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Trend of a population of Wild Rabbit *Oryctolagus cuniculus* (Linnaeus, 1758) in relation to Domestic Sheep *Ovis aries aries* (Linnaeus, 1758) grazing within a small insular protected area

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ABSTRACT The wild rabbit *Oryctolagus cuniculus* (Linnaeus, 1758) (Mammalia Leporidae) if present at high density can cause significant damages to crops and natural vegetation. The aim of this study, carried out from 2002 to 2008 in the Natural Reserve "Complesso Immacolatelle e Micio Conti", in the foothills of Mount Etna, was to investigate the relationship between the wild rabbit and the presence of grazing domestic sheep *Ovis aries aries* (Linnaeus, 1758) (Mammalia Bovidae), considering also the possible synergistic effect of these two herbivores on the natural vegetation in a small protected area. Precipitation during the month of September correlated statistically significantly with the density of rabbits. A comparison between the density values obtained during the period under study did not show statistically significant differences with the exception of 2006 and 2007 when, within the area, was present a flock of sheep (200–250 individuals), free to graze in the reserve. The abundance of rabbits in 2002–2005 and 2008 is equal to 6.97% more than the expected value; in the absence of the grazing sheep flock (2006–2007) instead the population assumed density values significantly higher than expected. Since grazing of rabbits, especially in summer, is critical for the subsequent composition of herbaceous vegetation, for the purposes of conservation and protection of natural or semi natural environments, especially with a small extension, it is desirable to properly assess and manage the presence of the wild rabbit, especially in areas where it is not original, for the effects it may have on plant communities and populations of arthropods, and to control sheep grazing as well to contain the caused damages.

KEY WORDS *Oryctolagus cuniculus*; *Ovis aries aries*; over grazing; small protected area.

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INTRODUCTION

The wild rabbit *Oryctolagus cuniculus* (Linnaeus, 1758) (Mammalia Leporidae) is considered to be endemic of the Iberian Peninsula (Dobson M., 1998; Alves et al., 2008; Amori et al., 2008) and since the Neolithic is widespread in the rest of the Mediterranean (Hardy et al., 1994; Ferrand & Branco, 2007; Alves et al., 2008; Amori et al., 2008). It has demonstrated to be a successful colonizer, since is currently present in at least 150 islands around the Mediterranean Basin (Masseti & De Marinis, 2008). It is a nocturnal and strongly gregarious animal, which can live in colonies the size of which is proportional to the availability of food. In Sicily is naturalized and widely distributed, although non-uniformly and with very variable density (Amori et al., 1996; AA.VV., 2008). Individuals present in this

area show intermediate size within the range of variability known for populations of Spain (Andalusia) and France (Camargue) (Siracusa et al., 2007; Lo Valvo et al., 2008); it is supposed that the current biometric characteristics of the species are the result of immissions for the purpose of restocking with strains of different origins (Lo Valvo et al., 2008).

In Southern Spain ecosystems it is a key species; it participates in determining the community structure of predators and scavengers, as well in supporting their populations density (Delibes & Hiraldo, 1981; Ferrer & Negro, 2004; Delibes-Mateos et al., 2007). Besides it plays a strong influence on the habitat of other species ("ecosystem engineers") by consuming vegetation, dispersing the seeds, spreading latrines and digging burrows (Delibes-Mateos et al., 2008; Delibes-Mateos et al., 2009; Gálvez-Bravo et al. 2009). It has a significant role even outside the areas of origin; being prey for many vertebrates, it maintains, at low density of grazing, a greater plant diversity and sustains a better quality of habitat for some species of invertebrates (Norbury, 1996; Wray, 2006). In contrast if present at high density can cause significant damage to crops and natural vegetation. In the Iberian Peninsula the wild rabbit is in decline from early '50s (Ward., 2005; Williams et al., 2007), and currently the state of conservation in this region, based on the IUCN criteria, is assessed as "Vulnerable" (Virgós et al., 2007). According to Smith & Boyer (2008; IUCN, 2013), the species is globally evaluated as near threatened (NT). For these reasons, it is necessary to manage the wild rabbit through scientific criteria to maintain auto-sustainable populations and prevent (or intervene in the case of) significant damage to the economy or to the natural heritage.

