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This paper has been contributed in honor of Azaria Alon on the occasion of his 90th birthday.

Note:

Roe deer and decapitated Anemone flowers

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ABSTRACT

The roe deer (*Capreolus capreolus*) has been locally extinct from the East Mediterranean since the beginning of the 20th century. A reintroduction program has been initiated in Israel where several deer have been released in the southern Carmel Mountains. The diet of roe deer is markedly different from that of other local ungulates. Their unique dietary preference for the generally unpalatable geophyte *Anemone coronaria* is especially notable. They typically consume anemone by "decapitating" the flowers, leaving the rest of the stem intact. We studied the consumption rate of anemone in four hand-reared deer in the Hai Bar Nature Reserve. During the flowering season, each deer consumed 65.5 ± 13.13 and 37.6 ± 13.85 anemone flowers/day in 2003 and 2004, respectively. These results indicate that roe deer may have a profound influence on anemone populations. Being secretive and flighty animals, roe deer are hard to detect. A preliminary survey conducted in Ramat HaNadiv Park, where a roe deer population of an unknown size exists, suggested that with proper calibration, the typical, easy-to-detect decapitated anemone flower might be used for monitoring roe deer presence and density.

Keywords: *Anemone coronaria*, diet, Mediterranean, reintroduction, roe deer

INTRODUCTION

The roe deer (*Capreolus capreolus*) is widespread in Europe (Andersen et al., 1998), but has been locally extinct from the East Mediterranean region since the beginning of the 20th century (Harrison and Bates, 1991). Since 1991, roe deer have been imported from France, Italy, and Hungary to reestablish a population in Israel. They have been released in Ramat HaNadiv Park (E34º56′/N32º33′) since 1996 (Woodley, 2001), and in the nearby Horshan mountains (E34º59′/N32º35′) since 2005.

We have found that local hand-reared female roe deer can maintain a relatively stable body mass throughout the year (Wallach, 2005; Wallach et al., 2007a), and their activity patterns and feeding strategy resemble those of central and northern Europe. They are polyphagic consumers and will switch from browsing to grazing and to fruit/seed consumption, depending on resource availability. They are also concentrate selectors and show preference for different plant parts in different seasons (Duncan et al., 1998; Wallach, 2005). Roe deer often feed on plants that are highly toxic to other mammalian herbivores (Mysterud and Østbye, 2004). This has been confirmed in Israel, where roe deer have been found to consume anemone (*Anemone coronaria*) flowers (Wallach, 2005).

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Fig. 1. (a) A roe deer about to consume an anemone flower. (b) An anemone that has been decapitated by roe deer. (c) An anemone that lost its flower by trampling or picking and thus does not have a precise cut.

Anemone is a common geophyte that is largely avoided by mammalian herbivores, probably due to the toxin protoanemonin, which may cause intense skin, oral, or gastrointestinal irritation (Knight and Walter, 2001). The enigmatic phenomenon of anemone plants that had their flower excised was first observed in Ramat HaNadiv Park, Israel (Dr. R. Schwartz-Tzachor, pers. comm.). Roe deer were the prime suspects because this phenomenon was not observed prior to the introduction of roe deer to this park (in 1996). Furthermore, none of the local ungulates are known to eat anemone flowers. Cows do not consume anemone (Ne'eman et al., 2003), and to the best of our knowledge, there have been no observations of other ungulates consuming this plant (Cnaani, 1972; Baharav, 1981; Geffen, 1995; Dolev, 1999).

Direct observations of four hand-reared roe deer confirmed that indeed, they eat anemone flowers in a typical manner (Fig. 1), leaving the stem intact. An anemone flower consumed by roe deer looks like a "decapitated" flower (either above or under the lateral leaves), and is distinguishable from flowers that have been picked by humans or trampled by other animals (Fig. 1c) by the clean cut.

