

Original study

A behavioural study of the Greek »Thrakian« sheep breed grazing on the rangelands of Rhodope, Greece

Konstantinos Karasabdis¹, Maria Yiakoulaki², Agapi Papazafeiriou¹, Ioannis Mountousis¹ and Konstantinos Papanikolaou¹

¹Department of Animal Production, Faculty of Agriculture, Forestry and Natural Environment Aristotle University of Thessaloniki, Thessaloniki, Greece, ²Department of Range Science, Faculty of Agriculture, Forestry & Natural Environment, Aristotle University of Thessaloniki, Thessaloniki, Greece

Abstract

The Greek Thrakian sheep breed is under extinction and information about their grazing behaviour is important to both welfare and performances. The grazing behaviour of the Thrakian sheep breed was investigated in the mountainous rangelands of North-Eastern Thrace, Greece from April to October 2012. Direct observations were carried out on six female sheep for two consecutive days at each month and the time spent on grazing, resting and rumination was recorded. Also, the daily distance travel by sheep flock was recorded with a handheld Global Positioning System. Sheep travelled on average 4.5 km/day and they walked their shortest distances during the summer months (July and August). Sheep spent 324.3 min/day (64.2% of their grazing activities) on feeding while they devoted less time ($P<0.05$) to resting and ruminating (134.4 and 46.4 min/day, respectively). The higher values of resting and ruminating were recorded during summer (163.2 min/day and 54.2 min/day, respectively). Time spent on grazing by sheep had significant ($P<0.05$) negative relationship to air temperature ($r=-0.966$) while the resting and ruminating time had a positive one ($r=0.935$; $P<0.01$ and $r=0.815$; $P<0.05$, respectively).

Keywords: grazing activity, vegetative period, »Thrakian« breed, Rhodopi

Archiv Tierzucht 57 (2014) 9, 1-10
doi: 10.7482/0003-9438-57-009

Received: 25 Januar 2014

Accepted: 3 April 2014

Online: 23 May 2014

Corresponding author:

Maria Yiakoulaki, email: yiak@for.auth.gr

Department of Range Science, Faculty of Agriculture, Forestry & Natural Environment, Aristotle University of Thessaloniki, Thessaloniki, Greece

© 2014 by the authors; licensee Leibniz Institute for Farm Animal Biology (FBN), Dummerstorf, Germany.

This is an Open Access article distributed under the terms and conditions of the Creative Commons Attribution 3.0 License (<http://creativecommons.org/licenses/by/3.0/>).

Introduction

The Thrakian sheep is an autochthonous Greek breed raised in the villages of NE Rhodopi, Thrace, Greece. The breed is characterized as under extinction (FAO 2007) since its population counts less than 1 000 heads (NSSG 2009). This breed can be included on the Tsigai group of breeds of South-Eastern Europe (Drăgănescu 2007, Georgoudis *et al.* 2011), which grazing in the isolated mountainous environment of the Thrakian area has evolved over many generations and developed some unique morphological and performance characteristics.

The farming system of the Thrakian sheep breed is based on the utilization of natural rangelands, which cannot provide forage to animals during the whole year (Karasabidis 2013). The farmers, in order to fill up the feed gap, utilize alternative forage resources, such as cereal stubble fields after crop harvesting during summer. In addition, they also make extensive use of purchased feedstuffs, mainly roughage and concentrates, during the entire year. Sheep flocks have a permanent base, located near the village from where they move every morning to rangelands and return at night. They are pure and permanently herded. Transhumance (seasonal mobility of farmers with their flocks between fixed summer and winter pastures) is not practised.

The grazing sheep divide their day among three main activities: feeding, ruminating and resting (Arnold 1981). By themselves these activities may be of greater academical interest than of practical value. However, when they are considered with other parameters, such as forage environment and climatic conditions, their consideration and also deviation from the normal may signal stress factors and suggest changes in management practices (Campbell *et al.* 1969, Hejcmanová *et al.* 2009).

