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Spatial and temporal activity of cattle grazing in Mediterranean oak woodland

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ABSTRACT

We examined the temporal and spatial variation patterns of the grazing activity of free-ranging cattle in Mediterranean oak woodland in the Western Galilee, Israel, as affected by seasonal and management factors.

The vegetation is dominated by scrub-oak woodland (*Quercus calliprinos* Webb.), interspersed with patches of semi-dwarf shrubs and herbaceous vegetation. High and moderate animal population densities of 0.55 and 0.33 cow ha^{-1}, respectively, were replicated twice. Cattle behavior was monitored with activity sensors on GPS collars, and pedometers, and spatial data were processed with Geographic Information System (GIS) tools.

Overall, cattle devoted 9.7 ± 0.7 h/day to grazing, mostly in woodland areas, although they are natural herbaceous grazers. Behavior was associated with seasonal changes in biotic and abiotic factors. Preference for the woody vegetation types was detectable over the annual time scale but large seasonal differences in preference canceled out to a large extent when viewed at that time scale. Cattle under high density spent more time grazing and made more use of woody vegetation and steeper slopes. Thus, relatively high population densities may be required for landscape-oriented management. The present findings should contribute to rational management of cattle grazing in Mediterranean woodlands.

1. Introduction

Mediterranean evergreen oak woodlands have been grazed by domestic ruminants, predominantly goats, for millennia. In addition to supporting animal production, grazing maintains an open woodland structure, reduces biomass and the risk of fire (Gutman et al., 2000), increases species diversity (Perevolotsky and Seligman, 1998), and facilitates recreational use of the landscape (Henkin, 2011). Over recent decades the woodlands of Israel have seen a massive decline in goat grazing, for a variety of socio-economic reasons; but there has been a modest revival of cattle grazing, introduced to increase meat production and, at least partially, to restore grazing as a means of woodland management. However, in contrast to its suitability for goats, which are well adapted to browsing in Mediterranean woodlands, the woody vegetation is considered unsuitable for cattle, because of its poor nutritional quality (Perevolotsky et al., 1993; Papachristou et al., 2005). The low prevalence of cattle grazing in Mediterranean woodlands is due, presumably, to the limited penetrability of the typically dense woody vegetation, low productivity of the herbaceous vegetation, and poor accessibility of the extensive woodland areas that grow on steep terrain. Although woodland utilization is affected by cattle behavior, knowledge of the behavior patterns of cows in Mediterranean woodlands, and of the spatial and temporal distributions of their grazing is scarce. Acquisition of this knowledge should help to resolve potential conflicts of interest between herd owners, land-management agencies, and conservationists, and, furthermore, it is important for sustainable landscape management (Zuo and Miller-Goodman, 2003; Bailey, 2004).

Spatial and temporal patterns of livestock behavior and utilization of the landscape are affected by abiotic factors such as slope, distance from water, and presence or absence of shade, as well as by biotic factors such as species composition of the vegetation, and forage quantity and quality (Arnold, 1981; Ganskopp, 2001;

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Bailey, 2005). Mediterranean oak woodlands are characterized by a patchy structure comprising a fine-scale mosaic of vegetation types that can influence grazing activity and spatial distribution of the cattle. In turn, heterogeneous distribution of the cattle in the woodland may result in uneven utilization of the vegetation (Bailey et al., 2006; Ganskopp and Bohnert, 2009). This can result in excessive grazing pressure in specific areas, which then may suffer degradation, while leaving other areas underutilized and, possibly, then prone to progressive closure by the woody vegetation and the attendant reduction of accessibility, increased fire risk, and loss of biodiversity (Perevolotsky and Seligman, 1998). Understanding the factors that influence cattle distribution in woodlands is a critical step in devising management strategies to foster uniformity of grazing pressure.

Spatial distribution and habitat selection of cattle have been studied in various rangelands around the world (Bailey et al., 2001; Schlecht et al., 2004; Kaufmann et al., 2013), including Israel (Henkin et al., 2012). However, little is known about grazing behavior in Mediterranean woodlands, where the logistical constraints on monitoring animals generally encountered in predominantly herbaceous landscapes are compounded by the fact that the animals cannot be easily observed. Such constraints are, at least partially, relieved by the use of animal collars that combine the Global Positioning System (GPS) with activity sensors to provide spatially and temporally continuous and accurate data collection regarding livestock grazing activities (Turner et al., 2000; Schlecht et al., 2004). Such data can be processed by a Geographic Information System (GIS) to relate animal location data to abiotic and biotic terrain factors.

The objectives of the present study were: 1) to analyze the effects of animal population density and season on the diurnal activity pattern and the spatial distribution of grazing activity of free-ranging cattle in Mediterranean oak woodlands; and 2) to analyze the roles of abiotic and biotic landscape features, including topography, vegetation structure, and the locations of watering and supplementary feeding points, in shaping the spatial distribution of grazing activity. Understanding the relationships between cattle behavior and these factors will help to develop a management program that seeks to combine sustainable utilization of Mediterranean oak woodlands with improved herd productivity and performance.

