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Spacing and nocturnal activity of wild boar *Sus scrofa* in a Mediterranean metropolitan park

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Collserola Park in northeastern Spain is an 8,000 ha Mediterranean forest park surrounded by the Barcelona metropolitan area with a population of some three million inhabitants. Wild boar *Sus scrofa* are common in Collserola and cause specific management problems. We obtained information on their activity and habitat use in different areas of the park by use of two field methods: prospecting of non-linear transects at night on foot and periodic monitoring of sign-survey plots. Prospecting of routes on foot provided information on summer nocturnal activity in different natural and semi-natural environments: feeding activity takes place mainly during 00:00-05:00, and the maximum amount of movements was registered during 20:00-00:00 and at dawn. Wild boar feeding activity was significantly lower on dry slopes than in other habitat types such as riparian woodland, valley bottoms and agricultural areas. Pellet-group density varied significantly between habitats, being higher in agricultural habitats, intermediate in riparian woodland and lowest on wooded slopes. In general, pellet-group density was higher on level ground than on slopes. The mean surface area rooted by wild boar was less than 5% in all survey periods. Rooting activity, which was dominated by surface rooting, was highest in winter and lowest in summer when soil conditions for rooting were poorest. Rooting activity varied significantly between habitat types, and distinct seasonal patterns were observed within individual habitat areas. The results we obtained support the view that the summer is a critical period for wild boar in Mediterranean environments and highlight the importance of ensuring certain scarce habitats for foraging activities during this season.

Key words: activity, pellet group, plot, rooting, *Sus scrofa*, transect, wild boar

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The wild boar *Sus scrofa* has increased its populations significantly during recent years in many parts of Spain (Tellería & Saez-Royuela 1985, Rosell 1995, Leranoz & Castien 1996, Rosell, Carretero & Bassols 1998, Gortázar, Herrero, Villafuerte & Marco 2000). The increase in the numbers of wild boar in rural areas has had specific consequences for both human activities and natural ecosystems, such as damage to crops, road traffic accidents (Markina 1999), negative effects on the re-

generation of certain tree species (Groot-Bruinderink & Hazebroek 1996), damage to sensitive plant communities (Onipchenko & Golikov 1996), as well as an increase in the risk of diseases being spread to domestic livestock (Artois 1997). Nevertheless, other studies have shown that in certain situations the disturbance caused by wild boar rooting activity can have beneficial effects on micro-habitat vegetation diversity (Milton, Dean & Klotz 1997), even where the wild boar is a non-native spe-

cies (Arrington, Toth & Koebel 1999). In Spain, wild boar are now found even in suburban areas and parks within the limits of certain large cities such as Zaragoza (Sanz 2000) and Barcelona (observations in our study) where their presence can lead to specific problems for both residents and wildlife managers.

Previous studies on populations of wild boar living in Mediterranean regions have pointed out the importance of the summer period for survival as seasonal drought conditions dry and harden the ground and thus limit rooting activity by wild boar (Massei, Genov, Staines & Gorman 1997b). In years of low forage availability in natural habitats, wild boar may be forced to seek alternative sources of food, such as agricultural crops (Fournier-Chambrillon, Maillard & Fournier 1996), and damages can become significant if population densities are high (Maillard 1998). If barriers such as game fences or major roads and railways limit access to alternative resources, the consequences for survival can be significant, and major population crashes have been registered in enclosed populations of wild boar in Mediterranean areas during the summer drought period in years following poor oak *Quercus* spp. mast production (Massei et al. 1997b).

The aim of our study was to obtain data both on summer nocturnal activity and on the use by free-living wild boar of natural and semi-natural Mediterranean habitats in a metropolitan park subjected to strong pressure by human activities and presence. The intense urban development and major transport infrastructures which surround the park act as a barrier to potential movements of wild boar to outlying areas in search of alternative foraging during periods of scarce food resources within the park. As such, there is a need to identify the characteristics of wild boar activity, habitat use and spacing in order to determine the priority aspects of foraging with a view to aiding management approaches that will permit the long term survival of the population and at the same time minimise conflicts with other, primarily human, park users. In previous studies on wild boar, data have been obtained on their ecology using a variety of methods such as direct observation during day-time, trapping and radio telemetry (Fernández-Llario & Carranza Almansa 1996, Russo, Massei & Genov 1997). However, it is only possible to observe wild boar during the day in relatively few

areas, and radio telemetry usually does not provide data on the specific type of activity developed by marked animals. Boitani, Mattei, Nonis & Corsi (1994) identified differences in habitat use between individual groups of wild boar using radio telemetry, but they also highlighted the difficulty in such studies of characterising general patterns of habitat use given the lack of data regarding activities developed in particular ecological contexts. In our study, direct detection of groups of wild boar at night allowed us to identify the main activities developed in different habitats in a Mediterranean environment.

