Habitat selection of the roe deer *Capreolus capreolus* (Artiodactyla: Cervidae) in an agroforestry system

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Abstract - The present study aimed at assessing the habitat preferences of the most widespread and abundant ungulate in Italy, the roe deer, in the Vallevecchia protected area (Venice). This area has been the object of naturalistic management and continuous environmental improvements in the last decades. Currently, the area is characterized by a high habitat heterogeneity, including deciduous woodlands, pine forests, wetlands, and farmlands. The study was carried out during the summers of 2017 and 2020. Data were collected along standardized transects, and the geo-localized records were divided into the corresponding habitats to calculate the Jacobs Index. In addition, chi-square test was applied, with the calculation of Pearson residuals to estimate the significance of associations to the habitats. The analyses show that in Vallevecchia the roe deer prefers woods and permanent meadows. Conversely, this ungulate avoids pine forests, wetlands and farmlands, despite their potential as sources of food and shelter. In line with other studies on agroforestry systems, wooded areas were most likely preferred because they provide shelter from disturbing factors and thermal stress, while meadows were likely chosen for trophic reasons. In this respect, we point out that in the studied area the preference for meadows was most likely due also to the availability of sprouts all year round, deriving from the constant mowing activities implemented in this habitat. In addition, our investigation underlines that the roe deer normally avoids maize and wheat crops, in accordance with similar studies. Moreover, the analyses highlight the preference for farmlands only if woods and grasslands are not present in the adjoining areas. Conversely, the proximity of these habitats results in a low impact on crops. In addition to encouraging the enforcement of current management actions in Vallevecchia, our results represent a contribution to a more effective management of the roe deer in agroforestry systems, aimed at limiting its impact in anthropized contexts and at achieving the conditions for a better coexistence of this deer with human activities.

Keywords: environmental preferences, farmlands, fauna management, northern Italy, ungulates.

Riassunto - Selezione dell'habitat del capriolo *Capreolus capreolus* (Artiodactyla: Cervidae) in un sistema agroforestale.

Il presente studio mira a valutare le preferenze ambientali dell'ungulato più diffuso e abbondante in Italia, il capriolo, nell'area protetta di Vallevecchia (Venezia). Quest'area è stata oggetto di gestione naturalistica e di continui miglioramenti ambientali negli ultimi decenni. Attualmente, l'area è caratterizzata da un'elevata eterogeneità di habitat, compresi boschi di latifoglie, pinete, zone umide e terreni agricoli. Lo studio è stato condotto durante le estati del 2017 e del 2020. I dati sono stati raccolti percorrendo transetti standardizzati e le osservazioni geolocalizzate sono state suddivise negli habitat corrispondenti per calcolare l'Indice di Jacobs. Inoltre è stato applicato il test chi-quadro, con il calcolo dei residui di Pearson per stimare la significatività delle associazioni agli habitat. I risultati delle analisi mostrano che a Vallevecchia il capriolo predilige boschi e prati stabili. Al contrario, questo ungulato evita pinete, zone umide e terreni agricoli, nonostante il loro potenziale come fonte di cibo e riparo. In linea con altri studi sui sistemi agroforestali, le aree boschive sono state preferite probabilmente perché offrono riparo da fattori di disturbo e stress termici, mentre i prati sono stati verosimilmente scelti per ragioni trofiche. A tal proposito si segnala che nell'area studiata la preferenza per i prati poteva essere legata anche alla disponibilità di germogli, presenti durante tutto l'anno in conseguenza delle costanti attività di sfalcio attuate in questo habitat. Inoltre, in accordo con studi analoghi, la nostra indagine sottolinea che il capriolo evita normalmente le colture di mais e frumento. Le analisi evidenziano la preferenza per i campi coltivati solo se nelle aree limitrofe non sono presenti boschi e praterie. Viceversa, la vicinanza di questi habitat si traduce in un basso impatto sulle colture. Oltre ad incoraggiare le attuali azioni gestionali a Vallevecchia, i nostri risultati rappresentano un contributo ad una più efficace gestione del capriolo nei sistemi agroforestali, finalizzata a limitarne l'impatto in contesti antropizzati e a realizzare le condizioni per una migliore convivenza di questo cervide con le attività umane.

