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Habitat requirements of wild boars in the northern Apennines (N Italy): a multi-level approach

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ABSTRACT

Habitat selection by wild boars was studied in a 20 km^2 study area located in the northern Apennines (N Italy) and covered mainly by broad-leaved woods. Wild boar tracks and signs were searched for along transects (49 km) and mapped from January to December 1990. Habitat selection was analysed on three levels: i) macro-habitat, i.e. the influence of general features of habitat on the attendance of the study area, by dividing the area into 25-ha sample squares and performing multiple regression analyses of the attendance index vs the habitat variables; ii) medium-habitat, by the distribution of signs in the different habitat types (types of woods, scrubs, crops, etc.) and in comparison with the availability of habitats; iii) micro-habitat, by measuring 20 micro-habitat variables in a 5-m plot in observation and control points and by carrying out logistic regression analyses to find out the most important variables characterizing the two types of points. The results of the analyses at the three levels were consistent in showing the great importance of the woody habitats and in particular of those with a higher degree of naturality such as broad-leaved mature woods, old coppices and mixed woods that provide food and shelter for wild boars. Some seasonal differences in habitat selection were found in relation to the changes in food and shelter availability and to the particular requirements of the wild boars (reproductive and farrowing periods). Generally all the analyses showed a habitat use with feeding and antipredatory meaning.

KEY WORDS: Wild boar - *Sus scrofa* - Habitat requirements - Mountain area - Multi-level approach - N Italy.

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INTRODUCTION

In Italy, in the last century, the wild boar (*Sus scrofa* Linnaeus 1758) population decreased dramatically as a consequence of strong hunting pressure and of generalized deforestation. At the beginning of this century the species decrease across Italy continued and during the fifties the wild boar presence was reduced to a few areas of central and southern Italy, to some areas near the border with France and to Sardinia. Populations were fragmented and isolated and characterized by marked differences in genetic characteristics, mainly due to their different origin (Randi *et al.*, 1989).

From the sixties onwards, wild boars markedly increased and occupied the hilly and mountainous areas of the Italian peninsula, mainly in the west (Apollonio *et al.*, 1988). Recently the population expansion has been recorded also in several zones of the Alps and in intensively cultivated plains. This recovery of the species was also observed in other countries of southern and central Europe and it is probably related to the release of hand-reared animals for hunting and to environmental changes (Saez-Royuela & Telleria, 1986; Sjarmidi & Gerard, 1988; Cargnelutti *et al.*, 1990). At present the wild boar can be considered one of the most important game species in the entire Mediterranean region. Further points of interest are associated with its economic importance because of the damage caused to agriculture and with its role as selected prey for large carnivores and in particular for the wolf (Boitani *et al.*, 1994; Mattioli *et al.* 1995; Meriggi & Lovari, 1996; Meriggi *et al.*, 1996).

Despite the importance of wild boar in forested and agricultural ecosystems, the ecology of the species, and particularly its relationships with landscape features have been little studied. Moreover, the available studies on wild boars mainly concern the pattern of habitat occupancy, activity, home ranges, and movements (Janeau & Spitz, 1984; Baber & Coblentz, 1986; Cousse & Janeau, 1992; Cousse *et al.*, 1992; Massei *et al.*, 1997; Russo *et al.*, 1997). Habitat selection has been considered only marginally and mostly as use of general features of habitat (Boitani *et al.*, 1994). So far, no study has dealt with different levels of habitat requirements and selection, from the influence of habitat structure and composition on the attendance of a particular study area to the pattern of selection of vegetation types, and to the selection of micro-characteristics inside the different habitat. The purpose of this research was to find out and analyse the habitat characteristics best suited to the species in mountain woodlands where the wild boar recovery has been especially remarkable in the last decades. The multi-level approach is particularly important as the criteria for selection may be different at each level even if a general pattern may be found (Johnson, 1980; Manly *et al.*, 1993).