Study area

The study was carried out in Collserola Park, a large metropolitan park covering some 8,000 ha situated in the surroundings of the city of Barcelona in northeastern Spain (Fig. 1). The Collserola mountains have an altitude of 60-512 m a.s.l. and form part of the Catalan coastal mountain range. The combination of a varied topography and the orientation of the mountain slopes leads to variation in the local microclimate within the Park, although in general it may be described as a typically Mediterranean climate with an average annual rainfall of 672 mm. Snow is rarely present and the annual average daily temperature is some 14°C with extremes ranging from -4 to +35°C. Correspondingly, the potential climax vegetation would be dense holm oak (*Quercetum ilicis galloprovinciale*) woodland dominated by holm oak *Quercus ilex* with scarce understorey and ground-layer vegetation dominated by ivy *Hedera helix*.

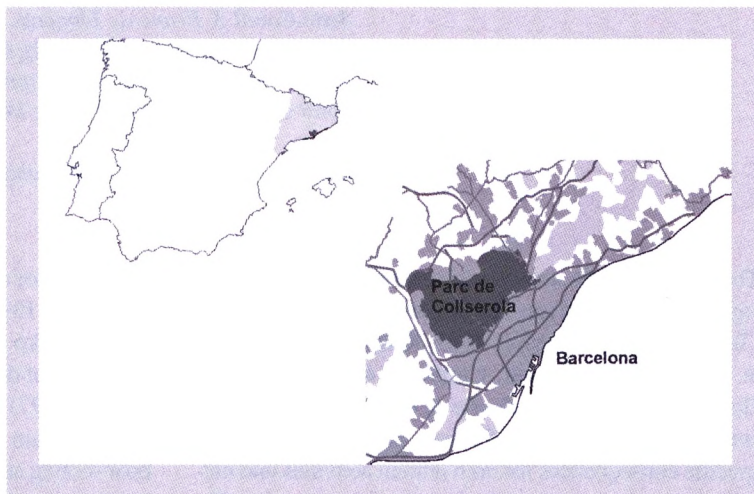


Figure 1. Location of Collserola Park in northeastern Spain with urbanised ground shown in medium grey and nearby natural areas in light grey.

However, due to human activity, the dominating tree species is at present Aleppo pine *Pinus halepensis* which covers most of the mountain slopes in the park andholm oak woods with an understorey of shrubs in denser areas such as Laurustinus *Viburnum tinus*, honeysuckle *Lonicera implexa*, sweet-scented Virgin's bower *Clematis flammula*, and of strawberry tree *Arbutus unedo*, bupleure *Bupleurum fruticosum*, Italian buckthorn *Rhamnus alaternus*, mock privet *Phillyrea latifolia* and broom *Genista triflora*, among others, where tree cover is less dense (De Bolòs i Capdevila 2000). In the more humid areas of the park, deciduous oak *Quercus cerrifolia* is also found together with holm oak. A fuller account of the vegetation of Collserola Park may be found in De Bolòs i Capdevila (2000). The majority of the woodland has a dense understorey, which makes it almost impossible to see wild boar within the wood and also impractical to undertake linear transects. Only small-scale agricultural areas exist in the park, many of which are now in decline and at present occupy in total less than 8% of its surface area. There are no other wild ungulates present in the park, and the largest wild carnivores are the red fox *Vulpes vulpes* and the badger *Meles meles*, although abandoned dogs *Canis familiaris*, which are relatively frequent (López de Padilla 2000), can occasionally disturb and chase wild boar (pers. obs.).

Collserola Park is surrounded by a large metropolitan area with some three million inhabitants, and is effectively isolated as such from other nearby natural and semi-natural areas. Also, there is an important road and rail axis which crosses the centre of the park via a series of tunnels running from southeast to northwest. Apart from the surrounding built-up areas, there are also a considerable number of residential areas within the limits of the park, located in primarily wooded areas, and the number of visitors is high, particularly during weekends. Hunting is carried out in approximately 50% of the surface area of the park during October-February (Patronat Metropolità del Parc de Collserola 1990), and routine data on wild boar are also obtained from the analysis of hunting returns (Bonet-Arbolí, Llimona, Pla, Rafart-Plaza, Padrós & Rodríguez-Teijeiro 2000, S. Cahill, unpubl. data).

Methods

The study was carried out between May 1998 and July 2000 and forms part of an on-going research project on wild boar in Collserola Park. Two distinct methods were used to obtain data on free-living wild boar with-

in the park: 1) Direct detection of groups of wild boar at night along non-linear transects of varied length. The results obtained from the transects correspond mainly to the summer period and provided information on activity and habitat use by wild boar in natural and semi-natural areas within the park; and 2) Periodic control of sign-survey plots at fixed stations between 1998 and 2000.

Night transects on foot

The main aim of night transects undertaken on foot was to detect as many groups of wild boar as possible, and to gather information on their location and activity based on the sounds they made. The two main activities considered in the analysis are feeding and movement, where movement refers only to directed movements from one location to another, usually involving trotting or running, and does not include slower walking movements made as the animals forage within a given area. Cases of movements due to flight behaviour, caused on occasions when groups detected the observer, are not considered in the analysis.

We walked a total of 67 transects at night between the end of May and the beginning of October 1998, with approximately one transect being prospected every two days during this period. Transects were of variable length with a mean of 5.6 km (range: 3.0-8.6 km), and the mean time taken to walk them was 6.6 hours (range: 3-10 hours). Transects were prospected during 20:00-07:00, although the starting and finishing time varied depending on the location and length of the transect.