MATERIALS AND METHODS

Potential impact of roe deer on *Anemone*

Anemone flower consumption highlights the potential effects that a reintroduced population can have on the flora of the East Mediterranean. *Anemone* has been largely free of its mammalian herbivore for over 100 years, and the plants often reach high densities where grazing ungulates selectively avoid them (Ne'eman et al., 2003). The reintroduction of roe deer to Israel may influence the distribution and abundance of this protected geophyte. We studied the diet composition of four hand-reared female roe deer that were born in the captive breeding colony (Wallach, 2005; Wallach et al., 2007b). At the age of 6–8 months, they were released into a 10-ha fenced section of a natural, dry Mediterranean maquis within the boundaries of the Hai Bar Nature Reserve in the Carmel ridge (E34º97′/N32º72′, 450 m asl). The study site was a heterogeneous mosaic of dense scrub and open areas where *A. coronaria* plants were common. Diet composition and feeding behavior of the deer were monitored for two years (Wallach, 2005). During the trials, the deer fed on the natural vegetation (without supplements) and were supplied with water ad libitum. The number of anemone flowers consumed per day was estimated in the winter of 2003 and 2004. Estimation was based on observations of daily food consumption, intake rates, and proportion of anemone flower in their diet. In addition, we compared the difference between leaf and flower consumption to determine which plant part was preferred and therefore more affected.

Anemone flower decapitation indicates deer distribution

Roe deer are secretive and flighty animals. We predicted that their unique anemone consumption can serve as a sign of roe deer presence and may provide an estimated measure of roe deer density. Therefore, we compared anemone flower consumption in Ramat HaNadiv Park, comprising similar habitats and holding a reintroduced deer population of unknown size, while the Hai Bar reserve served as a standard measuring unit (the 10-ha site described above). In the winter of 2005, two study units of similar size (10 ha), often used by foraging deer, were assigned in Ramat HaNadiv Park. Within each

Table 1
Average number (±SE) of anemone flowers/plot/day that were available, eaten, or produced seeds in Hai Bar, Ramat HaNadiv site a, and Ramat HaNadiv site b

	Trial date	Available flowers	Eaten	Produced seeds
Hai Bar	14/2/05	17.08 ± 4.32	0.50 ± 0.10	0.25 ± 0.11
	22/2/05	25.04 ± 5.43	1.21 ± 0.94	0.79 ± 0.39
	1/3/05	18.25 ± 3.68	0.67 ± 0.19	2.88 ± 0.72
Ramat HaNadiv a	21/2/05	26.33 ± 5.35	0.13 ± 0.07	1.79 ± 0.42
	3/3/05	8.79 ± 1.90	0	1.54 ± 0.35
Ramat HaNadiv b	21/2/05	13.17 ± 1.28	0.04 ± 0.04	0.21 ± 0.09
	3/3/05	11.33 ± 2.06	0	1.92 ± 0.17

10-ha unit, 8 plots of 5 × 5 m were chosen. Each plot had ~ ≥5 anemone flowers. The plots were not visibly marked to avoid potential biases. Instead, we sketched a detailed map of each plot. On day 1, all flowers were mapped, and on the following three days, each flower was monitored, adding new flowers when they emerged. Observations in the Hai Bar plots were repeated three times, and flower counting in Ramat HaNadiv plots was repeated twice. Two types of indices were used to estimate deer density: (1) the number of marked plots with eaten anemone flowers and (2) the average proportion of flowers consumed per plot. To estimate deer density in Ramat HaNadiv, we calculated the ratio between these indices in the "control" (Hai Bar) and the two units in Ramat HaNadiv. We also compared consumption rates to flower density.

RESULTS AND DISCUSSION

In the Hai Bar reserve, anemone flowers made up 0.91% and 0.52% of the deers' diet, accounting for 65.5 ± 13.13 and 37.6 ± 13.85 anemone flowers/deer/day in 2003 and 2004, respectively. Although both leaves and flowers were consumed, flowers were preferred once available in February (2003: paired $t = 4.05$, df = 3, $p < 0.05$; 2004: paired $t = 2.68$, df = 3, $p = 0.08$). In the Hai Bar, an average of 37.5% of plots had at least one flower eaten each day, and over the 3-day trial period, 62.5–87.5% of plots had at least one flower eaten during the three-day study period. The average proportion of flowers per plot that were consumed per day was 2.7%, 4.5%, and 3.4% (overall range 1–9%) in each trial (out of approximately 165, 200, and 168 flowers monitored, respectively). In the first two trials, more flowers were eaten than those producing seeds (Table 1a). Density-dependent consumption was the highest at low and high flower densities (Fig. 2). This correlation was found to be weak but nevertheless statistically significant ($R^2 = 0.11$, df = 69, $p < 0.05$). In Ramat HaNadiv Park, out of approximately 615 flowers that were monitored in both sites and repetitions, only 4 flowers were consumed, and many produced seeds (Table 1). If indeed, anemone