Studies on the grazing behaviour of sheep breeds that are naturally adapted to mountainous area of Mediterranean zone are sparse. Loridas *et al.* (2011) have studied the grazing behaviour of the indigenous sheep of the Greek breed »Serres« in a typical lowland and mountainous pasture of the Prefecture of Serres, Northern Greece. In the present study the grazing activities of the Thrakian sheep breed are investigated in their natural environment during a 7 month period. Specifically, the objectives were: (a) to determine the daily route travelled by sheep, (b) to record the time spent on grazing, resting and rumination, (c) to determine the effect of air temperature on grazing activities as well as the interactions of these parameters.

Material and methods

Study area

The study was conducted at Plagia village (longitude 25°42.869'E, latitude 41°08'216''N) which is located on the foothills of Vrsini Mountain in the Prefecture of Rhodopi, Thrace, Greece (Figure 1). The altitude of the study area is 205m. Mean annual precipitation was 488.5mm and mean annual air temperature was 14.3°C (HNMS 2012), indicating a Mediterranean climate. The hottest and driest months were July and August, while the coldest ones were January and February. The highest percentage of humidity appeared at December.

The dominated vegetation of the rangeland consisted of woody species such as *Phillyrea media*, *Acer campestre*, *Carpinus orientalis*, *Pyracantha coccinea*, *Arbutus unedo*, *Prunus spinosa*, *Rubus fruticosus*, *Salix amygdalina*, *Sambucus nigra* and herbaceous species e.g. *Chrysopogon gryllus*, *Bromus hordeaceus*, *Hordeum murinum*, *Cistus salvifolius*, *Fragaria vesca*, *Vicia dasycarpa*, *Trifolium campestre*, *Medicago lupulina*, *Trifolium angustifolium*, *Crepis setosa*, *Poa bulbosa*, *Festuca heterophylla* etc.