We prospected five main habitat types during transects: dry wooded slopes, humid wooded slopes, valley bottoms, riparian woodlands and agricultural habitats. The distinction between dry and humid slopes is based on appreciable qualitative differences between the two with regard to the composition of the vegetation and the quantity and dryness of leaf litter and humus within the woods. These differences respond mainly to aspect, although the vertical distance from the valley bottoms, where conditions tend to be cooler and more humid, also influences the vegetation composition in the area (De Bolòs i Capdevila 2000). In general, the dominance of tree heath *Erica arborea* in the understorey and the presence of ivy serve to classify slopes as either dry or humid, respectively.

Most groups (87%) of wild boar were only detected aurally, without the use of a spotlight, and therefore we only undertook transects when and where conditions were favourable for aural detection, i.e. in the absence of noise from e.g. wind and rain, and far from noisy human activities. We walked transects along small for-

est tracks and trails at a slow pace and in a careful manner in order to avoid making sudden noises. Normally only one person walked the transect to reduce the risks of the observer being detected by the wild boar. We made frequent pauses during the transect in order to listen for sounds of wild boar activity and to detect groups before getting too close to them. When a group was detected, we made a slow approach until it was possible to confirm that the noises were caused by wild boar and determine their activity. Also, on occasions, we repeated part of a transect at a later stage during the night to aid the identification of certain activities and locations of groups. Whenever it was unclear whether the animals detected were wild boar, or it was impossible to determine their activity, we did not consider the detection in the analysis.

Sign-survey plots

In an area of the park where hunting is not practised, we established a total of 40 sign-survey plots (each of 3 m x 3 m) at random in the various habitat types. We located plots in agricultural habitats (five plots in crop fields and eight plots in small terraced fields mixed with fruit trees), on wooded slopes (15 plots), in riparian woodland (seven plots) and in a firebreak (five plots). Initially, we surveyed these plots monthly between the summer and winter of 1998, and later every three months from spring 1999 onwards. It was not possible to inspect all of the established plots due to circumstances alien to the research (e.g. fields recently ploughed) during some surveys. Thus the total number of plots surveyed during each inspection varied between 31 and 38. During inspections, we examined plots in detail for the presence of wild boar pellet groups and other signs, and for the presence of rooting activity. We classified rooting activity as either 'deep rooting' (ground dug to > 10 cm depth), 'surface rooting' (ground rooted to < 10 cm) or 'mixed rooting' when both deep and surface rooting occurred together at the same plot. When rooting activity was present, we calculated the percentage surface area of the plot which had been rooted by wild boar.

At each plot, we calculated a simple index of the suitability of soil conditions for rooting activity based on a qualitative assessment of the humidity and compactness of the soil at the surface and at a depth of 10 cm. We scored humidity as 0 for completely dry soil, 0.5 for humid soil and 1.0 for moist or wet soil. Ground was scored as 0 if compacted and hard and 1.0 if loose and uncompacted. We calculated the index as the mean of the four values scored (humidity and compactness at surface and at 10 cm) at each plot during each inspection. We coded the index by multiplying by 10 to facil-

itate comparisons with observed rooting activity. High values implied good rooting conditions and lower values indicated poorer conditions.

Data analysis

For statistical analysis, we used t-tests and ANOVA for comparisons of means where data displayed a normal distribution, and the Kruskal-Wallis, Mann-Whitney, Chi-squared and Fisher's exact tests for non-parametric comparisons. According to Zar (1984), we performed non-parametric multiple comparisons following significant results from the Kruskal-Wallis tests, and values of Q and standard errors (SE) are quoted accordingly. For large sample sizes, we used a normal approximation to the Mann-Whitney test when this test was appropriate, and corresponding Z values are quoted in such cases (Zar 1984). We used two-tailed tests on all occasions. Spearman's Correlation (Sr) was used for analysis of correlations. The standard deviation (SD) is quoted in the text with the values of means given. Data analyses were performed using SPSS for Windows, version 7.5 (SPSS Inc. 1990).

We analysed data obtained on groups of wild boar detected during foot transects to examine nocturnal activity with regard to the two most frequent activities detected: feeding and moving. In the analysis of wild boar behaviour, we examined nocturnal activity in relation to: 1) its temporal distribution, 2) altitude, 3) habitat type and 4) topography. For topography, we compared the activity of groups detected on level ground with that of groups on sloping ground. We considered ground as sloping if the gradient was > 10%. To facilitate the interpretation of results, the time of day is quoted as local summer time and has not been adjusted to solar time, as all the data on activity were collected during the summer time period.