MATERIALS AND METHODS

Study area

The study area (20 km^2) was located on the northern slopes of the northern Apennines (N Italy) between 600 and 1100 m a.s.l. The climate is sub-Mediterranean of the Apennines with yearly average temperatures of 10° C (minimum, January -0.2° C; maximum, July 23.5° C) and rainfall (1070 mm/year) concentrated in May and November. Forests cover 62% of the whole area, scrub 8% and arable land 30%. Villages and human settlements are located outside the area at its boundaries. Woods are mainly coppices whereas mature woods and reafforestations covered small surfaces. The main tree species were oaks (*Quercus pubescens* and *Q. cerris*), hornbeam (*Ostrya carpinifolia*), chestnut (*Castanea sativa*), and beech (*Fagus sylvatica*). Reafforestations consist of pines (*Pinus niger* and *P. silvestris*) and larches (*Larix decidua*). One stream crosses the study area and several pools and puddles are present mainly in spring and in autumn. The growing season goes from April to early October.

The wild boar population originated in immigration from the Tyrrhenian slopes of the Apennines and in release for hunting. In January 1990 we recorded by snow tracking a density of 2.3 wild boars per km^2 in the study area, i.e. 47 individuals in the period following the hunting season and before the birth months (March to May). Population composition estimate was 14 adults (>2 years old), 25 subadults (1-2 years old), and 8 young (<1 year old). No other ungulate species were present in the study area and wild boars were harvested from October to December; this was the main cause of mortality given the absence of large predators.

Methods

The study was carried out from January 1988 to December 1990, by searching for wild boar tracks and signs along seven transects, each of 7 km, traced to follow the contour lines and randomly selected to ensure a complete coverage of the study area. All transects were surveyed once a season (winter: December to February; spring: March to May; summer: June to August; autumn: September to November). We did not use the footpaths to trace the transects to avoid the possibility that wild boar tracks followed the transect; anyway when this case occurred the entire track was considered as only one sign. In the same way we considered the rooting areas as separate signs. It was assumed that tracks and signs were equally detectable in all habitats and seasons because of their conspicuousness. Tracks and signs were mapped and classified on the basis of different activities: rooting and feeding, travelling, resting, wallowing and rubbing.

Habitat requirements were analysed at three different levels: macro-, medium- and micro-habitat. For the macro-habitat level, the analyses were aimed to define the relationships between wild boar presence and the habitat, in a multivariate way. We analysed the influence of habitat structure and composition on the attendance of different portions of the study area, by dividing the area into 25-ha squares (500-m side). In each square an attendance index (AI) was calculated as the ratio of the total number of tracks and signs found in the square to the total length of transects in the square. Moreover the values of 28 habitat variables were measured in each square from aerial photographs at 1:10,000 scale by means of a digitizer connected with an IBM personal computer (Appendix I). Then multiple regression analyses (MRA) were performed by the stepwise forward selection method with the seasonal AI as dependent variables and the habitat variables as independent ones. The question to answer was: what are the general characteristics of habitat that influence positively or negatively the attendance of wild boars in the study area?

For medium-habitat level, the analyses were aimed to define the pattern of habitat selection. We assessed the proportions of the different habitat types present in the study area (deciduous woods, conifer woods, crops, and scrubs). Woods were also distinguished on the basis of their exploitation type (coppices, old coppices, mature woods) and of the dominant species; for this classification we adopted the random point method because of the difficulty in detecting the exact boundaries of the different types of wood (Marcum & Loftsgaarden, 1980). The observed frequency and the proportion of wild boar tracks and signs in each habitat type (observed usage proportion, OUP) were then calculated and compared with those expected (expected usage proportion, EUP) on the basis of usage as availability, by means of the χ^2 test goodness-of-fit and Bonferroni's confidence interval analysis (Manly *et al.*, 1993). For each activity, the use of the different habitat types was compared to their availability by a preference index (PI - Jacobs, 1974). The question to answer was: what are the types of habitat selected by wild boars?

