ha in size. To monitor travel, the 18 cows were each bi-pedometered with digital pedometers attached to their front legs.

The least square mean travel (±standard error) over the 81-day study period indicated supplemented and non-supplemented cows traveled similar ($P>0.05$) distances of 7.7±0.7 and 7.9±0.7 km day^{-1}, respectively. Lactating and non-lactating cows likewise traveled similar ($P>0.05$) distances of 7.6±0.7 and 8.2±0.7 km day^{-1}, respectively. Daylight ranged between 14.2 and 13.2 h throughout the study with daily travel decreasing ($P<0.01$) at a rate of 0.06±<0.01 km day^{-1}. Mean daily cow travel was positively correlated ($P<0.01$) to both total amount of precipitation received ($r=0.37$) and mean hours of daylight ($r=0.35$) during the period in which travel was monitored. Mean daily cow travel was negatively correlated ($r=-0.21$; $P<0.05$) to mean daily relative humidity of the previous sampling period. However, mean daily cow travel was not ($P>0.05$) correlated to mean relative humidity of the period in which travel was monitored or to total amount of precipitation received during the previous sampling period. Correlation coefficients were negative

*Cooperative investigations of the Agricultural Research Service, U.S. Department of Agriculture and the New Mexico Agricultural Experiment Station. Journal Article No. 1508, Agricultural Experiment Station, New Mexico State University, Las Cruces, NM, U.S.A.

0168-1591/90/$03.50

($P<0.01$) and ranged between $r=-0.37$ and $r=-0.26$ for mean daily cow travel and mean ambient air temperatures (mid-range, minimum and maximum) regardless of sampling period.

INTRODUCTION

Understanding the behavior of free-ranging cattle contributes to better livestock management and a knowledge of their nutritional needs (Anderson et al., 1985). Travel is an aggregate response to many abiotic and biotic stimuli. Travel is an important activity of range livestock as they forage and move to obtain available water (Lynch, 1977). Foraging probably accounts for the largest percentage of travel (Moorefield and Hopkins, 1951; Wagnon, 1963; Low et al., 1978), and may occupy more than 50% of daily activity (Cory, 1927; Dwyer, 1961).

Cattle travel can be affected by ambient air temperature (Malechek and Smith, 1976), wind (Dwyer, 1961; Ruckebusch and Bueno, 1978), topography (Anderson and Kothmann, 1977), parasite infestation (Harvey and Launchbaugh, 1982; Lefcourt and Schmidtmann, 1989), grazing strategy (Anderson and Kothmann, 1980), pasture size (Wagnon, 1963; Arave and Albright, 1981), water location (Low et al., 1978), salt placement (Cook, 1970), and innate characteristics of the animal (Anderson and Kothmann, 1977; Low et al., 1978). *Bos indicus* genotypes tend to travel farther on a daily basis than *Bos taurus* cattle (Herbel and Nelson, 1966; Hafez and Bouissou, 1975). However, there also appear to be breed differences approaching as much as 1 km day^{-1} within the *B. taurus* species of cows having different milk production potentials (Lathrop et al., 1988). Maximum daily travel of Hereford cows on annual California rangeland occurred early in the growing season (February and March) when new growth was scarce. As forage matured (April and late May), travel decreased and was least in June when most forage was dry (Wagnon, 1963). Results of daily travel in relation to forage availability are variable. Cattle have also been reported to graze more when forage is in short supply (Lofgreen et al., 1957; Low et al., 1978). However, Ruckebusch and Bueno (1978) found that Aubrac cows spent less time walking as the forage supply diminished.

Protein supplement has been shown to affect animal travel (Wagnon, 1963; Box et al., 1965). Cattle travel has also been positively correlated to forage crude protein content (Anderson and Kothmann, 1980). Time of day when energy supplements are administered may change the temporal grazing profile of cattle (Adams, 1985).

Dairy cows in estrus have been monitored to travel almost four times more than those in anestrus (Kiddy, 1977). *Bos taurus* cows with steer calves have been monitored to travel 1.3 km day^{-1} farther ($P<0.01$) than similar cows with heifer calves (Lathrop et al., 1988).