Results

Night transects on foot

During the 67 transects prospecting on foot in 1998, a total of 318 groups of wild boar were detected with a mean of 4.8 ± 3.6 groups per transect (range: 0-14 groups). Feeding was the most frequent (> 60-70% of detections) nocturnal activity detected in most months during May-September (N = 226 groups detected), with the exception of June when a higher proportion of detected groups were moving (54% of groups moving; N = 50 groups), although overall, the difference between months did not reach significance ($\chi^2 = 9.3$, $df = 4$, $P = 0.055$). There was no significant difference between the

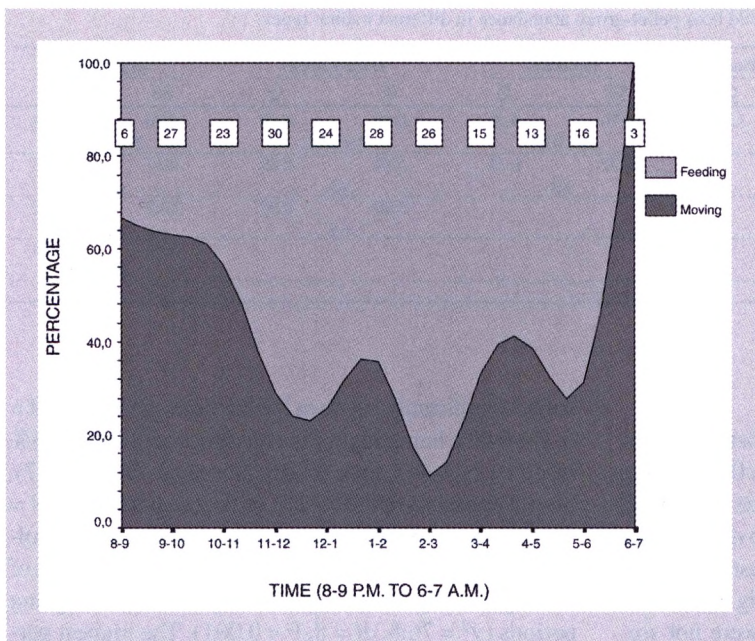


Figure 2. Summer nocturnal activity pattern of wild boar in Collserola Park expressed (in %) according to hour (from 8-9 p.m. to 6-7 a.m.). The figures in frames refer to the number of groups detected during each time interval.

mean altitude where groups of wild boar were detected feeding (160.9 ± 76.6 m a.s.l.; $N = 131$ groups) or moving (171.7 ± 68.9 m a.s.l.; $N = 79$ groups; t-test of difference: $t = 0.304$, $df = 208$, $P > 0.5$). However, there was significant temporal variation in the altitude at which groups were detected during the study (1-way ANOVA: $F_{4,317} = 50.5$; $P < 0.001$), May being higher (286.6 ± 82.4 m a.s.l.) than the other months prospect-ed (June-September).

The temporal distribution of the two main nocturnal activities, i.e. feeding or moving, was based on a total of 211 groups of wild boar detected during 20:00-07:00 (Fig. 2). There was a significant difference in the proportion of the two activities detected during different time intervals throughout the night ($\chi^2 = 29.2$, $df = 10$, $P < 0.005$). In general, feeding was the most important nocturnal activity detected, and it continued at high levels until late into the night: more than 60% of detections made during 05:00-06:00 still corresponded to groups of wild boar which were feeding. Most feeding activity (~70%) was concentrated during 00:00-05:00 with a maximum registered during 02:00-03:00. At the beginning of the night (20:00-0:00), the majority of detections (~60%) corresponded to groups of wild boar which were moving at a rapid pace from one area to another, presumably from day-time resting sites to night-time foraging areas. The few detections made at the end of the night (06:00-07:00; $N = 3$ groups) all cor-

responded to groups that were moving. Feeding activity was interspersed during the central hours of the night with pulses of movement activity (see Fig. 2).

There was a significant difference in the proportion of feeding and movement activities detected in different habitats ($\chi^2 = 62.7$, $df = 4$, $P < 0.001$). This difference was due to the extremely low levels of feeding activity detected on dry wooded slopes where only 13.3% ($N = 45$) of groups of wild boar detected were feeding, in comparison with other habitat types where this activity accounted for > 65% ($N = 147$) of detections (Fig. 3). The proportion of groups showing feeding activity was highest in riparian woodland (84.6%; $N = 13$ groups), followed by agricultural habitats (81%; $N = 58$ groups) and valley bottoms (77.4%; $N = 53$ groups), although the absolute number of detec-

tions made in riparian woodland was lower due to the relative scarcity of this habitat type in the park. Overall, the proportion of groups of wild boar detected feeding on level ground (77.0%; $N = 113$ groups) was significantly higher than the corresponding proportion for groups detected on sloping terrain (44.8% of groups feeding; $N = 96$ groups; Fisher's Exact Test: $P < 0.001$).

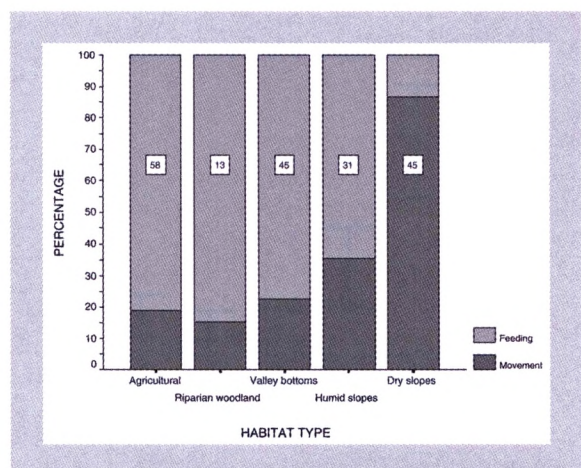


Figure 3. Summer nocturnal activity pattern of wild boar in Collserola Park expressed (in %) in relation to each of the five habitat types. The figures in frames refer to the number of groups detected in each habitat.