For the micro-habitat level we compared the sites where tracks and signs were recorded (observation points) with a number of random sites (control points), at least as many as the observation points and selected at the intersections of a grid with lines 25 m apart (Edge *et al.*, 1987; Thomas & Taylor, 1990). Comparisons were carried out by multivariate and univariate analysis of variance (MANOVA and one-way ANOVA) and logistic regression analysis (LogRA), performed on 20 habitat variables measured in 5-m radius plots on both observation and control points (Appendix II), for the whole year and for each season. MANOVA was used to test the global differences of the average values of continuous variables between observation and control points, and one-way ANOVA was used to identify the most important variables that contributed to the differences. The LogRA was chosen to produce a model of micro-habitat selection by wild boars by using also categorical variables, and by assessing the probability of occurrence of the event, i.e. a point to be an observation of wild boar signs. We adopted the stepwise forward selection procedure (maximum-likelihood method) to obtain a subset of micro-habitat variables and to estimate the equation parameters. The contribution of each variable to the model was determined by the R statistic (Norusis, 1992). The significance of coefficients was calculated by the univariate Wald statistic and the likelihood ratio test. Categorical habitat variables were coded as dummy variables and their regression coefficients represented the effect of each new category compared to the overall effect of the variable (Norusis, 1992). The effectiveness of the model was assessed in five ways: i) the log-likelihood of the model was compared to that of the model with the constant only; ii) the goodness-of-fit statistic (Z^2) was used to compare the observed probabilities with those predicted by the model; iii) the goodness-of-fit with all the variables was tested by the model χ^2 test; iv) the R statistic and the estimated odds - Esp(B) - were used to assess the effect of the single variables which entered the model; v) finally, the percentage of cases correctly classified was used to evaluate the ability of the model to describe the initial data (Norusis, 1992). The basic assumption we took to analyse selection at micro-habitat level was that, if wild boars use the micro-habitat elements indifferently, the variables characterizing sample plots should not show any differences between observation and control points. This is the null hypothezis that we tested by MANOVA, one-way ANOVA and by LogRA. Consequently, the number of significant differences detected by the analysis of variance, the degree of separation between observation and control points showed by logistic analyses and the ability of logistic models to classify the cases of the two groups correctly may be taken as measures of micro-habitat selection. The variables that entered the models should be the most important characteristics of micro-habitat for wild boar selection.

RESULTS

In the three years of research we collected a total of 628 records of tracks and signs (98 in winter, 179 in spring, 209 in summer, and 142 in autumn). Because of the lack of changes in the use of the different habitats

TABLE I - *Results of multiple regression analysis of wild boar attendance index versus habitat variables (pooled seasons).*

Habitat variables	Partial regression coefficient	SE	P
Mixed woods (%)	1.4	0.26	<0.0001
Wallowing site distance (m)	-0.0005	0.00010	<0.0001
Broad-leaved mature woods (%)	6.3	2.20	<0.0001
Wallowing site number	0.1	0.03	0.006
Farm distance (m)	-0.0002	0.00009	0.007
Coppices (%)	0.3	0.13	0.015
Road distance (m)	0.0004	0.00021	0.037
Constant = 0.45	R^2 = 0.69	df = 67	F = 17.00 · P < 0.0001

during the study period (χ^2 = 1.01, df = 10, P = 0.999), we performed the analyses on the data of the three years pooled.

Macro-habitat level

The AI ranged from 0 to 45.2 signs per km (mean = 5.1, SE = 0.90, *n* = 77). Over the whole year the MRA of AI on the habitat variables explained 69% of AI variance. Seven habitat variables entered the model with a significant partial regression coefficient (Table I). The AI increased with an increasing percentage of mixed woods, mature deciduous woods, coppices, the number of pools and the distance of the square centre from roads, while it decreased with increasing distance from the nearest pool and from inhabited areas.

The MRA relative to each season showed lower percentages of explained variance (winter: 23%; spring: 42%; summer: 59%; autumn: 45%), possibly in relation to the reduced number of habitat variables in the models. In winter and in spring, only one variable was selected: the distance from pools (B = -0.0002, SE = 0.0001, P < 0.05), in winter, and their number (B = 0.1, SE = 0.02, P < 0.001), in spring. In summer, four habitat variables were included in the model: the AI increased with increasing percentage of mixed woods (B = 0.9, SE = 0.18, P < 0.001) and number of pools (B = 0.1, SE = 0.03, P < 0.001), and decreased with increasing distance from pools (B = -0.0003, SE = 0.00007, P < 0.001) and the percentage of mature conifer woods (B = -0.6, SE = 0.24, P < 0.01). Finally, three variables significantly influenced the AI in autumn: the number of pools (B = 0.2, SE = 0.02, P < 0.01), the percentage of mature deciduous woods (B = 4.8, SE = 1.57, P < 0.01), with positive coefficients, and the distance from streams with negative ones (B = -0.0002, SE = 0.0001, P < 0.05).