The aim of the present study was to investigate the relationship between wild rabbit and domestic sheep *Ovis aries aries* (Linnaeus, 1758) (Mammalia Bovidae), considering also the possible synergistic effect of these two grazing herbivores on the annual development of natural vegetation in a small protected area.

MATERIALS AND METHODS

Study area

The study area is the Natural Reserve "Complesso Immacolatelle e Micio Conti", an area in the foothills of Mount Etna. It is included within the SIC ITA070008 ("Complesso Grotte Immacolatelle, Micio Conti e boschi limitrofi") and covers about 70 hectares; it is divided into a Zone A of absolute restriction and a Zone B where the fruition is permitted (Fig. 1).

In the area habitats are affected by agro-pastoral activities, which determined the degradation of the original vegetation. The tree cover consists of *Quercus virgiliana* (Ten.), *Quercus amplifolia* Gus., which are accompanied by *Celtis australis* L.; there are also several individuals of *Olea europea* L., remains of an ancient cultivation. The herbaceous vegetation that colonizes the most degraded areas has several species typical of arid and uncultivated lands as *Hyparrhenia hirta* (L.), *Carlina corymbosa* L., *Lobularia marittima* (L.), *Dittrichia graveolens* (L.) Greuter, *Micrometria graeca* (L.), *Mandragora autumnalis* Bertol and the endemic *Helitropium bocconei* Guss. Finally, the crags are covered with plant species characteristic of the Mediterranean maquis including *Euphorbia dendroides* L. associated with various other sclerophyllous such as *Olea oleaster* (Hoffmg. et Lk.), *Pistacia therebintus* L., *Rhamnus alaternus* L. and liana species as *Smilax aspera* L., *Asparagus acutifolius* L. and *A. albus* L.

Monitoring survey design

For counting rabbits was applied the method proposed by Taylor & Williams (1956), used for similar studies in the Doñana National Park (Spain) (Moreno & Villafuerte, 1992) and in several protected areas of Sicily (Caruso & Siracusa, 2001; Siracusa et al., 2004; Siracusa et al., 2005; Siracusa et al., 2007). This methodology consists in counting the number of excrement in fixed detection stations scattered randomly in the study area. The data may provide information on population size and numerical trends over time (Meriggi, 1991). This method has been confirmed successful for the good correlation between the number of excrements and the density of animals (Wood, 1988; Palomares, 2001). To obtain an estimation of the density of animals (D) in an area of identified surface, knowing the number of excrements deposited daily by the animal (r) and the period of time in which these have been deposited (t), we applied the formula of Eberhardt & Van Etten (1956):