Table 1. Non-parametric multiple comparison of wild boar pellet-group abundance in different habitat types.

Type of habitat	N	Riparian woodland		Firebreak		Humid slopes		Dry slopes	
		SE	Q	SE	Q	SE	Q	SE	Q
Agricultural	79	7.04	3.26	6.76	3.72	6.76	4.49	6.76	4.49
Riparian woodland	68	P < 0.05		6.37	0.35	5.80	0.89	6.37	1.16
Firebreak	50			n.s.		5.80	0.90	5.80	0.89
Humid slopes	50					n.s.		5.80	0.00
Dry slopes	50							n.s.	

n.s. = not significant

Sign-survey plots

Pellet-group density varied significantly between habitats (Kruskal-Wallis: $H = 14.1$, $df = 4$, $P < 0.01$), being significantly higher in agricultural habitats than in all other habitat types (Table 1). Pellet-group density was intermediate in riparian woodland and lowest on dry and humid wooded slopes and in firebreaks (Fig. 4), but the differences between these habitat types were not significant (see Table 1). Overall, pellet-group density was higher on level ground (9.76 ± 27.4 ; $N = 173$) than on sloping terrain (1.34 ± 5.5 ; $N = 174$; Mann-Whitney test: $Z = -4.15$, $N = 347$, $P < 0.001$) and this difference was maintained even when agricultural habitats, in which all plots were located on level ground, were removed from the analysis (Mann-Whitney test: $Z = -2.73$, $N = 268$, $P < 0.01$).

Rooting activity, when present, was dominated by surface rooting (< 10 cm depth), and deep rooting was not present in more than 10% of all plots during any given survey period (Fig. 5). Where rooting activity was present, the proportion of plots with deep rooting events

varied significantly between habitat types ($\chi^2 = 12.6$, $df = 4$, $P < 0.02$), being higher in riparian woodland (20.5% of plots; $N = 44$), than on dry slopes (3.7%; $N = 27$), humid slopes (3.6%; $N = 28$) or firebreaks (3.2%; $N = 31$). No deep rooting events were recorded in agricultural habitats. The proportion of plots with presence of rooting activity varied significantly between sampling periods ($\chi^2 = 76.8$, $df = 8$, $P < 0.001$). The highest percentage occurrence of rooting was recorded in winter, both in 1998 (83.3%; $N = 30$) and in 1999 (84.4%; $N = 32$), whereas the lowest values were registered in summer (1998: 10.5%; $N = 38$; 1999: 25.8%; $N = 31$). Overall, the percentage surface area of ground rooted was quite low (mean 1.64 ± 5.06 %; $N = 310$) and mean values were less than 5% in all survey periods (Fig. 6). There was also significant seasonal variation in the surface area rooted at plots by wild boar (Kruskal-Wallis: $H = 77.7$, $df = 8$, $P < 0.001$), although this did not necessarily follow the exact same pattern from year to year (e.g. it was high in spring 1999 and low in spring 2000). Nevertheless, rooting was always lowest during the summer

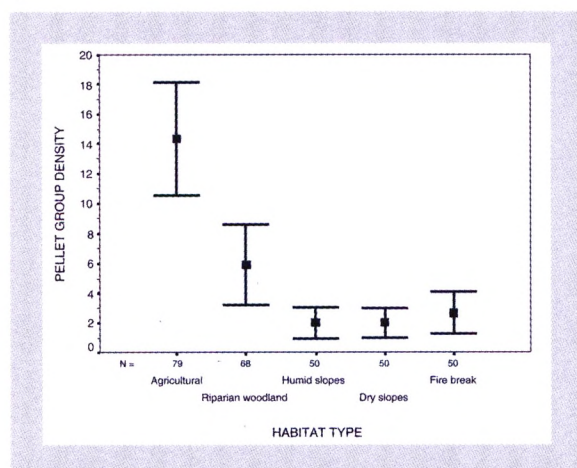


Figure 4. Wild boar pellet group density in relation to the five types of habitat in Collserola Park. Bars indicate standard error of the mean, and the figures below the axis refer to the total number of plots surveyed in each habitat.