This study was conducted using free-ranging lactating and non-lactating cows. The first objective was to determine the effect of protein supplement on daily cow travel when supplemented and non-supplemented cattle were maintained together as a single herd. A second objective was to evaluate the relationship between daily travel and the abiotic factors of ambient air temperature, relative humidity, precipitation and hours of daylight.

ANIMALS, MATERIALS AND METHODS

Data were collected between 29 May and 18 August 1986 on the Jornada Experimental Range. The range headquarters (32°27′ N, 106°45′ W) is on the Jornada de Muerte plain in Dona Ana County, NM. Elevations range from 1200 to 2800 m above sea level. Vegetation is typical of semidesert rangeland, and includes grasses, forbs and shrubs growing in a patchwork mosaic dictated by soil differences and moisture variations from the mean yearly long-term (1916–1986) precipitation of 228 cm recorded at headquarters (Paulsen and Ares, 1962). Climatological data were collected daily at ranch headquarters. However, vegetation was not sampled in this study. Precipitation during the first 8 months of 1986 was 49% above the 70-year (8-month) average of 147 mm. Weather parameters measured at ranch headquarters included mid-range ((maximum+minimum)/2), maximum and minimum ambient air temperature, relative humidity, precipitation and hours of daylight expressed as means by sampling period (Table 1).

Out of a herd of 69 cows which were weighed and supplemented between 16 April and 16 July, 18 mature (>4 years of age) Santa Gertrudis ×Here-

TABLE 1

Minimum and maximum ambient air temperatures, relative humidity, total precipitation, and hours of daylight by time interval at Jornada Experimental Range Headquarters, Dona Ana County, NM, 1986

Interval	Ambient air temperatures (°C)				Relative humidity (%)		Total precipitation (cm)	Daylight (h)	
	Minimum		Maximum						
	$\bar{x}$	Range	$\bar{x}$	Range	$\bar{x}$	Range		$\bar{x}$	Range
29 May–6 June	12	7–14	28	21–32	75	52–90	2.4	14.1	14.0–14.1
6–13 June	14	9–20	33	32–36	40	28–68	0.0	14.2	14.1–14.2
13–26 June	16	13–19	33	23–38	56	22–90	5.4	14.2	14.1–14.2
26 June–8 July	18	16–21	32	24–35	67	36–86	1.5	14.2	14.2–14.2
8–21 July	17	14–19	33	36–38	76	62–90	4.4	14.2	14.2–14.2
21 July–4 Aug.	16	14–20	35	29–38	64	42–95	0.7	14.1	14.0–14.1
4–11 Aug.	19	17–21	35	32–38	65	48–77	0.5	13.8	13.7–14.0
11–16 Aug.	16	14–18	35	29–38	72	52–91	0.7	13.6	13.5–13.6

Adapted from U.S. Department of Commerce, 1986.

ford and Hereford×Santa Gertrudis crossbred cows trained to wear digital pedometers were selected for evaluation. The non-supplemented control group contained 5 lactating and 5 non-lactating animals while 4 lactating and 4 non-lactating animals composed the supplemented group.

Supplemented animals were separated from the single herd of cows only during feeding. As the herd moved single-file through a unidirectional maze, animals were first weighed and then allowed to drink water before being released back into the pasture or shunted into pens for feeding. Use of an electronic identification/weighing system made automated separation possible (Rouda, 1988; Rouda et al., 1988). Each cow was given a unique identification number which had been encoded in an external transponder which hung from a band around the animal's neck. The transponder activated the weighing system and pneumatic gates which moved to automatically sort animals into pens or directly back to the pasture. Animals in the supplemented group each received 5 kg of 41% crude protein cottonseed pellet per feeding. Because supplementation was correlated with the animal's frequency to return to headquarters to drink water, feeding occurred on average every 3.5 days; this provided a mean intake of 1.4 kg per head day^{-1}.