Parole chiave: gestione faunistica, nord Italia, preferenze ambientali, terreni agricoli, ungulati.

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INTRODUCTION

In the Italian peninsula and most of the European continent, the roe deer *Capreolus capreolus* (Linnaeus 1758) was widespread almost everywhere until the beginning

of the 16th century (Randi, 2005; Apollonio *et al*., 2010). The considerable development of agriculture, deforestation, habitat fragmentation, reduction in environmental diversity and increasing anthropic pressure triggered a rapid decline of this species, with a consequent substantial shrinking of its range. At the beginning of the 20th century this ungulate reached almost total extinction in Italy (Biosa *et al*., 2015). Only since the 1950s-60s there has been a recolonization and expansion of its range, thanks to the reintroduction programmes and environmental requalification. In addition, protective measures were implemented, which, together with the progressive anthropic abandonment of mountainous areas and, in part, the countryside, allowed the roe deer to regain some suitable habitats (Randi, 2005; Linnell *et al*., 2020).

More generally, conservation-aimed translocations have played a major role in favouring the increase of roe deer numbers. These management actions require that ecologically suitable release areas are identified and a feasibility study is conducted (Apollonio *et al*., 2010). This is the case of the restocking of roe deer in the Vallevecchia area (Brussa di Caorle, Venice), which took place in 2003-2004 with 26 individuals from the near Bologna plain (Carnevali *et al*., 2009). In recent decades the area has been subjected to various environmental improvement projects implemented by Veneto Agricoltura Agency. One of these actions was aimed at recreating lowland environments, historically present in the Venetian territory, where the roe deer was a widespread species. At the beginning of the management actions the roe deer was already settling spontaneously in Vallevecchia, as in much of the upper Venetian area.

In this context, the aim of our study was to assess the habitat preferences of this ungulate in order to contribute to the definition of an improved environmental management protocol for the investigated area and similar agroforestry systems.

STUDY AREA

Vallevecchia (centroid: 45°37’40.2”N, 12°56’51.2”E) is a coastal area of high naturalistic importance, covering almost 950 hectares between the urban centres of Caorle and Bibione (Venice) (Fig. 1), and recognised by the European Union as a Special Area of Conservation (SAC) and Special Protection Area (SPA), mostly for the presence of a complex coastal dune system. Vallevecchia has undergone numerous environmental redevelopments in recent decades, hence its naturalistic importance. These actions were mainly promoted by Veneto Agricoltura, an Agency which manages a demonstration farm in the area, which focuses on experimental production using innovative low environmental impact techniques.

The environmental improvement measures in the area and its geographical position have created a complex environmental mosaic, consisting of various biotopes: forests, farmlands, lagoons, marshes and sandy coastline. The combination of these environments makes Vallevecchia an important biodiversity hotspot, with a peculiar and unique coexistence of numerous animal and plant species.

MATERIALS AND METHODS

The survey took place during the summer (mid-June to end-July) of 2017 and 2020. Data were collected by walking along predefined transects, chosen according to their accessibility, visibility and the types of habitats present. The presence of roe deer was recorded by direct sightings or by indirect signs such as footprints or tracks.

A total of 6 transects of varying lengths were used (Fig. 1), walked at a speed of about 1 km/h, and, if necessary, with pauses of ca. 15-20 minutes in the areas with the highest visibility. During 2017 the transects were covered 7 times each, while in 2020 the transects were covered 5 times each. The routes were walked at dawn and dusk, approximately from 5.00 a.m. to 8.00 a.m. and from 8.30 p.m. to 9.30 p.m., with occasional slight variations depending on weather conditions. The chosen time frames represent the peaks of the roe deer circadian activity and are characterised by the lowest anthropic disturbance in the area and in its proximity.