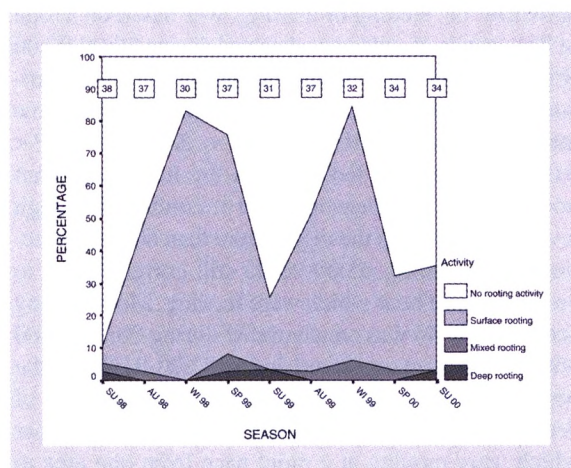


Figure 5. Seasonal changes in rooting activity during 1998-2000 expressed (in % of survey plots) according to type of rooting. The figures in frames refer to the number of plots surveyed during each season (Su = summer, Au = autumn, Wi = winter, Sp = spring).

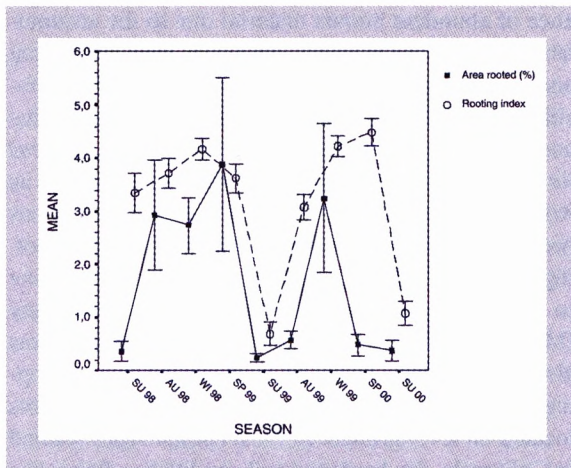


Figure 6. Seasonal changes in the mean percentage of the surface area rooted (■, —) by wild boar at survey plots and mean value of the rooting index (○, - -) during 1998-2000. Bars indicate standard error of the mean. The seasons are abbreviated in the same manner as in Figure 5.

period, when less than 0.5% of the surface area of plots was disturbed by this activity (see Fig. 6). The rooting index obtained at plots also varied significantly between seasons (Kruskal-Wallis: $H = 123.3$, $df = 8$, $P < 0.001$): the lowest values, corresponding to the poorest soil conditions for rooting, were recorded in the summers of 1999 and 2000 (median value of index = 0 in both summers; $N = 31$ and 35 , respectively) and the highest in spring 2000 and winter 1999 (median = 5.0 in both periods; $N = 34$ and 32 , respectively). Overall, there was a significant correlation between the rooting index and the surface area rooted at plots ($S_r = 0.254$; $N = 347$, $P < 0.01$), although during some periods with apparently good rooting conditions, such as autumn 1999 and spring 2000, rooting activity remained low (see Fig. 6).

The percentage surface area rooted at plots varied significantly between different habitat types (Kruskal-Wallis: $H = 36.1$, $df = 4$, $P < 0.001$), being significantly lower in agricultural habitats (median = 0.0%) than in all other habitat types (Table 2). The percentage surface area rooted also differed significantly between other habitat types (see Table 2), being higher in firebreaks (medi-

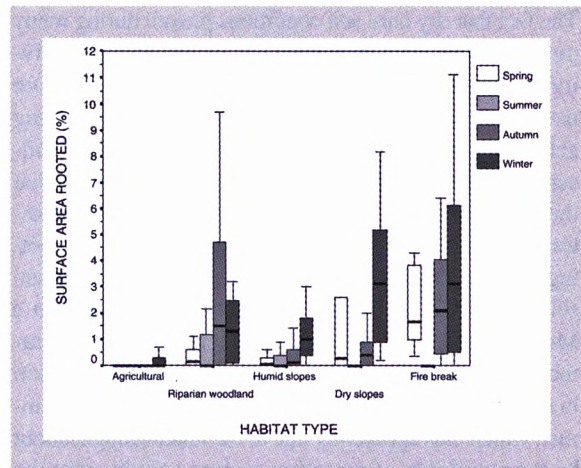


Figure 7. Percentage of surface area rooted by wild boar according to type of habitat and season. Values displayed are the median (bold horizontal bars), interquartile range (boxes) and maxima (upper bars).

an = 0.95%) than on humid slopes (median = 0.15%) and dry slopes (median = 0.23%) and higher in riparian woodland (median = 0.4%) than on humid slopes. The surface area rooted showed distinct seasonal patterns in different habitats (Fig. 7). In firebreaks and on wooded slopes, the highest levels of rooting were registered in winter, whilst in riparian woodland, rooting was slightly higher in autumn (see Fig. 7). Rooting in agricultural habitats was only appreciable in winter (see Fig. 7). In general, rooting was low or absent in most habitats in summer, and was only appreciable in riparian woodland and to a lesser extent also on humid slopes (see Fig. 7) during this period.

Discussion

In general, the percentage surface area of ground rooted by wild boar in Collserola was low in comparison with other studies carried out on the species (Mackin 1970, Jezierski & Myrcha 1975, Howe, Singer & Ackerman 1981, Hone 1988, Kotanen 1995, Welander 2000).

Table 2. Non-parametric multiple comparison of percentage surface area rooted by wild boar in different habitat types.