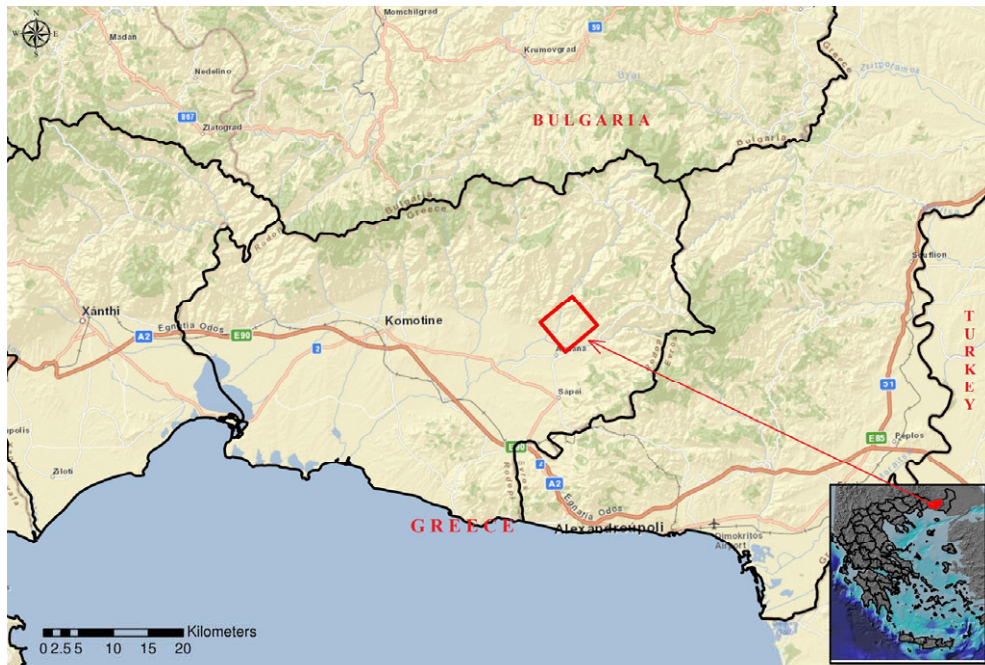


Figure 1
Location of the study area

Description of the Thracian sheep breed

The Greek sheep of the Thracian breed has a height that reaches 55-60 cm at the withers in females and 62-65 cm in males. Live body weight ranges from 35-45 kg in females and 45-55 kg in males. Colouring is usually white with black or brown spots in the face and limbs and a ring around the eyes. The head is conic, elongated and with a straight line between the forehead and the nose. The ears are small and semi-erect. The males have minute spiral horns while the females have no horns. The wool is thick (the breed belongs to coarse woolled sheep), very fine, of good quality and covers the body almost entirely. Wool production reaches 1.5-2.0 kg/animal/year. The animals usually enter their reproductive years during their second year and the births occur during January-February. They have a high fertility but low lambing rate of 1.1. They are raised for milk and meat purposes. Milk production ranges between 60 and 100 kg in 210 days and meat production is 7-9 kg/animal.

Measurements

A focal sampling technique (Altman 1974) was used to determine the grazing activities of sheep. Six (2-years-old) female sheep were marked with large numbers on their sides and followed continuously by two observers for two consecutive days at each month from April to October 2012. During this period the feeding of sheep is mainly dependent on grazing in rangelands. Additionally, the farmers lead their animals to graze on cereal stubble fields after crop harvesting from July to August. The animals were observed from a certain distance so that they would not be disturbed during grazing. Observations started as soon as the animals left the shed, after given enough time (20 min) for them to become accustomed to the observers' presence. The animals remained in the rangeland from 9.00 to 19.00 due to the normal practice of the farmers to pen them during night hours. The observers were equipped with synchronized chronometers, mini DV video cameras and observation protocol forms. Grazing activities were defined as follows: grazing time (grazing or browsing while walking or standing), resting time (standing or laying for rest) and ruminating (time spent on rumination). During the study period, the daily track of the flock was recorded with the use of a handheld Global Positioning System (Garmin e-Trex Vista; Garmin, Schaffhausen, Switzerland). The mean route was imported into ArcGIS desktop 10.0 (Esri, Redlands, CA, USA) and distance travel was measured.

Air temperature (°C) was measured twice per day (early in the morning and at noon) by using an electronic thermometer. These measurements were compared with those given by Hellenic National Meteorological Service, Greece for the year 2012.

All the recorded data were processed using the statistical program SPSS version 19 (SPSS Inc., Chicago, IL, USA). Behavioural parameters for each month were subjected to analysis of variance for repeated measures. Mean comparison between adjacent months were obtained with Students' t-test for a significant level $P < 0.05$. All »±« symbols in the text refer to standard error of mean (SEM). Pearson correlation analysis (Steel & Torrie 1980) between the behavioural parameters was also performed.

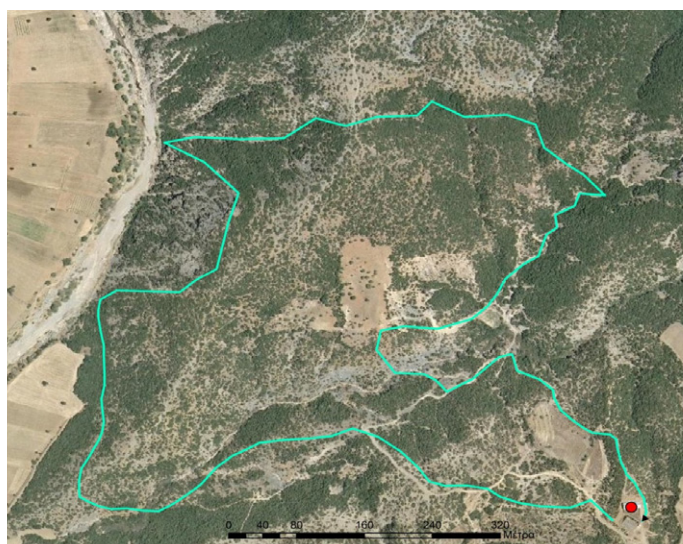


Figure 2
Daily grazing route of the Thrakian sheep breed on rangelands of Plagia village of Rhodopi, Thrace, Greece

Results

Distance travel

The route that the sheep flock followed daily throughout the study period is presented in Figure 2. Average distance travel of the Thracian sheep breed was 4.46 km/day (Table 1) with the smaller distance travelled in August and the greater in September. The statistical analysis showed that the distance travelled in May and April was significantly different ($P<0.05$) than that in July, August and September. During July and August the distance travel of sheep was significantly ($P<0.05$) shorter from all other months. Distance travel was significantly affected ($P<0.05$) by grazing time ($r=+0.708$) but there was no relationship with the other grazing activities or temperature (Table 2).