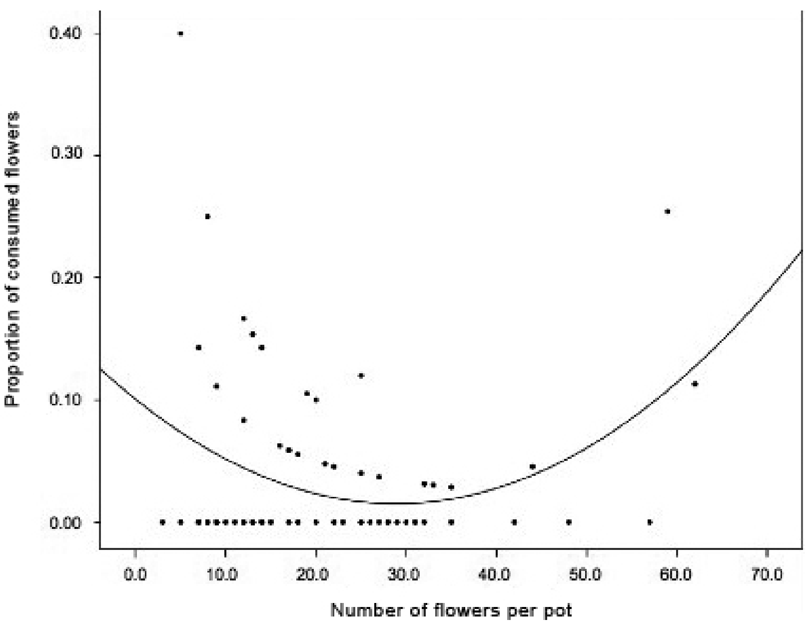

Fig. 2. The proportion of flowers consumed by the deer in relation to flower density in each plot (density dependence). The curve is quadratic and shows that the highest proportion of flowers eaten is at low and high flower density (the curve should only be viewed as functional in the limits of $0 \leq x \geq 65$).

Table 2
A proposed estimate of roe deer density in Ramat HaNadiv. Marked plots are plots in which at least one flower was eaten each day

Site	% marked plots/day	% flowers eaten/plot/day	Deer density (/10 ha)
Hai Bar	38%	3.5%	4
Ramat HaNadiv	4%	0.2%	0.22–0.42

flower consumption rate in Ramat HaNadiv was similar to the rate in Hai Bar, the former supports approximately 0.3 deer/ha (Table 2). We suggest that monitoring of anemone flower consumption might help to provide rough estimations of roe deer population density. Even at apparently low roe deer densities, such as in Ramat HaNadiv, their presence can be detected in this fashion. Our results suggest that decapitated anemone flowers can reliably indicate deer presence in the winter and spring. It might be site-specific, affected by anemone density, plant diversity, cover, and predators. Therefore, further research and fine-tune calibration are certainly needed before using this typical sign of roe deer presence as an index for its density.

The consumption of anemone (*A. coronaria*) flowers is an example of the selective feeding strategy of the roe deer. We also found that roe deer selectively consume other flowers such as those of *Ceratonia siliqua*, *Cistus salviifolius*, *Quercus calliprinos*, *Sarcopoterium spinosum*, and *Thrincia tuberosa* (Wallach, 2005). Whereas a general, high-bulk consumer might cause structural changes in the vegetation (e.g., Persian fallow deer), a selective feeder might have a stronger impact on specific plant species. Roe deer can have a unique impact on the structure and dynamics of vegetation communities (e.g., Ammer, 1996; Carranza and Mateos-Quesada, 2001; Partl et al., 2002). It is becoming apparent that this is also the case in the East Mediterranean region.

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