Medium-habitat level

For the whole year wild boars selected mature deciduous woods, old coppices and mixed woods, while they used coppices, conifer reafforestations, and crops less than the availability. Mature conifer woods and scrubs were used as available (Table II). We recorded a significant difference between expected and observed frequencies among different types of coppices (χ^2 = 353.23, df = 3, P < 0.001): in particular, coppices dominated by chestnuts were selected (EUP = 0.056, OUP = 0.297, P < 0.01), whereas those dominated by beeches and hornbeams were used less than the availability (EUP = 0.154, OUP = 0.080, P < 0.01 and EUP = 0.552, OUP = 0.424, P < 0.01, respectively). Oak coppices were used as available (EUP = 0.238, OUP = 0.197, NS). Also among the different types of mature woods, we recorded significant differences between usage and availability (χ^2 = 136.55, df = 3, P < 0.001). Broad-leaved mature woods (mainly chestnut woods) were selected (EUP = 0.090, OUP = 0.291, P < 0.01), larch woods were used less than the availability (EUP = 0.270, OUP = 0.039, P < 0.01) and pine woods (*P. niger* and *P. silvestris*) were used as available (EUP = 0.580, OUP = 0.580, NS and EUP = 0.060, OUP = 0.088, NS, respectively).

TABLE II - *Results of Bonferroni simultaneous confidence interval analysis for the use of different habitat types by wild boars (EUP = expected usage proportion; OUP = observed usage proportion; pooled seasons* n = *628).*

Habitat types	EUP	OUP	P
Broad-leaved mature woods	0.040	0.161	<0.01
Mixed woods	0.030	0.090	<0.01
Conifer mature woods	0.037	0.064	NS
Old coppices	0.045	0.127	<0.01
Coppices	0.477	0.380	<0.01
Reafforestations	0.020	0.005	<0.01
Scrubs	0.082	0.097	NS
Crops	0.300	0.076	<0.01

The distribution of tracks and signs in different habitat types showed significant seasonal differences (χ^2 = 90.14, df = 9, P < 0.0001). Observations were collected in coppices mainly in summer, in mature woods in winter, in scrubs in autumn and in crops in winter (Fig. 1). We found significant differences between expected and observed usage proportions of the different habitat types in all seasons (P < 0.0001 in all cases). Coppices (EUP = 0.522) were selected in summer (OUP = 0.684, P < 0.01), used less than the availability in autumn and winter (OUP = 0.367 and 0.266 respectively, P < 0.01), and used as available in spring (OUP = 0.542, NS). Mature woods (EUP = 0.096) were selected in all seasons (OUP = 0.263 to 0.459, P < 0.01). Scrubs (EUP = 0.082) were used in proportion to their availability in spring and winter (OUP = 0.078 and 0.122 respectively, NS), less than the availability in summer (OUP = 0.015, P < 0.01), and selected in autumn (OUP = 0.225, P < 0.01). Crops (EUP = 0.300) were used less than the availability in all seasons (OUP = 0.038 to 0.153, P < 0.01).

Wild boars chose different habitat types for different activities: feeding and travelling signs were found particularly in mature deciduous woods (PI = 0.93 and 0.94, respectively) and old coppices (PI = 0.59 and 0.47, respectively), rubbing and wallowing were above all in mature deciduous woods (PI = 0.97) and mixed woods (PI = 0.62), while mature deciduous woods (PI = 0.98), mixed woods (PI = 0.39), and scrub (PI = 0.55) were selected for sleeping.

Micro-habitat level

MANOVA showed significant global differences between the average values of continuous micro-habitat variables of observation and control points for the whole year and in all seasons (Wilks' Lambda = 0.51 to 0.77, P < 0.01 in all cases). The variables that significantly contributed to the global differences were eight for the whole year, only three in winter, seven in spring, eight in summer, and six in autumn. The slope was significantly lower in observation than in control points only in winter (P < 0.05), whereas in the other seasons the two means were not different. Litter was always less thick in observation plots (winter: P < 0.01; spring: P < 0.05; summer and autumn: P < 0.001); the brightness at 0, 60 and 150 cm from the ground was significantly lower in observation points all the year round, with the exception of winter, with the greatest differences (P < 0.001) in spring and summer. The density of vegetation was greater in observation plots for the whole year (P < 0.001), in winter (P < 0.01), spring (P < 0.001), and summer (P < 0.001). The distance from water showed lower average values in observation points for the whole year (P < 0.001), in summer (P < 0.05), and in autumn (P < 0.001); the same pattern was observed for the distance from the wood edges (year: P < 0.001; spring, summer, and autumn: P < 0.01), and, finally, the clearing distance was greater in observation points in spring (P < 0.05), summer (P < 0.05), and over the whole year (P < 0.01).