Table 1
Monthly effect on grazing activities parameters of the Thracian breed sheep

Month	Distance travel, m	Grazing time, min	Resting time, min	Ruminating time, min	Air Temperature, °C
April	4453.2 ¹ ±89.5 ^b	337.8±18.2 ^a	122.8±7.3 ^e	43.1±4.6 ^c	13.5±2.7
May	4465.3±99.4 ^b	334.3±16.5 ^{a,b}	121.2±4.4 ^e	42.7±2.7 ^c	13.6±2.8
June	4513.3±87.5 ^{a,b}	331.7±14.9 ^{a,b}	129.6±3.4 ^d	41.1±2.9 ^c	15.3±2.4
July	4343.7±90.4 ^c	302.3±29.7 ^{c,d}	148.3±2.0 ^b	48.4±1.7 ^b	28.4±1.7
August	4324.8±81.3 ^c	295.2±35.5 ^d	163.2±2.8 ^a	54.2±1.2 ^a	27.1±1.9
September	4564.4±33.8 ^a	318.9±14.3 ^{b,c}	141.4±3.8 ^c	53.±1.7 ^a	22.5±2.1
October	4509.4±9.2 ^{a,b}	333.4±8.7 ^{a,b}	129.25±2.5 ^d	46.4±1.4 ^b	17±2.9
Mean	4464.0±104.5	324.3±22.3 ^a	134.4±13.9 ^b	46.4±5.4 ^c	18.8±5.8

¹Mean values±Standard error of mean (SEM), Means with different letters along the same column differ at $P<0.05$, Means of grazing activities in the same row with different letters differ at $P<0.05$

Grazing time

Grazing was the higher ($P<0.05$) activity of sheep of the Thracian breed followed by resting and ruminating (Table 1). Grazing time ranged from 295 to 337.8 min/day for August and April, respectively. Time spent for grazing in the months with the higher temperature (July, August and September) was significantly lower ($P<0.05$) compared to the other months. Time spent on grazing by sheep was negatively affected ($P<0.05$) by temperature ($r=-0.966$) as well as the other behavioural parameters ($r=-0.973$ and $r=-0.786$ for resting time and ruminating time, respectively). There was also, a positive relationship ($P<0.05$) between grazing time and travel distance of sheep (Table 2).

Table 2
Relationships between parameters that affect the grazing behavior of the Thracian breed sheep

	Grazing time	Distance travel	Resting time	Ruminating time	Air temperature
Grazing time	1				
Distance travel	0.708*	1			
Resting time	-0.973**	-0.605	1		
Ruminating time	-0.786*	-0.256	0.846**	1	
Air temperature	-0.966*	-0.604	0.935**	0.815*	1

Level of significance: * $P<0.05$, ** $P<0.01$

Resting time

Monthly variation of resting time is presented in Table 1. The values ranged from 121.2 min/day to 163.2 min/day for May and August, respectively. Resting time observed in August was significantly higher ($P<0.05$) from that of all the other months. Significant differences ($P<0.05$) were also observed among resting time in May, July and September. Resting time (Table 2) was strongly affected ($P<0.01$) by temperature ($r=+0.935$) and ruminating time ($r=+0.864$), while there was a negative relation with grazing time ($r=-0.973$).

Ruminating time

Ruminating time ranged from 41.10 to 54.2 min/day for the months June and August, respectively. Statistical analysis showed that during August and September the sheep ruminated significantly longer ($P<0.05$) compared to the other months. During April, May and June the lower values ($P<0.05$) of ruminating time were observed compared to the remaining months, without significant differences ($P<0.05$) among these months. There was also a significant ($P<0.05$) positive relationship ($r=0.815$) between ruminating time and temperature (Table 2).