$$D = d/rt$$

where d is the mean density of excrement for sam-

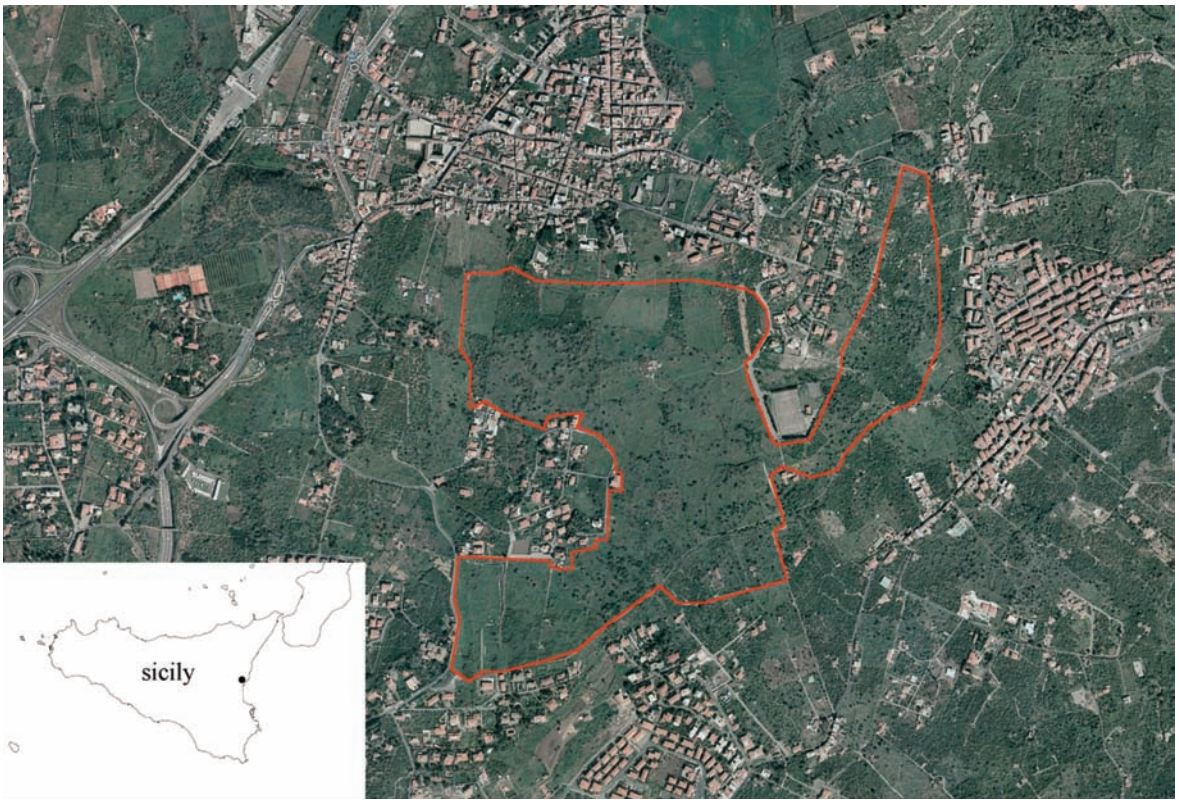

Figure 1. View from above of the study area; red line represents the boundaries of the Reserve.

pling station. Due to the lack of experimental data for Sicily, r was considered equal to 350, the value reported by Moreno & Villafuerte (1992) for the Mediterranean environments, value however not far from those found in the UK and Australia (Lockley in Pages, 1980; Wood, 1988). The parameter (t) is instead the number of days between the cleaning of stations and counting.

The number of stations (n = 30), with circular shape and large 1.54 m^2, was chosen in function of the abundance of excrement (> 30 escr./1.54 m^2) found at the site subjected to investigation. This value was defined based on asymptotic functions of the ratio number of plots-mean value of excrement found. The number of pellets per station also showed an aggregate distribution (variance considerably higher than the average); extreme values found tend to alter the average because the distribution of data appeared irregular (Fowler & Cohen, 1993).

Between 2002 and 2008 we calculated the annual density of the rabbit population in the Reserve through monthly surveys of the population (see also Siracusa et al., 2005). At the same time have been measured some meteorological parameters (mean annual temperature, mean annual precipitation, total precipitation and annual total precipitation for each month of the year) in order to verify a possible influence of these on the annual density of wild rabbits. The correlations were made both considering the values of the same year and those of the previous year in order to identify a possible delayed influence of these parameters.

In the course of the study was estimated as well (by direct counting) the number of grazing sheep present, with the purpose to verify for any interference with the population of wild rabbit, also to assess the amount of grazing pressure of both sheep and rabbits. Was also calculated an expected value of density (spec./ha) of wild rabbit, combining the number of species of Poacae present and the altitude above sea level using 9 different sample areas by the technique of Multiple Regression. For the comparison between the abundance of rabbits in different years under investigation was used instead the χ^2 test. For the correlation

between variables (meteorological parameters and density) was used the Spearman rank correlation coefficient (rs).

Statistical analyses were performed using the software STATISTICA 5.0.

RESULTS

The annual average density of wild rabbits was found to be 44.79± 27.34 (s.d.) ind./ha, with a minimum value of 25.6 ind./ha in 2005 and a maximum value of 94.6 ind./ha in 2007 (Fig. 2).

The value of density can be predicted by the number of species of Poacae and the altitude above sea level (R^2= 0.822; $F_{2,6}$ = 13.881; P < 0.006), where both variables resulted as predictive (p <0.003) (Fig. 3).