The cow herd was moved from a triangular, 2006-ha pasture to an adjoining triangular, 2617-ha pasture on 28 May. The following day, 18 of the 69 cows were pedometered on the metacarpus of each foreleg with Digi-Meter* digital pedometers manufactured by Edge Mark in Japan (Fig. 1). These instruments had previously been used successfully on free-ranging cattle (Anderson and Kothmann, 1977; Anderson and Urquhart, 1986). Pedometer correction factors were developed for each instrument–leg combination by walking the animals 3.2 km and adjusting the pedometer reading to this value to reflect accurate distances walked by the cattle. Correction factors were calculated by dividing the distance recorded by the pedometer by the actual distance walked (Walker et al., 1985; Anderson and Urquhart, 1986). Pedometers were calibrated at the start and again before the pedometers were removed on 18 August. Numbers taken directly from the pedometers were recorded in accordance with guidelines set by Anderson and Urquhart (1986). Daily travel was estimated by dividing the difference between consecutive readings by the individual calibration factor, then expressing this distance on a 24 h basis. Raw pedometer readings between 29 May and 8 July were adjusted using the 28 May correction factor. Pedometer readings between 21 July and 18 August were adjusted using the correction factor obtained on 18 August. Numbers from the pedometers worn on the right and left legs were summed and divided by 2 to form the data base for each cow used to determine the mean

*Mention of a trademark does not constitute a guarantee or a warranty of the product by the United States Department of Agriculture, Agricultural Research Service, or New Mexico State University, and does not imply its approval to the exclusion of other products that may be suitable.

Fig. 1. Digital pedometers enclosed in plastic cases attached to cow's forelegs.

travel profile of the two groups. Data collected between 29 May and 8 July (period of supplementation) was compared with travel between 21 July and 18 August (post-supplementation period). All pedometered animals were trapped into pens approximately every 10 days in order to obtain pedometer readings. Average values for each of the eight sampling periods were used in the computations.

Estimated mean daily travel data were analyzed by analysis of variance using a split plot with a completely randomized design. The two levels of supplement and physiological status (lactating vs. non-lactating) were on the whole plot, and sampling period on the split plot. The error term (error a) for testing whole-plot effects was animal within supplementation and lactation levels; the error term for testing split-plot effects (error b) was period by animal within supplementation and lactation level. Differences in daily travel over the entire experimental period (28 May to 18 August) were also tested. Whenever significant F values ($P<0.05$) were obtained, means were separated by the Scheffe procedure (Steel and Torrie, 1980). The relationships between daily travel and selected climatological parameters were analyzed using correlation analysis (Draper and Smith, 1981). Procedures of the Statistical Analysis System (SAS Institute, 1985) were used in all analyses. All means are followed by ± standard errors.

RESULTS

Cows traveled a mean distance of 7.8 ± 0.46 km day^{-1} ($n = 147$). This distance is within the 6.9–14.6 km day^{-1} range described by Herbel and Nelson (1966), and the 5.6–10.6 km day^{-1} range described by Anderson and Urquhart (1986) for daily travel of beef cattle grazing similar arid rangeland pastures.

Mean daily travel of cows by feeding group, physiological status and sampling period is given in Table 2. However, none of the two- and three-way interactions tested proved significant ($P > 0.05$).

Protein supplementation with cottonseed pellets did not affect ($P > 0.05$) daily travel. Differences between these data collected using pedometers and previous work involving observation, in which protein supplement apparently influenced animal travel, may reflect differences in experimental technique and design. Wagnon (1963) estimated animal travel by plotting herd movement on a map. He reported that supplemented cows traveled less than non-supplemented cows (3.8 vs. 4.1 km day^{-1}, respectively), and stated that

TABLE 2

Least square means (LSM) and associated standard errors (SE) for daily travel (km day^{-1}) of free-ranging beef cows grazing semidesert rangeland by supplement level (41% CP cottonseed pellets), physiological status and sampling period

Category	No. animals	LSM	SE
Supplement level (kg per head day^{-1})			
1.4	8	7.9^{a}	0.69
0.0	10	7.9^{a}	0.67
Physiological status			
Lactating	9	7.6^{a}	0.71
Supplemented	4	7.7	0.98
Control	5	7.6	1.02
Non-lactating	9	8.2^{a}	0.66
Supplemented	4	8.2	0.98
Control	5	8.3	0.87
Sampling period			
29 May–8 July	18	9.1^{a}	0.37
Supplemented	8	9.0	0.56
Control	10	9.1	0.50
21 July–18 August	18	6.8^{b}	0.33
Supplemented	8	6.8	0.46
Control	10	6.7	0.48