Air temperature

The variation of air temperature during the study period is presented in Table 1. Air temperature ranged between 13.5 to 28.4°C for April and July, respectively. July and August were the months with the higher air temperature while April and May with the lower one.

Diurnal pattern of grazing activities of the Thrakian sheep breed

The diurnal pattern of grazing activities of sheep throughout the study period is presented in Figure 3. Two major grazing periods were recognized. The first one in the morning occurs immediately after the animals have been driven to rangelands and lasts about three hours.

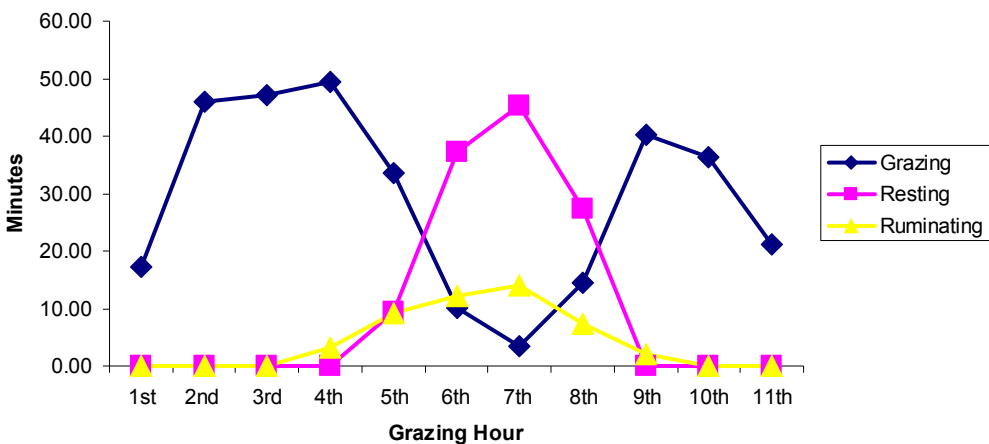


Figure 3
Diurnal pattern of grazing activities (min) of the Thrakian sheep breed on rangelands of Rhodopi, Thrace, Greece

The second one appears in the afternoon and lasts for two hours, particularly during the 9th and 10th hour of the grazing day and before the sheep return to shed. The activity of resting was recorded between the 4th and the 9th grazing hour with the highest value appearing in the 7th hour. Sheep do not rest during the first three grazing hours as well as the last three ones. Sheep do not ruminate at all during the three morning hours. Ruminating started from the 3rd hour and reaches its highest value in the 7th hour. It diminishes during the afternoon grazing period so as to be eliminated at the 9th hour.

Discussion

The average distance travel of the Thracian sheep breed (4.5 km/day) is in accordance to those reported by Loridas *et al.* (2011) for the Greek breed of sheep »Serres« grazing in the mountainous pastures (4.4 km/day) and Chrupek *et al.* (2006) for the Polish heath sheep (5.5 km/day) grazing on fallow lands in Poland. However, Evangelou *et al.* (2013) have reported that sheep travel on average 7.5 km/day during the grazing day in Askos village, Northern Greece and that they walk their greatest distances during the summer period (8.5 km/day) and the shortest during spring (6.2 km/day). These findings were not confirmed in the present study where sheep's grazing route was shorter during the summer months (July and August) probably due to high air temperatures of this period. Also, the daily grazing pattern of herded flocks is greatly affected by the shepherd (Schlecht *et al.* 2006) but without his constant interference (Baumont *et al.* 2000). The shepherd decides the grazing area in the landscape, while animals, as soon as they reach the area, are left uncontrolled to choose their feeding stations (Arnon *et al.* 2011) and to express their grazing behaviour.