The expected value of density is equal to 36.3 (± 95.0 % 51.1–21.5) ind./ha. None of the climatic variables correlated statistically significantly with the density of the species, with the exception of the significant negative correlation between the density of rabbits and the annual amount of precipitation during the month of September (r_s=- 0.929; n=7; p=0.002).

The comparison between the density values obtained does not show statistically significant differences during the years 2002, 2003, 2004, 2005 and 2008 (χ^2=2.74, df=4, p < 0.60). However, there are differences with the abundance values observed in 2006 and 2007 (χ^2=19.51, df=2, P=0.000). Noteworthy, during the all period, with the exception of 2006 and 2007, within the area was present a flock of sheep (200–250 individuals) free to graze in the reserve.

DISCUSSION

In Sicily, the main factors that seem to affect the density of this species are the extension of abandoned ex-cultivated areas (and / or uncultivated areas) (Caruso & Siracusa, 2001; Siracusa et al., 2007), the altitude above sea level and the number of species of Poacae (Caruso & Siracusa, 2001; Siracusa et al., 2007).

It's rather less probable that the wild rabbit is generally subject to limitation by the community of predators (Trout & Tittensor, 1989; Moreno & Villafuerte, 1992; Trout et al., 2000; Caruso & Siracusa, 2001; Siracusa et al., 2004; Siracusa et al., 2007). Habitat fragmentation is also considered one of the causes of the decline of local populations of wild rabbit (Virgós et al., 2003); the site is not isolated from the surrounding areas and the degree of fragmentation of the territory, for the presence of the wild rabbit, can be considered of small entity with the opportunity for individuals to disperse and maintain normal phenomenon of immigration/emigration.

In another area with Mediterranean climate, predominantly semiarid, in the NE of Spain, Calvete et al. (2004) found a positive correlation between

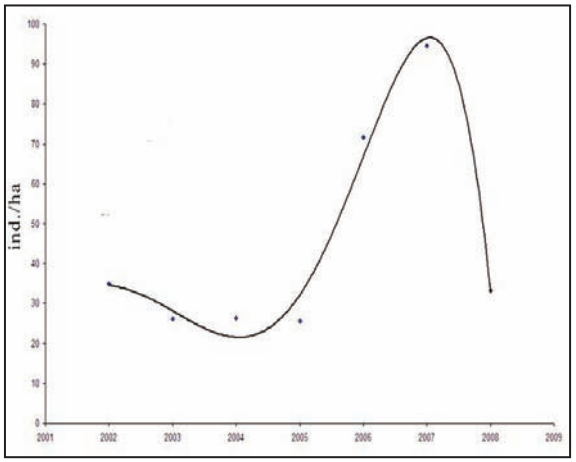

Figure 1. Annual trend of wild rabbit abundance observed during the years 2002-2008 within the Reserve "Immacolatelle-Micio Conti"

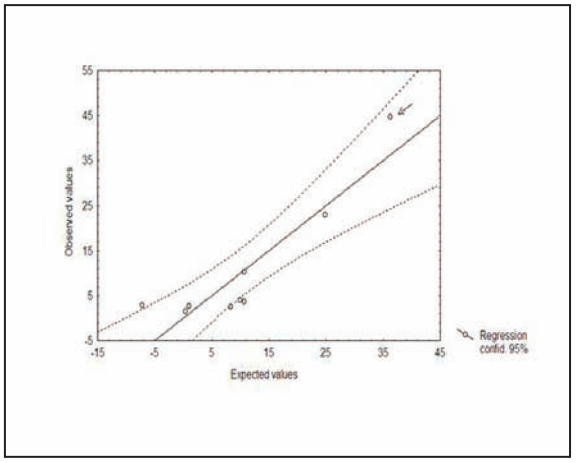

Figure 2. Expected and observed values of wild rabbit density at nine different sites in the Etna area (the arrow indicates the Reserve "Immacolatelle-Micio Conti").

the annual mean temperature, the average of rainfall in the months of February and May, and abundance of rabbits in different sites, while the average rainfall for the months of September and November correlated negatively.