Type of habitat	N	Riparian woodland		Firebreak		Humid slopes		Dry slopes	
		SE	Q	SE	Q	SE	Q	SE	Q
Agricultural	79	7.04	9.24	6.76	10.95	6.76	5.76	6.76	7.48
Riparian woodland	68	P < 0.001		6.37	1.39	6.37	4.11	6.37	2.28
Firebreak	50			n.s.		5.80	6.04	5.80	4.031
Humid slopes	50					P < 0.001		5.80	2.01
Dry slopes	50							n.s.	

n.s. = not significant

The fact that dry hard soil conditions prevail during many months of the year may limit the extent of such activity in typically Mediterranean habitats, while in more northerly latitudes ground frost can also limit rooting activity (Welander 2000). The results obtained in Collserola support the view expressed by other authors that the summer is a critical period for wild boar in Mediterranean regions due to the limited possibilities for rooting activity (Dardaillon 1987, Massei et al. 1997b). Massei et al. (1997b) showed mortality of wild boar in a Mediterranean coastal area to be related to high summer temperatures, and they found a dramatic reduction in mortality following the first rains at the end of the summer, which was apparently due to the relief brought about by the possibility of renewing rooting activity after the end of the drought. In Collserola, the incidence of rooting by wild boar was lower in summer than during any other period, being lowest in all habitat types during this season. In summer, appreciable levels of rooting activity were only registered in more mesic habitat types such as riparian woodlands and humid wooded slopes. Studies on habitat use by wild boar in Doñana in the south of Spain have also shown a preference for areas with higher soil humidity during the dry summer period (Braza & Álvarez 1989). In Collserola, rooting activity was highest in winter, while the situation in spring and autumn varied depending on the year, possibly in response to the availability of alternative, preferred, food sources during these periods (Dardaillon 1987). Nevertheless, rooting activity was clearly seasonal, and other studies have also shown similar patterns with generally higher levels of rooting from autumn to spring (Dardaillon 1986, Kotanen 1995, Welander 2000), which is sometimes related to the increased availability of forest fruits such as oak and beech *Fagus* spp. mast (Groot-Bruinderink & Hazebroek 1996).

In the present study, most rooting activity was made in the upper surface layer of soil and humus, as has also been found by other authors (Groot-Bruinderink & Hazebroek 1996), and deep rooting events were confined almost exclusively to riparian woodland where the presence of fine humid soils facilitated this activity. Wild boar have been shown to have a preference for rooting in damp soils in both drier regions of southern Europe (Dardaillon 1986) and more mesic parts of northern Europe (Welander 2000), and this has been attributed to increased food availability in such soils (Welander 2000). Relatively high levels of rooting registered in the firebreak habitat studied in Collserola might be explained by several factors. Among these factors are: 1) better soil and productivity conditions (the area was cultivated some decades ago but is now covered by woodland), 2) pres-

ence of abundant humus material due to the accumulation of decaying branches and leaves from tree felling and wood clearance activities or 3) vegetation composition; tree felling and clearance activities are selective and favour the presence of the oak mast species *Quercus ilex* and *Q. cerrioides* and other fruiting trees such as *Arbutus unedo*. Enhanced fertility and productivity has been interpreted as a possible explanation for higher rooting activity of wild boar on set-aside fields with respect to non-arable slopes and hill tops in central Germany (Milton et al. 1997). In Collserola, feeding activity was also proportionally higher on level ground than on sloping terrain, and pellet-group density was higher on plots located on level ground. In most habitat types studied in Collserola, dry hardened soil conditions often make it very difficult for wild boar to root more than the upper few centimetres of soil. An exception to this are agricultural areas, which often have good conditions for deep rooting during certain periods, such as winter or spring, although generally in summer the ground is too hard even for surface rooting. Nevertheless, even when soil conditions were apparently quite good, no deep rooting events were recorded in agricultural habitats. This result concurs with findings obtained elsewhere which indicate lower levels of wild boar rooting on arable land (Welander 2000). Nevertheless, higher pellet-group densities testified to the importance in Collserola of small-scale agricultural habitats for foraging by wild boar. Feeding in such areas was on above ground parts of planted crops (usually wheat) or grasses growing in fields, as well as on fallen fruits of cultivated trees such as figs *Ficus carica*, almonds *Amygdalus communis* or varieties of small plums *Prunus* spp., the latter apparently being of some importance in certain areas of the park during the early dry summer period (pers. obs.).

Important differences were observed in Collserola in relation to the spatial patterns of nocturnal activity of wild boar during the summer period. Wild boar were seldom detected feeding in summer on dry wooded slopes, which account for the largest surface area in the park, and most detections made on these slopes were of groups moving through this habitat which is dominated by Aleppo pine *Pinus halepensis*. Nevertheless, rooting activity was comparatively high on these slopes during winter, although lower levels of rooting activity have been registered in coniferous woods in comparison to deciduous woods in more northern parts of the wild boar range (Welander 2000). In our study, most groups of wild boar detected in other habitats, such as riparian woodland, valley bottoms and agricultural areas, were feeding. These habitats occupy proportionally less surface area in the park and are of clear importance to wild boar

during the critical summer period when food is scarce. In some of the areas, the presence of stone pine *Pinus pinea* was apparently also important to wild boar in summer due to the edible pine seeds they produce. In Mediterranean parts of Italy, seeds of this species and grasses make up most of the wild boar diet during summer (Massei, Genov & Staines 1996).