Logistic regression analysis performed on pooled data of the whole years (n = 554) correctly classified 76.3% of total cases (85.1% of control and 64.7% of observation points). Eight variables entered the model, of which brightness 0 (B = -0.02, SE = 0.004, P < 0.0001, R = -0.189), litter (B = -0.52, SE = 0.01, P < 0.0001, R = -0.183), and wood distance (B = -0.01, SE = 0.002, P < 0.0001, R = -0.172) made the greatest contribution. The probability of the event occurring (a point to be an observation) increased as brightness at soil level, litter thickness, and distance from woods decreased. In winter, the model derived from LogRA correctly classified 79.0% of total cases (90.1% of control and 55.9% of observation). Three variables entered the model: the probability of observation occurrence increased as the age of woods and the density of vegetation increased, and it decreased with the increase of litter thickness (Table III). In spring, 91.5% of control points and 86.1% of observation ones were correctly classified by four variables which entered the model: the presence of young woods, the decrease of brightness at 150 cm from the soil level, and the presence of clayey soils increased the probability of a point being an observation of wild boar signs, whilst the distance from clearings did not seem to be relevant (Table IV). The LogRA carried out on summer data showed an overall correct classification of 78.4% (82.3% of control points and 74.3% of observations). Five variables were selected by stepwise forward procedure; among these grass height (<20 cm) increased the probability of wild boar sign occurrence, whilst litter thickness and brightness entered with negative regression coefficients (Table V). Finally the logistic model for autumn correctly classified 76.9% of total cases (83.5% of control points and 66.7% of observations). Of the three variables that entered the model litter thickness and the distance from wood boundaries showed a negative effect, and slimy soils strongly increased the probability of a point being an observation of wild boar signs (Table VI).

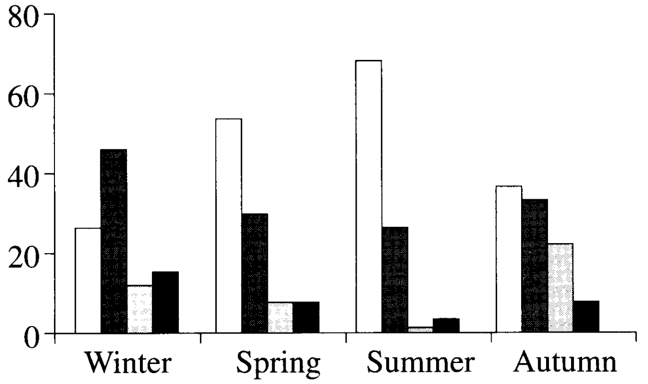

Fig. 1 - Seasonal changes of percentage frequency of occurrence of wild boar signs in the different habitats (□, coppices; ■, mature woods; ▩, scrubs; ■, crops).

TABLE III - *Results of logistic regression analysis for micro-habitat selection by wild boars in winter (observations:* n = *34; controls:* n = *71).*

Variables[a]	B (SE)	P	R[b]	Esp. (B)[b]
Wood age	-	0.0305	0.148	-
Wood age 1	-1.38 (0.60)	0.0219	-0.157	0.25
Wood age 2	-0.72 (0.54)	0.1837	0.000	0.49
Wood age 3	0.65 (0.39)	0.0986	0.074	1.92
Litter	-0.76 (0.23)	0.0010	-0.260	0.47
Veg. Density	0.03 (0.02)	0.0520	0.116	1.03
Constant	-0.64 (0.62)	-	-	-
	Model evaluation	χ^2	df	P
	-2 Log likelihood[b]	100.86	-	-
	Goodness of fit[b]	100.09	-	-
	Model $\chi^{2(b)}$	31.38	5	<0.0001
	Improvement[b]	9.91	3	0.0194

[a], legend in Appendix II; [b], explanations in the text.