In this protected area of Mount Etna the total rainfall for the month of September is negatively correlated with the density per year. It is possible that heavy rainfall in early autumn can determine an increase of winter mortality due to various factors such as greater difficulty in thermoregulation, excessive soil moisture with limited plant growth resulting in food shortages and delays in beginning of the breeding season (Calvete et al., 2004). Meteorological events, concentrated in a few days can also have negative effects on rabbit populations, especially in open areas (Palomares, 2003).

The abundance of rabbits in 2002–2005 and 2008 (29.30 ± 4.48 ind./ha) is equal to 6.97% more than the expected value. In the absence of the grazing sheep flock (2006–2007) instead the population assumed density values (83.1 ind./ha) significantly higher than expected (23.8 ind./ha); under these conditions the grazing of rabbits, especially in late summer, resulted in high proportions. Generally speaking, the remarkable grazing of rabbits in the summer is critical as fundamental for the subsequent composition of herbaceous vegetation in the following spring (Myers & Poole, 1963). To this it should be also added the grazing activity of sheep.

As an indication, if one considers 390.9 gr the food ingested daily by a rabbit (Meakin et al., 2002) for its metabolic needs, the annual demand per hectare of the population is on average 17.5 kg of vegetables. It should also be estimated that a sheep consumes the equivalent of 10–16 rabbits (Myers et al., 1994).

In addition, the density values occurred in 2006 and 2007 are high when compared with other areas of Mount Etna (Siracusa et al., 2004). An excessive presence of rabbits, because of overgrazing, may adversely affect the normal evolution in the succession of the vegetation (Zeevalking & Fresco in Begon et al., 1986) determining a reduction of plants diversity and sometimes even causing the extinction of some species. The most important factors that cause these changes are the selection by the rabbit of some species and parts of plants, especially during the critical period of vegetative growth, and the mechanical destruction of the soil surface; both of these factors facilitate, in competition, some species than others (Myers & Pool, 1963).

Herbivores influence the species richness of plants in many terrestrial ecosystems by affecting their structure, composition and function; the number of plant species is also closely linked to the size of the area (AA.VV. in Albon et al., 2007; Olofsson et al., 2008). Grazing and deposition of excrements of rabbits creates spatial heterogeneity in vegetation and soil resources.

An overexploitation of vegetation, due to an excessive number of rabbits, tends so to reduce the heterogeneity and structural complexity of plant communities with indirect effects on populations of arthropods (both phytophagous and predators - 'intermediate disturbance hypothesis'), in particular on the abundance of many species with consequent negative effects on functionality of the ecosystem considered (compare for example Moss & Hassal, 2006).

It should be also taken into consideration the high impact of sheep, due to their behaviour that tends to be aggregative and with limited displacements, with consequent action of disturbance in limited areas. Among the effects of the removal of sheep there are significant changes in the composition and structure of vegetation, with clear repercussions on populations of wild herbivores (Hope et al., 1996). Are also documented the effects of sheep grazing on the arthropod communities through changes in the composition and structure of vegetation heterogeneity (Dennis, 2003).

Wild rabbits and sheep, as well as other domestic ruminants are herbivorous grazers that often feed on the same plant species; for this reason among them there is a strong competition for food (Dawson & Ellis, 1979; Soriguer, 1983).

CONCLUSIONS

The relationship wild rabbit-vegetation-habitat has been studied thoroughly both in the area where the species is native and where it has been introduced (see for example Copson & Whinam, 1998; Moller et al., 1997; Norbury & Norbury, 1996; Zeevalking & Fresco, 1977; Denyer et al., 2007 and their references). A moderate grazing is considered positive for vegetation, contributing to increase diversity; the disappearance of the rabbit in

some areas has in fact led to the development of dominant plant species with consequent effects on plant communities (such as decrease or disappearance of the most sensitive species and reduction of biological diversity).

For the purposes of conservation and protection of natural or semi natural environments (especially with small extension) it is desirable to properly assess and manage the presence of the wild rabbit, especially in areas where it is not original, and to control as well sheep grazing in order to contain the caused damages.

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