Column means within the same supplement level, physiological status, and sampling period with different superscripts differ ($P < 0.05$).

these values did not include travel incurred between grazing areas. Box et al. (1965) estimated travel by tracing cow movement on a map and recording vehicle odometer readings. They found that non-supplemented cows walked twice as far as those supplemented (6.6 vs. 3.1 km day^{-1}, respectively), and non-supplemented animals foraged throughout the pasture, whereas supplemented animals remained within a more restricted area. No mention is made of amount of travel incurred while grazing. In both of these studies supplemented and non-supplemented cows were maintained in separate pastures; therefore, travel differences were confounded by possible pasture differences related to standing crop or other factors, in addition to level of supplement.

Our data indicate lactation had no effect on mean daily travel of cows ($P>0.05$). Lactating cows with calves came to headquarters to drink water without their calves. Arnold and Dudzinski (1978) indicate cows may leave their calves in the charge of a "guard-cow" when forage availability or water location dictates they cover excessive distances. Cows on similar rangeland in their last trimester of gestation traveled about the same ($P>0.05$) distances as non-pregnant animals (Anderson and Urquhart, 1986).

The cows traveled 34% farther between 29 May and 8 July than they did between 21 July and 18 August. When daily travel was examined over the 81-day period, distances traveled by cows decreased ($P<0.01$) at a rate of $0.06 \pm <0.01$ km day^{-1}. Similar linear declines in travel have been reported in Texas by Anderson and Kothmann (1980). However, in Montana between mid-July and mid-August daily travel of beef cows increased ($P<0.05$) at a rate of 0.02 km day^{-1} (Lathrop et al., 1988). A possible explanation for the higher daily travel between 29 May and 8 July may have been exploratory behavior, often exhibited by cattle when they are moved to a new environment (Arnold and Dudzinski, 1978; Gluesing and Balph, 1980). Moving cattle into a new pasture has been shown by Anderson and Urquhart (1986) to increase ($P<0.0001$) their daily travel by as much as 30%. In this study, animals were moved into the pasture where travel was monitored only 24 h before data collection began. Daily travel has been shown to be positively correlated to forage availability (Ruckebusch and Bueno, 1978). However, standing crop was not concurrently sampled in the present study to investigate this hypothesis.

Daily travel was plotted against the various climatic factors measured. The scatter diagrams obtained displayed no quadratic or cubic tendencies. Coefficients of linear correlation between the various climatological parameters tested and animal travel are given in Table 3. Cow travel was negatively correlated ($P<0.01$) to mean mid-range, mean minimum and mean maximum daily ambient air temperatures during the sampling period, and also during the previous period. Previous research has shown that cattle reduce their energy expenditure (activity) during periods of high and low ambient air temperature (Malechek and Smith, 1976; Shaw and Dodd, 1979; Anderson et al.,

TABLE 3

Correlation coefficients (r) and observed level of significance (OSL) between travel (km day^{-1}) of cows grazing semidesert rangeland and abiotic factors ($n=129$)

Interaction	r	OSL
Travel × mean mid-range daily ambient air temperature	−0.37	$P<0.01$
Travel × mean minimum daily ambient air temperature	−0.35	$P<0.01$
Travel × mean maximum daily ambient air temperature	−0.32	$P<0.01$
Travel × mean mid-range daily ambient air temperature during the previous sampling period	−0.33	$P<0.01$
Travel × mean minimum daily ambient air temperature during the previous sampling period	−0.35	$P<0.01$
Travel × mean maximum daily ambient air temperature during the previous sampling period	−0.26	$P<0.01$
Travel × mean daily relative humidity	−0.14	$P=0.12$
Travel × mean daily relative humidity during the previous sampling period	−0.21	$P<0.05$
Travel × total amount of precipitation received	0.37	$P<0.01$
Travel × total amount of precipitation received during the previous sampling period	−0.02	$P=0.85$
Travel × mean daily hours of daylight	0.35	$P<0.01$