2. Materials and methods

2.1. Study site

The study was conducted at the Hatal Experimental Farm in Western Galilee, Israel (long. 35°15′, lat. 33°01′), from October 2007 through November 2009. The site was described in detail by Henkin et al. (2005). Briefly, the site is at 400–500 m a.s.l. and consists of moderate to steep slopes of up to 40°. Limestone and dolomite rocks form 15–40% of the surface cover, and between them are pockets of terra rossa soil up to 40 cm deep. The dominant vegetation is scrub-oak woodland (*Quercus calliprinos* Webb), interspersed with batha vegetation comprising shrubs and dwarf shrubs, mainly *Calicotome villosa* (Poiret) Link and *Sarcopoterium spinosum* (L.) Spach. Herbaceous vegetation occurs as patches in open areas among the woody vegetation, and provides 3–4 months of high-quality forage during winter and spring. The climate is typically Mediterranean, with mild winters and hot dry summers. The hydrological year (and hence measurement of annual rainfall) commences on 1 October. The long-term average (±SD) annual rainfall is 796 ± 201 mm, most of which falls between November and March. Annual rainfall was 535 mm in 2007/8 (i.e. 1 Oct. 2007–30 Sept. 2008) and 610 mm in 2008/9, which are low values compared with the long-term average, and 797 mm in 2009/10. The average, minimum, and maximum ambient temperatures during the experimental periods were 19.5, 8.3, and 35.5 °C, respectively, in spring; 27.8, 18.8, and 38.8 °C, respectively, in summer; and 23.2, 13.4, and 37.5 °C, respectively, in fall.

2.2. Experiment treatments, animals and grazing management

Experiments were approved by the animal experimentation ethics committee of the Agricultural Research Organization. The experimental area occupied 212 ha, divided into four paddocks (East, West, North, South), each of 40–66 ha (Table 1; Supplementary Fig. S1). Treatments were two animal population densities – moderate and high relative to common practice, of 0.33 and 0.55 cow·ha^{-1}, respectively – which were replicated twice and randomly assigned to the four paddocks for the duration of the experiment. The paddock sizes were chosen to be representative of those found among commercial producers in the study region, and the number of animals per group was intended to be sufficiently large to yield robust results. The animals comprised the farm's resident herd of 94 Baladi (*Bos Taurus*) × Hereford cows aged 3–12 years, of average body weight 502 ± 9 kg, and of fair-to-good body condition (at least 2.5 on scale of Edmonson et al., 1989) after calving. Cows were randomly allocated to paddocks for the duration of the experiment with the single constraint of being balanced by age. Calving occurred predominantly during November through March, and the calves were weaned in early June. The average annual calving and weaning rates were 85 ± 3% and 76 ± 3%, respectively.

Following early-season grazing deferment, the cows entered the paddocks in spring (mid-March), grazed through fall (mid-November), in accordance with vegetation conditions, and averaged 260 grazing days per year. They had continuous access to water, and supplementary feed was provided during late summer and fall (May–November). During the rest of the year – mid-November through mid-March – the cattle were kept in holding paddocks outside the experimental area.

2.3. Monitoring cattle location and activity

Cattle behavior was monitored in three seasons of the 2007/8 hydrological year: at the beginning of the rainy season in the fall (October–November), when the diet comprises mainly woody vegetation, oak acorns and supplementary feed; in the spring (March–April), when the diet comprises green herbaceous vegetation and woody vegetation; and in the summer (July–August), when the diet comprises dry herbaceous vegetation, woody vegetation and supplementary feed (Brosh et al., 2006a). Monitoring was similarly conducted in the spring and summer of the 2008/9 hydrological year, and in the fall of the 2009/10 hydrological year.

Animal location and activity were monitored with Lotek 3300LR GPS collars with activity sensors (Lotek Engineering, Newmarket, ON, Canada) in conjunction with IceTag pedometers (IceRobotics Ltd, Edinburgh, Scotland, UK) (Supplementary Fig. S2). In each of the six monitoring seasons, the devices were deployed on eight randomly selected cows in one paddock and transferred weekly to eight animals in another paddock until the completion of one cycle of the four paddocks. The order in which the paddocks were monitored was randomized at each cycle. The weight, physiological status (empty, lactating, early pregnancy, late pregnancy) and body condition score (Edmonson et al., 1989) of every cow in the paddock were recorded; the last of data on a 1–5 scale (1 = low, 5 = high). These measurements were recorded either when the equipment was fitted or when it was removed.

Based on Ungar et al. (2011), the collars were programmed to store latitude, longitude, and elevation, as well as associated data comprising date, time, ambient temperature, and motion sensor counts at 5-min intervals. The pedometers provided step counts,

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