To analyse the habitat preferences of the roe deer, we based on direct observations only. We calculated manually the total area monitored for each habitat (Tab. 1) using QGIS (v. 3.10.10; qgis.org). Each transect was subdivided into shorter sections based on the varying detectability conditions observed within each habitat. This decision made it possible to increase the accuracy of the definition of the entire investigated area. Jacobs’ Environmental Preference Index (D) (Jacobs, 1974) was calculated by comparing the proportion of individuals detected in each habitat with the proportion of the total area of each environment.

In addition, chi-square test (χ^2) was applied on the data matrix of the observations subdivided for each habitat. In case of failures to respect the assumptions required by the test, the Monte Carlo method variant was used (Agresti, 2007). Finally, Pearson residuals were calculated in order to highlight the habitats that make the test itself significant (Sharpe, 2015).

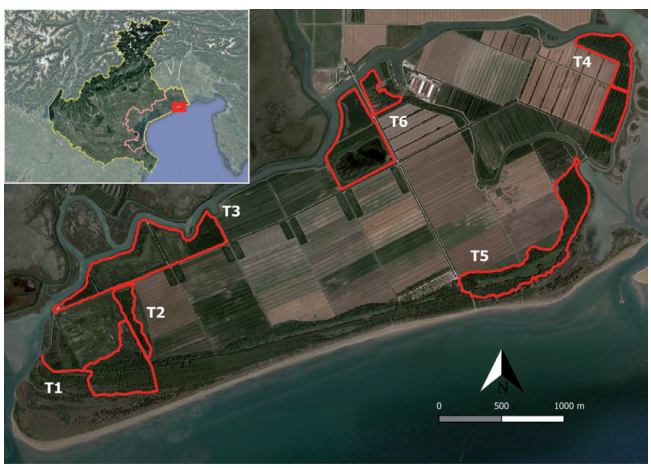

Fig. 1 - Study area: Vallevecchia (Venice). The walked transects (T1 to T6) are highlighted in red. / Area di studio: Vallevecchia (Venezia). I transetti percorsi (da T1 a T6) sono evidenziati in rosso.

RESULTS

Globally, during the 2017 survey, the average value of roe deer observed across transects was 3.24 ± 2.09 (S.D.), while in the 2020 survey it corresponded to 4.80 ± 3.71. The maximum numbers of roe deer recorded along a single transect were 14 (21 June 2017), and 19 (28 July 2020). As for the records of individuals along each transect, T2 and T5 exhibited the highest values in both years (2017-survey, T2: 5.83 ± 2.53 (S.D.), T5: 7.25 ± 4.24, respectively; 2020-survey, T2: 7.60 ± 1.14, T5: 10.40 ± 6.39, respectively), whereas transect T1 and T6 showed the lowest (2017-survey, T1: 1.67 ± 0.82 (S.D.), T6: 1.57 ± 0.97, respectively; 2020-survey, T1: 1.00 ± 1.22, T6: 1.40 ± 1.34, respectively). During various sessions, no roe deer was observed in transects characterized by the pine forest. Some individuals were detected along the trails that connect the different habitats.

The significance of the chi-square test (χ^2, $p<0.0005$) led to the calculation of Pearson residuals. Only those habitats were selected that simultaneously satisfied both the Jacobs Index and the significance of the single Pearson residuals, in either positive or negative cases (Tab. 1).

The analyses showed that, in both study years, woodland and permanent grassland were the habitats most preferred by roe deer, sometimes with a marked significance. In the 2020 survey, other analogous habitats such as hedges and banked grassland were similarly preferred. With regard to the habitats that were avoided in relation to their availability, there was no congruence between the two sampling years. Indeed, in 2017 roe deer avoided wetlands and pine forest, whereas in 2020 they tended to avoid agricultural crops, such as maize and wheat (Tab. 1).

DISCUSSION

The roe deer, an ungulate typically linked to ecotonal environments (Apollonio *et al*., 2010; Lovari *et al*., 2017), often moves among woods, meadows and cultivated fields (Hewison *et al*., 2001). As expected, on some occasions we observed various individuals moving along the paths and trails that connect the different habitats of the investigated area.