1985). However, recent work by Beverlin et al. (1989) and Dunn et al. (1988) indicates the length of thermal acclimation within cattle can vary within and between seasons and may be shorter than the 9–14 day thermal acclimation period proposed by Senft and Rittenhouse (1985). Because ambient air temperatures stimulate both plants and animals, abrupt changes may cause responses that can be easily explained. However, gradual temperature changes can produce a habituated response in both plants and animals that makes it difficult to accurately determine if specific biological responses are temperature mediated under natural conditions. In this study, it was impossible to determine what percentage of the negative correlation between travel and temperature was the result of temperature influence on the animal versus a temperature influence on the vegetation, which in turn, may have influenced travel. If mean daily relative humidity and travel were taken consecutively no correlation ($P>0.05$) existed. However, if the relative humidity of a previous period was correlated ($r=-0.21$) with the mean travel of the present period there was a relationship ($P<0.05$). A similar result was obtained by Anderson and Kothmann (1980). Travel was positively correlated ($r=0.37$; $P<0.01$) to the total amount of rainfall received during a sampling period, but was not affected ($P>0.05$) by previously received precipitation. These data support the observation that during periods of rainfall, cattle become restless and prefer to walk rather than lie down (Dwyer, 1961; Rutter, 1968). Daily travel and daylength were positively correlated ($r=0.35$; $P<0.01$). Other research also supports this finding (Cory, 1927; Shaw et al., 1977).

DISCUSSION

Travel of free-ranging beef cattle is a behavior essential for obtaining food and water as evidenced by the mean travel of 7.8 ± 0.46 km day^{-1} recorded. The estimate that 50% of a free-ranging cow's day is occupied by travel (Dwyer, 1961) is not surprising when contrasted to the travel of Hereford cow–calf pairs maintained in confinement in which the mean travel of cow and calf was 0.61 and 0.14 km day^{-1}, respectively (Schake and Riggs, 1972).

Administering cottonseed protein supplement at a mean rate of 1.4 kg per head day^{-1} every 3.5 days did not ($P > 0.05$) affect daily travel or the mean daily change in cow liveweight of supplemented cows compared with non-supplemented cows. Coleman and Wyatt (1982) contend that infrequent feeding of protein supplement may be used successfully as a means to supplement range forage. Our data on the entire herd of 69 cows neither confirm nor refute this hypothesis based on the liveweight profile of the cows. The technique to provide supplement and obtain cow travel data capitalized on the innate behavior of animals to drink water. By maintaining a single herd, differences in travel and liveweight between supplemented and non-supplemented were not confounded with pasture differences (Rouda et al., 1988). In addition, disruption of normal behaviors was minimized. Normal morning and afternoon grazing intervals can be altered with conventional supplementation procedures (Wagnon, 1963; Adams, 1985) or supplemented cattle may spend time in a more restricted area compared with controls (Box et al., 1965).

Even though detailed temporal and spatial travel patterns are not available using digital pedometers, data acquisition is obtained throughout consecutive 24 h periods of time. Pedometers are desirable tools to monitor relative not absolute distances traveled by free-ranging cows without the observer influencing the observation (Anderson and Urquhart, 1986). Periodic observations of the entire herd of 69 cows while at pasture did not indicate supplemented and non-supplemented animals were not acting in synchrony. The gregarious nature of cattle to organize into social groups, arising from their evolutionary history (Stricklin and Mench, 1987), and their desire to attain gut fill apparently overrode the temporary separation of the supplemented from the non-supplemented cows once they were together on the pasture.

A suckling calf did not ($P > 0.05$) limit dam travel within pastures > 2000 ha. This finding is consistent with reports that free-ranging cows normally leave their calves to graze or go to water, especially when calves are quite young (Arnold, 1985).

Reduced exploratory behavior, decreasing day length, cessation of supplementation, and other biotic or abiotic factors acting in combination may have been responsible for the decreased ($P < 0.01$) daily travel of $0.06 \pm < 0.01$ km day^{-1} observed between May and August. The climatological factors which correlated ($P < 0.05$) with cow travel were mean mid-range, mean minimum and mean maximum daily ambient air temperatures, amount of precipitation received and length of daylight. Possibly higher correlations between travel and the thermal environment may result if the combined effects of radiant energy and air movement are estimated using blackglobe temperature in combination with wet and dry bulb temperatures to estimate environmental warmth or wet bulb globe temperatures (Yousef, 1990). Further research designed to minimize confounding and accurately identify management and weather factors which influence free-ranging cattle travel are needed.