The Thracian sheep breed spent 5.4 hours (64.2%) of their grazing activities on feeding. These results are in accordance with the findings of Loridas *et al.* (2011) for the Greek sheep of breed »Serres« grazing in the lowland (64.6%) and in the mountainous pastures (59.6%). In contrary to our results Arnold & Dudzinski (1978) and Fierro & Bryant (1990) have reported that sheep spent less time on feeding (30-40% and 52%, respectively). This activity also varied when sheep grazed together with goats in a mixed flock in several forage environments and climate conditions (Animut *et al.* 2005, Yiakoulaki *et al.* 2005, 2009). The Thracian sheep breed devoted less time in summer months to this activity while they spent more time in the spring and autumn. Similarly, Evangelou *et al.* (2013) have reported that sheep spent less time on feeding (34.1%) during summer compared to winter and spring (57.8% and 61.9%, respectively). Seasonal variation in grazing time of sheep probably reflects the influence of air temperature. When temperature increased during the hot hours of the day, sheep tend to avoid grazing, thus reducing their daily grazing time. (Arnold & Dudzinski 1978, Strittmatter 2001, Zupan *et al.* 2010). However, Chrupek *et al.* (2006) have reported that grazing activity of heath sheep on fallow lands of Poland was independent from temperature. The time spend grazing also depends on the physiological status of the animals, the age, the availability of forage in the rangeland and the supplementary feed (Arnold 1981, Goetsch *et al.* 2012).

Resting time was longer during the summer months and ranged from 141.4 min/day to 163.2 min/day. This is due to the high temperatures of the season that make it necessary for the sheep to find a shade and spend more time resting during the hottest hours of the day (Shinde *et al.* 1997). Loridas *et al.* (2011) have reported lower values for the Greek sheep

breed »Serres« (127 min/day and 131.4 min/day in the lowland and mountainous pastures, respectively). On the other hand, other researchers reported longer resting time periods, ranging from 320 min/day (Evangelou *et al.* 2013), to approximately 600 min/day (Fischer *et al.* 2008). During resting time the sheep stand together forming groups and hide their heads under the flanks of other sheep, trying to find protection against the sun. Therefore, shade from trees or constructed shelters and nearby water (Bailey 2005) should be available to sheep in rangelands for their thermoregulation during this critical period. In this study it has also been observed that sheep did not lay down for rest but they preferred to stand. Similarly, Fierro & Bryant (1990) reported that sheep have a tendency to rest more on foot than lying down (58 vs. 35 min/690 min observation period).

The activity of rumination was the less frequent activity (9.2%). This was probably due to the normal practice of the farmers to pen their animals during the night hours. Therefore, animals have long time for rumination but not for feeding. It was stated by Van Soest (1994) that sheep graze in the morning and evening and ruminate mainly at night, though there is some rumination at midday. Rumination generally occurs when the animals are lying or whilst standing. During rumination the animals are in a state of drowsiness and there has been speculation about whether ruminants do actually sleep (Dwyer 2009). In our study higher rumination time, ranged from 48.4-54.2 min/day, was observed during the summer months. This is related to the greater resting time also observed during the same months. According to Squires (1971), ruminating alternates with grazing and resting and is directly related to resting time. Moreover, rumination rate and time are excellent indices of forage quality (Demment *et al.* 1987). The higher rumination time observed in summer may also be related to low quality of forage consumed by sheep. According to Papanastasis *et al.* (2008) forage of Mediterranean grasslands is dormant and depleted during this period and shepherds are forced to lead their animals for grazing on cereal stubble fields (Yiakoulaki *et al.* 2005, Yiakoulaki & Papanastasis 2005).

The diurnal grazing pattern of sheep observed in the present study confirms other reports that two major feeding periods exist during the day (Bueno & Ruckebusch 1979, Fierro & Bryant 1990). The sheep's grazing pattern is also divided by a resting and ruminating period in the middle of the day. The same trend was also reported by Shinde *et al.* (1997) where grazing was generally observed at any time of day or night, but was most intensive in the morning and late afternoon until dusk.

It is concluded that the Thrakian sheep breed naturally adapted to mountainous rangelands of Thrace, adjust the pattern of their grazing activities as well as their daily movements according to air temperature. The animals walked shorter distances and spent less time on feeding during the summer months while they devoted more time on resting and ruminating.