TABLE IV - *Results of logistic regression analysis for micro-habitat selection by wild boars in spring (observations:* n = *79; controls:* n = *87).*

Variables[a]	B (SE)	P	R[b]	Esp. (B)[b]
Wood age	-	0.0013	0.206	-
Wood age 1	1.09 (0.64)	0.0903	0.061	2.98
Wood age 2	-2.06 (0.59)	0.0005	-0.209	0.13
Wood age 3	-0.87 (0.47)	0.0619	-0.080	0.42
Brightness 150	-0.18 (0.03)	0.0001	-0.383	0.84
Soil type	-	0.0001	0.247	-
Soil type 1	-1.76 (0.49)	0.0003	-0.218	0.17
Soil type 2	1.37 (0.46)	0.0026	0.175	3.95
Clearing distance	0.003 (0.001)	0.0302	0.108	1.00
Constant	15.70 (2.75)	-	-	-
	Model evaluation	χ^2	df	P
	-2 Log likelihood[b]	88.09	-	-
	Goodness of fit[b]	128.03	-	-
	Model $\chi^{2(b)}$	141.65	5	<0.0001
	Improvement[b]	4.66	3	0.0194

[a], legend in Appendix II; [b], explanations in the text.

DISCUSSION

For the whole year, it seems that attendance in the different portions (sample squares) of the study area depends mainly on the availability of suitable habitat for feeding and sheltering (mixed woods, broad-leaved mature woods, coppices), on the proximity of water sites for wallowing and cleaning (Braza & Alvarez, 1989), and on the quietness of the zone, particularly with regard to access roads that can bring tourists, hunters, and mushroom pickers. Farms proved attractive for wild boars, possibly because of the presence of some types of cultivation, such as small cereals, vineyards, and orchards that are used in some periods of the year. Streams and pools were elements of habitat with a positive effect on attendance in all seasons; moreover, in summer, mixed and conifer woods gained importance as did broad-leaved mature woods in autumn.

At the medium-habitat level, wild boars showed a clear positive selection for forestry habitat all the year round. Woods are actually the most suitable habitat to find food and shelter both from man and from preda-

TABLE V - *Results of Logistic Regression Analysis for micro-habitat selection by wild boars in summer (observations:* n = 74*; controls:* n = 79*).*

Variables[(a)]	B (SE)	P	R[(b)]	Esp. (B)[(b)]
Grass height	-	0.0356	0.110	-
Grass height 1	1.19 (0.46)	0.0093	0.150	3.30
Grass height 2	-0.61 (0.66)	0.3546	0.000	0.54
Grass height 3	0.06 (0.37)	0.8795	0.000	1.06
Litter	-1.06 (0.28)	0.0002	-0.236	0.35
Brightness 0	-0.02 (0.01)	0.0016	-0.193	0.98
Veg. density	-0.02 (0.01)	0.0309	-0.112	0.98
Wood distance	-0.01 (0.004)	0.0412	-0.101	0.99
Constant	2.46 (0.50)	-	-	-
	Model evaluation	χ^2	df	P
	-2 Log likelihood[(b)]	138.98	-	-
	Goodness of fit[(b)]	153.65	-	-
	Model $\chi^{2(b)}$	72.96	7	<0.0001
	Improvement[(b)]	9.65	3	0.0217

[(a)], legend in Appendix II; [(b)], explanations in the text.

TABLE VI - *Results of logistic regression analysis for micro-habitat selection by wild boars in autumn (observations:* n = 51*; controls:* n = 79*).*

Variables[(a)]	B (SE)	P	R[(b)]	Esp. (B)[(b)]
Litter	-0.56 (0.16)	0.0005	-0.240	0.57
Soil state	-	0.0262	0.136	-
Soil state 1	-0.96 (0.45)	0.0338	-0.120	0.38
Soil state 2	-0.23 (0.42)	0.5767	0.000	0.79
Soil state 3	2.25 (0.84)	0.0073	0.173	9.45
Wood distance	-0,01 (0.005)	0.0056	-0.180	0.99
Constant	0.89 (0.41)	-		
	Model evaluation	χ^2	df	P
	-2 Log likelihood[(b)]	126.56	-	-
	Goodness of fit[(b)]	136.69	-	-
	Model $\chi^{2(b)}$	47.58	5	<0.0001
	Improvement[(b)]	14.52	1	0.0001