REFERENCES

Adams, D.C., 1985. Effect of time of supplementation on performance, forage intake and grazing behavior of yearling beef steers grazing russian wild ryegrass in the fall. J. Anim. Sci., 61: 1037–1042.

Anderson, D.M. and Kothmann, M.M., 1977. Monitoring animal travel with digital pedometers. J. Range Manage., 30: 316–317.

Anderson, D.M. and Kothmann, M.M., 1980. Relationship of distance traveled with diet and weather for Hereford heifers. J. Range Manage., 33 217–220.

Anderson, D.M. and Urquhart, N.S., 1986. Using digital pedometers to monitor travel of cows grazing arid rangeland. Appl. Anim. Behav. Sci., 16: 11–23.

Anderson, D.M., Smith, J.N. and Hulet, C.V., 1985. Livestock behavior – The neglected link in understanding the plant–animal interface. In: F.H. Baker and R.K. Jones (Editors), Proceedings of a Conference on Multispecies Grazing. Winrock International, Morrilton, AR, pp. 116–148.

Arave, G.W. and Albright, J.L., 1981. Cattle behavior. J. Dairy Sci., 64: 1318–1329.

Arnold, G.W., 1985. Nursing and maternal care. In: A.F. Fraser (Editor) Ethology of Farm Animals. World Animal Science, Vol. A5. Elsevier, New York, pp. 349–360.

Arnold, G.W. and Dudzinski, M.L., 1978. Ethology of Free-ranging Domestic Animals. Elsevier, New York, 198 pp.

Beverlin, S.K., Havstad, K.M., Ayers, E.L. and Petersen, M.K., 1989. Forage intake responses to winter cold exposure of free-ranging beef cows. Appl. Anim. Behav. Sci., 23: 75–85.

Box, T.W., Brown, G. and Liles, J., 1965. Influence of winter supplemental feeding of cottonseed cake on activities of beef cows. J. Range Manage., 18: 124–126.

Coleman, S.W. and Wyatt, R.D., 1982. Cottonseed meal or small grains forages as protein supplements fed at different intervals. J. Anim. Sci., 55: 11–17.

Cook, C.W., 1970. Energy budget of the range and range livestock. Colo. Agric. Exp. Stn. Bull. 109, 28 pp.

Cory, V.W., 1927. Activities of livestock on the range. Tex. Agric. Exp. Stn. Bull. 367, 47 pp.

Draper, N.R. and Smith, H., 1981. Applied Regression Analysis. Wiley, New York, 709 pp.

Dunn, R.W., Havstad, K.M. and Ayers, E.L., 1988. Grazing behavior responses of rangeland beef cows to winter ambient temperatures and age. Appl. Anim. Behav. Sci., 21: 201–207.

Dwyer, D.D., 1961. Activities and grazing preferences of cows with calves in northern Osage County, Oklahoma, Okla. Agric. Exp. Stn. Bull. 558, 61 pp.

Gluesing, E.A. and Balph, D.F., 1980. An aspect of feeding behavior and its importance to grazing systems. J. Range Manage., 33: 426–427.

Hafez, E.S.E. and Bouissou, M.F., 1975. The behavior of cattle. In: E.S.E. Hafez (Editor), The Behavior of Domestic Animals. Balliere, Tindall and Cassell, London, pp. 203–245.

Harvey, T.L. and Launchbaugh, J.L., 1982. Effect of horn flies on behavior of cattle. J. Econ. Entomol., 75: 25–27.