References

- Altmann J (1974) Observational Study of Behavior: Sampling Methods. *Behaviour* 49, 227-267
- Animut G, Goetsch AL, Aiken GE, Puchala R, Detweiler G, Krehbiel CR, Merkel RC, Sahlou T, Dawson LJ, Johnson ZB, Gipson TA (2005) Grazing behavior and energy expenditure by sheep and goats co-grazing grass/forb pastures at three stocking rates. *Small Rumin Res* 59, 191-201

- Arnold GW (1981) Grazing behavior. In: Morley FHW (ed.) *Grazing Animals*. World Animal Science. Elsevier, Amsterdam *et al.*, 79-104
- Arnold GW, Dudzinski ML (1978) *Ethology of free-ranging domestic animals*. Elsevier, Amsterdam *et al.*
- Arnon A, Svoray T, Ungar ED (2011) The spatial dimension of pastoral herding: A case study from the northern Negev. *Isr J Ecol Evol* 57, 129-149
- Bailey DW (2005) Identification and Creation of Optimum Habitat Conditions for Livestock. *Rangeland Ecol Manage* 58, 109-118
- Baumont R, Prache S, Meuret M, Morand-Fehr P (2000) How forage characteristics influence behaviour and intake in small ruminants: a review. *Livest Prod Sci* 64, 15-28
- Bueno L, Ruckebusch Y (1979) Ingestive behaviour in sheep under field conditions. *Appl Anim Ethol* 5, 179-187
- Campbell JB, Stringam E, Gervais P (1969) Pasture activities of cattle and sheep. In: Campbell JB (ed.) *Experimental methods for evaluating herbage*. Canada Department of Agriculture, Pub. 1315, 105-112
- Chrupek D, Groberek J, Niznikowski R, Brzostowski H, Strzelec E, Popielarczyk D, Marciniak M (2006) Characteristic of Polish heath sheep grazing behaviour on fallow lands during vegetative period, concerning pasturage time and weather conditions. *Arch Tierz* 49, Special Issue, 353-358
- Demment MW, Laca EA, Greenwood GB (1987) Intake in grazing ruminants: a conceptual framework. In: Owens FN (ed.) *Feed Intake by Cattle*. Symposium Proceedings, Agricultural Experimental Station, Oklahoma State University, 208-225
- Drăgănescu C (2007) A note on Balkan sheep breeds origin and their taxonomy. *Arch Zoot* 10, 90-101
- Dwyer DM (2009) Microstructural analysis of ingestive behaviour reveals no contribution of palatability to the incomplete extinction of a conditioned taste aversion. *Q J Exp Psychol* 62, 9-17
- Evangelou C, Yiakoulaki MD, Papanastasis VP (2013) Spatio-temporal analysis of sheep and goats grazing in different forage resources of Northern Greece. In: Vrahnakis M, Kyriazopoulos AP, Chouvardas D, Fotiadis G (eds.) *Dry Grasslands of Europe: Grazing and Ecosystems Services*. Proceedings of the 9th European Dry Grassland Meeting (EDGM), Prespa, Greece, 19-23 May 2012, Hellenic Range and Pasture Society (HERPAS), Thessaloniki, Greece, 133-138
- FAO (2007) Breeds currently recorded in the Global Databank for Animal Genetic Resources. Food and Agriculture Organization of the United Nations. Rome, Italy ftp://ftp.fao.org/DOCREP/fao/010/a1250e/annexes/Breeds-documented-GlobalDbank-AnimalGeneticResources/List_breeds.pdf [last accessed 14.04.2014]
- Fierro LC, Bryant FC (1990) Grazing activities and bioenergetics of sheep on native range in Southern Peru. *Small Rumin Res* 3, 135-146
- Fischer A, Schalitz G, Behrendt A (2008) Comparative studies on the grazing behaviour of fallow deer and sheep in winter. *Arch Tierz* 51, 487-497
- Georgoudis A, Ligda C, Karkavelia E, Kotsaftiki A, Mizeli C (2011) *Autochthonous Farm Animal Breed of Greece*. 1st ed., Thessaloniki, Greece http://www.rfp-europe.org/fileadmin/SITE_ERFP/country_reports/Greece/Greek_FAbreeds_en.pdf [last accessed 14.04.2014]
- Goetsch AL, Gipson TA, Askar AR, Puchala R (2010) Invited review: Feeding behavior of goats. *J Anim Sci* 88, 361-373
- Hejcmanová P, Stejskalová M, Pavlů V, Hejcman M (2009) Behavioural patterns of heifers under intensive and extensive continuous grazing on species-rich pasture in the Czech Republic. *Appl Anim Behav Sci* 117, 137-143
- HNMS (2012) Hellenic National Meteorological Service. Athens, Greece, www.hnms.gr/hnms/english/index.html [last accessed 14.04.2014]
- Karasabdis K (2013) [Grazing Behaviour of the Thracian sheep on Rhodope's pastureland]. MSc Thesis, Aristotle University of Thessaloniki, Greece [in Greek, English summary]
- Loridas A, Mountousis I, Roukos C, Yiakoulaki M, Papanikolaou K (2011) Grazing behavior of the greek breed of sheep »Serres« in lowland and mountainous pastures. *Arch Tierz* 54, 165-176