In any case, the main result is a notable preference for wooded areas and meadows. Most of the records, in relation to the areas investigated, consisted of individuals frequenting these environments, although for different purposes (i.e. feeding, sheltering, etc.). These results are in agreement with other studies, which report that, in a diversified agricultural context such as Vallevecchia, roe deer seem to prefer open pastures, but usually close to woodlands (Walhstrom & Kjellander, 1995; Cornelis *et al*., 1999; Lovari *et al*., 2017), where they find their shelter (Cederlund *et al*., 1998; Mysterud & Ostbye, 1999; Saïd & Servanty, 2005; Saïd *et al*., 2005; Benhaiem *et al*., 2008). Furthermore, in relation to woods and hedges, it is likely that these habitats provide protection from the sun. In fact, many individuals were detected lying in the shade of trees or shrubs. Moreover, some studies on cervids confirm the preference for habitats that provide shelter from the sun and thermal stress, especially in warmer seasons (Mancinelli *et al*., 2015).

The preference for the above-mentioned environments shall be highlighted as an important aspect for land management. In the mainly agricultural context of Vallevecchia, this preference results in a significant reduction of the roe deer impact on crops, as reflected also by the parallel partial avoidance of these environments; overall, these outcomes are in line with previous studies (e.g. Cornelis *et al*., 1999; Abbas *et al*., 2012). However, in this respect, our data stimulate a further observation. In the investigated area, the roe deer preference for meadows is most likely related also to the availability of sprouts almost all year round, which derives from the

Tab. 1 - Values of the Jacobs' Index (D) and Pearson residuals calculated for each habitat in both survey years. Significant results are highlighted: preferred habitats in green, avoided habitats in orange. / Valori dell'indice di Jacobs (D) e dei residui di Pearson calcolati per ciascun habitat in entrambi gli anni di indagine. Si evidenziano i risultati significativi: in verde gli habitat preferiti, in arancione gli habitat evitati.

2017		
Habitat	**D**	**Pearson residuals**
Headland	0,16	1,24
Hedge	0,22	1,33
Maize	-0,50	-1,15
Meadows on the embankment	0,01	0,07
Permanent meadows	0,32	2,98
Pine forest	-0,38	-2,47
Sorghum	-0,24	-1,88
Wetlands	-0,42	-2,97
Wheat	0,20	1,43
Woods	0,26	2,84
2020		
Habitat	**D**	**Pearson residuals**
Headland	0,02	0,16
Hedge	0,76	7,81
Maize	-0,68	-5,73
Meadows on the embankment	0,68	5,37
Permanent meadows	0,65	8,67
Pine forest	-0,61	-1,54
Sorghum	-0,08	-0,74
Wetlands	-0,01	-0,02
Wheat	-0,23	-2,47
Woods	0,78	11,44

regular mowing activity included in the ordinary management of the SAC-SPA Vallevecchia. Further studies will hopefully confirm this very plausible hypothesis.

As for the avoided habitats, interestingly, we observed that the pine forest, although potentially representing an excellent refuge area, was not a preferred environment for roe deer. We hypothesize that the underlying reason is the presence of a rather sparse understory, which makes this habitat scarcely suitable both for trophic purposes and for shelter. Similarly, roe deer also tended to avoid wetlands and reedbeds, despite the fact that they may represent areas highly suitable for shelter and food (i.e. sprouts and seedlings). However, it cannot be excluded that this result is connected to the low number of records collected, which in turn may partially depend on the poor visibility that characterises these environments. Finally, the trend towards avoiding maize and wheat crops, which was particularly highlighted in 2020, confirms earlier studies (e.g. Putman, 1986; Cornelis *et al*., 1999; Morellet *et al*., 2011) that report the preference of roe deer for farmland only in the absence of woodland and meadows, suggesting a limited impact on crops if this animal can rely on such environments in the area.

CONCLUSIONS

In general, the outcomes of our study represent a contribution to the proper management of roe deer in agro-forestry environments. In particular, our results show that the management choices made in the Vallevecchia protected area are in the right direction and deserve to be continued and improved. First, it has been shown that carefully choosing land use, when possible, is strategic; second, implementing targeted management actions, such as mowing meadows, can help reduce the impact of roe deer on human activities, thus allowing better coexistence between this ungulate and people.

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