Herbel, C.H. and Nelson, A.B., 1966. Activities of Hereford and Santa Gertrudis cattle on a southern New Mexico range. J. Range Manage., 19: 173–176.
Kiddy, C.A., 1977. Variation in physical activity as an indication of estrus in dairy cows. J. Dairy Sci., 60(2): 235–243.
Lathrop, W.J., Kress, D.D., Havstad, K.M., Doornbos, D.E. and Ayers, E.L., 1988. Grazing behavior of rangeland beef cows differing in milk production. Appl. Anim. Behav. Sci., 21: 315–327.
Lefcourt, A.M. and Schmidtmann, E.T., 1989. Body temperature of dry cows on pasture: Environmental and behavioral effects. J. Dairy Sci., 72: 3040–3049.
Lofgreen, G.P., Meyer, J.H. and Hull, J.L., 1957. Behavior patterns of sheep and cattle being fed pasture or silage. J. Anim. Sci., 16: 773–780.
Low, W.A., Hodder, R.A. and Abel, D.E., 1978. Watering behaviour of British breed cattle in central Australia. In: K.M.W. Howes (Editor), Studies of the Australian Arid Zone, Part 3. Water in Rangelands. CSIRO, Melbourne, pp. 167–177.
Lynch, J.J., 1977. Movement of some range herbivores in relation to their feed and water supply. In: Proceedings of the 2nd U.S.-Australia Rangeland Panel. Aust. Rangel. Soc., Perth, pp. 163–172.
Malechek, J.C. and Smith, B.M., 1976. Behavior of range cows in response to winter weather. J. Range Manage., 29: 9–12.
Moorefield, J.G. and Hopkins, H.H., 1951. Grazing habits of cattle in mixed prairie pasture. J. Range Manage., 4: 151–157.
Paulsen, H.A. and Ares, F.N., 1962. Grazing values and management of black grama and tobosa grasslands and associated shrub ranges of the Southwest. U.S.D.A. Tech. Bull. 1270, 56 pp.
Rouda, R.R., 1988. Effect of protein supplementation on performance, water intake, and travel of beef cattle grazing semidesert rangeland in southcentral New Mexico. Ph.D. Dissertation, New Mexico State University, Las Cruces, 136 pp.
Rouda, R.R., Anderson, D.M. and Herbel, C.H., 1988. Protein supplementation, daily gain, water intake and travel of free-ranging cattle on the Jornada Experimental Range. In: Livestock Research Briefs and Cattle Growers Short Course, New Mexico State University, Las Cruces, 99 pp.
Ruckebusch, Y. and Bueno, L., 1978. An analysis of the ingestive behavior and activity of cattle under field conditions. Appl. Anim. Ethol., 4: 301–313.
Rutter, N., 1968. Time lapse photographic studies of livestock behavior outdoors on the College Farm, Aberystwyth. J. Agric. Sci. Camb., 71: 257–265.
Schake, L.M. and Riggs, J.K., 1972. Behavior of beef cattle in confinement, a technical report. Tex. Agric. Exp. Stn., Tech. Rep. No. 27, 12 pp.
Senft, R.L. and Rittenhouse, L.R., 1985. A model of thermal acclimation in cattle. J. Anim. Sci., 61: 297–306.
Shaw, R.B. and Dodd, J.D., 1979. Cattle activities and preferences following strip application of herbicide. J. Range Manage., 32: 449–452.
Shaw, R.B., Tanner, G.W. and Dodd, J.D., 1977. Cattle activities and preferences following patterned herbicide application. Proc. 30th Annu. Meet. Soc. Range Manage. (Abstr.), p. 36.
Statistical Analysis System Institute, 1985. SAS User's Guide: Statistics. SAS Institute, Cary, NC, 956 pp.
Steel, R.G.D. and Torrie, J.H., 1980. Principles and Procedures of Statistics: A Biometrical Approach, McGraw-Hill, New York, 2nd edn, 633 pp.
Stricklin, W.R. and Mench, J.A., 1987. Social organization. Vet. Clin. N. Am. Food Anim. Pract., 3: 307–322.
U.S.Department of Commerce, 1986. National Oceanic and Atmospheric Administration. Climatology data annual summary: New Mexico, 90(13). Asheville, NC, 29 pp.
Wagnon, K.A., 1963. Behavior of beef cows on a California range. Calif. Agric. Exp. Stn. Bull. 779, 58 pp.

Walker, J.W., Heitschmidt, R.K. and Dowhower, S.L., 1985. Evaluation of pedometers for measuring distance traveled by cattle on two grazing systems. J. Range Manage., 38: 90–93.4
Yousef, M.K., 1990. Importance of field studies in stress physiology. In: D.M. Anderson, K.M. Havstad and F.C. Hinds (Editors) Stress and the Free-ranging Animal. N.Mex. Agric. Exp. Stn. Reg. Res. Rep. 646, Las Cruces, pp. 14–29.