- NSSG (2009) Statistical Yearbook of Greece 2008. National Statistical Service of Greece, Piraeus, Greece http://dlib.statistics.gr/Book/GRESYE_01_0002_00060.pdf [last accessed 14.04.2014]
- Papanastasis VP, Yiakoulaki MD, Decandia M, Dini-Papanastasi O (2008) Integrating woody species into livestock feeding in the Mediterranean areas of Europe. *Anim Feed Sci Technol* 140, 1-17
- Shinde AK, Karim SA, Patnayak BC, Mann JS (1997) Dietary preference and grazing behaviour of sheep on *Cenchrus ciliaris* pasture in semi-arid region of India. *Small Rumin Res* 26, 119-122
- Schlecht E, Hiernaux P, Kadaouré I, Hülsebusch C, Mahler F (2006) A spatio-temporal analysis of forage availability and grazing and excretion behaviour of herded and free grazing cattle, sheep and goats in Western Niger. *Agric Ecosyst Environ* 113, 226-242
- Squires VR (1971) Temporal patterns of activity in a small flock of merino sheep as determined by an automatic recording technique. *Anim Behav* 19, 657-660
- Steel RGD, Torrie JH (1980) Principles and Procedures of Statistics: A Biometrical Approach. 2nd ed., McGraw-Hill, New York *et al.*
- Strittmatter K (2001) [The behaviour of sheep of different breeds on pastures recultivated after mining]. *Arch Tierz* 44, Special Issue, 224-229 [in German]
- Van Soest PJ (1994) Nutritional ecology of the ruminant. 2nd ed., Cornell University Press, Ithaca, NY, USA
- Yiakoulaki MD, Pantazopoulos CI, Papanastasis VP (2005) Sheep and goat behaviour grazing on stubble in northern Greece. In: Georgoudis A, Rosati A, Monsconi C (eds.) Animal production and natural resources utilisation in the Mediterranean mountain areas. Proceedings of the International Mediterranean Symposium, Ioannina, Greece, EAAP Publ. No. 115, Wageningen, The Netherlands, 216-219
- Yiakoulaki MD, Papanastasis VP (2005) Diet selection of sheep and goats grazing on cereal stubble in Northern Greece. In: Molina AE, Salem BH, Biala K, Morand-Fehr P (eds.) Sustainable grazing, Nutritional Utilization and quality of sheep and goat products. Options Méditerranéennes: Série A, Séminaires Méditerranéens 67, 245-250
- Yiakoulaki MD, Zarovali MP, Papanastasis VP (2009) Foraging behaviour of sheep and goats grazing on silvopastoral systems in Northern Greece. In: Papachristou TG, Parissi ZM, Ben Salem H, Morand-Fehr P (eds.) Nutritional and foraging ecology of sheep and goats. Options Méditerranéennes: Série A, Séminaires Méditerranéens 85, 79-84
- Zupan M, Bojkovski D, Štuhec I, Kompan D (2010) Foraging behaviour of sheep at pasture with different types of vegetation in a paddock. *Acta Argic Slov* 96, 103-109