In Collserola, high levels of nocturnal feeding activity were detected throughout the night almost until dawn, possibly in response to food scarcity during the summer period. Other studies in Mediterranean areas have demonstrated a reduction in mobility and an increase in time spent on foraging as a response to food shortage and high population density (Massei, Genov, Staines & Gorman 1997a). In our study, population levels were also known to be higher in 1998, when data were collected on nocturnal activity, than in other years (S. Cahill, unpubl. data). Seasonal movements by wild boar have also been reported as a response to food shortage (Belden & Pelton 1975, Singer, Otto, Tipton & Hable 1981), although home-range size, which tends to be higher for wild boar inhabiting more arid environments (Gabor, Hellgren, Van Den Bussche & Silvy 1999, Boitani et al. 1994), has been shown to decrease during such periods in enclosed populations where migration is not possible (Massei et al. 1997a). In Collserola, long-distance seasonal migrations to outlying areas with better foraging are also seriously limited by the barrier effect of transport infrastructure and urban development beyond the periphery of the park. The higher mean altitude at which groups of wild boar were detected during May than in other months prospected (June-September), together with an increase in the proportion of movements detected during the month of June, might reflect a shift in nocturnal foraging activity closer to cooler and more humid valley bottoms where food availability is likely to be greater than higher up on drier slopes during summer. Daily movements are frequent in wild boar due to distinct spatial and habitat requirements for safe day-time refuge areas and nocturnal foraging sites (Boitani et al. 1994). This may particularly be true for certain groups of individuals, and females with piglets, for example, have been seen to avoid insecure areas (Spitz & Janeau 1995). In Collserola, the important levels of movement activity detected at the beginning and end of the night clearly indicate such daily migrations between day-time resting and night-time feeding areas, although as yet little information is available on the preferred habitat type for refuge areas. Studies carried out on other wild boar populations occupying similar environments in Mediterranean regions indicate that forest is the preferred day-time

refuge habitat type and that activity is mostly nocturnal, showing a shifting seasonal pattern in line with sunset and sunrise (Boitani et al. 1994). The relative scarcity of some preferred habitat types for foraging, such as agricultural areas, valley bottoms and riparian woodland, might also increase the need for further movements during the night between distinct foraging sites. Hourly movements of wild boar have been shown to increase when food is scarce (Singer et al. 1981), and in Collserola Park minor peaks of movement activity were detected during the middle hours of the night, which possibly reflect changes from one foraging site to another as patchy resources are depleted.

A patchy distribution of preferred foraging sites has obvious implications for the spacing and activity patterns of wild boar, particularly during the critical summer period. In a metropolitan context, such as that of Collserola, further reduction in the availability of key habitats due to, for instance, the abandonment of small-scale agricultural activities, increased urbanisation and inaccessibility caused by barriers, may oblige wild boar to increasingly turn to other anthropogenic food sources in suburban areas during periods of food scarcity. At these places, their presence is already causing concern because of increased risk of, e.g., road traffic accidents, disturbance and damage in residential areas and habituation to people. Due to landscape, social and ecological changes, ungulates are an increasingly growing source of conflict in urban residential areas where efficient population control measures are more difficult to apply (Doerr, McAninch & Wiggers 2001, Whittaker, Manfredo, Fix, Sinnott, Miller & Vaske 2001). In the case of wild boar, effective population control using traditional hunting methods can be either limited (Boitani, Trapanese, Mattei & Nonis 1995) or conflictive, and there is a growing need for alternative approaches based on integrated management of populations and problems at both landscape and social levels (e.g. land use management, education and application of mitigation measures). As such, it is important to guarantee the preservation of, and access to, preferred key habitats within the park in order to ensure the long term sustainability of the wild boar population in harmony with human presence and activities in this highly anthropogenic environment where migration to and from outlying natural areas is not at present an option due to its isolation.

In conclusion, we found that wild boar show distinct use of different habitat types for nocturnal feeding during summer, with clear preferences for foraging in more mesic habitats, such as valley bottoms, riparian woodland and humid slopes, which occupy propor-

tionally much less surface area in such Mediterranean environments. On the contrary, feeding activity in the predominating habitat type, i.e. dry wooded slopes of aleppo pine, was very low in summer. The low levels of rooting activity registered in summer, combined with the relative scarcity of preferred foraging areas during this period, supports the idea that this season is a critical time for wild boar in Mediterranean regions. In Collserola, wild boar movement activity is highest at the beginning and at the end of the night, indicating daily movements to and from nocturnal foraging sites, and there is some evidence of further movements between distinct foraging sites during the central hours of the night. The limited possibilities for seasonal migration to and from outlying areas beyond the park's boundaries, where alternative food sources could be found, means that traditional wild boar habitat requirements must be met within the park, especially in summer, in order to reduce a growing dependence on anthropogenic food sources in a metropolitan context where specific conflicts can arise.

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