[(a)], legend in Appendix II; [(b)], explanations in the text.

tors to which the species is quite vulnerable because of its gregariousness and easy detectability (Endler, 1991; Huggard, 1993; Meriggi *et al.*, 1996). Among the different types of woods, broad-leaved mature ones (mainly chestnut and beech) were selected because of their greater fruit production, and so were old coppices because of their more complex vegetation structure that provides better shelter and higher food availability than young coppices. The seasonal changes in habitat selection that we recorded in our study area are probably related to the vegetation growth and to the requirements of wild boars. The two types of coppices pooled together were selected in summer because they offer a markedly greater cover than mature woods, for which the minimum value of usage proportion was recorded in this season. Scrubs were used mainly in autumn when they offer the maximum availability of fruits of different species. Crops were significantly used less than their availability in all seasons, but their usage increased in winter: in this season, wild boars mostly eat windfalls (apples and pears) scattered in the fields and abandoned by humans as a food resource (pers. obs.). Surprisingly, the usage of crops was very low in summer. In fact, in our study area damage was done several times in summer in cereal fields, but the incidents were usually concentrated in a few days when the wheat was ripening, and mainly in the fields near the wood edges (Dardaillon, 1986; Vassant & Breton, 1986; Gerard *et al.,* 1991; Meriggi & Sacchi, 1992).

With regard to the composition of different types of wood, it appears evident that wild boars mainly select on the basis of food availability. In fact, among coppices, those with dominant chestnuts were selected and those with oaks were used as available, while beech and hornbeam coppices were used less than the availability. Among mature woods those with broad-leaved species were selected (mainly old chestnut woods for fruit production), whereas the different species of conifers were used less than or as available. We observed an increased use of conifer woods in summer when the ground is dry and hard because of drought and when rooting is difficult in other woods. On the other hand, below the conifers the ground is soft because of the thick layer of needles and wild boars can easily search for larvae and other food (Massei & Genov, 1995).

A few changes in habitat selection in relation to the different activities were recorded in our study area. In particular, the types of woods characterized by high food availability, such as broad-leaved mature woods, old coppices, and mixed woods, were selected for feeding. The same habitats were selected also for resting. This result is consistent with the findings of other studies carried out by radio tracking, that evidenced a strong association between feeding and resting sites and between wild boar activity and food availability of habitats (Boitani *et al.,* 1994).

The results of the analyses of variance and LogRA showed a moderate selection of micro-habitat by wild boars over the whole year. As for the macro-habitat selection was higher in spring and summer and lower in autumn and winter. Spring and summer are critical seasons for wild boars in southern Europe because most births are concentrated in this period (Heck & Raschke, 1980; Mauget *et al.,* 1984) and because of food shortage in the woods.

The lower selection of micro-habitat in winter may be due to a greater generalized usage of the study area as a consequence of the reproductive behaviour of wild boars and, in particular, of the increase and spacing of male home ranges to overlap those of several females (Kurz & Marchinton, 1972; Singer *et al.,* 1981; Boitani *et al.,* 1994). The decrease in micro-habitat selection in autumn is probably a consequence of hunting disturbance, scattering and forcing the animals into sub-optimal and unfavourable habitats.

Both multivariate and univariate analyses of variance and logistic regression models showed that the wild boar presence was related mainly to the woods and to the areas close to wood boundaries, while open areas and large clearings were avoided. Moreover, the univariate analyses showed that, in winter, wild boars searched for sites with gentler slopes and less dense vegetation; in summer and in autumn high canopy and understory cover, together with the proximity to pools, characterized their choices. These results are substantially in accordance with those of the macro- and medium- level habitat analyses, and in particular with the high usage of more stratified and dense woods for sheltering and feeding. Water for wallowing and fresh and damp sites are of great importance particularly in summer and in early autumn when temperatures are high and rainfall rare, with a consequent drying-up of streams and springs (Braza & Alvarez, 1989).

Logistic regression analyses evidenced the role of other variables in micro-habitat selection by wild boars. Wood age was important in winter and spring: in winter mature woods offer greater food availability, thus increasing the probability of wild boar presence; in spring, young woods meet wild boar requirements of dense cover for farrowing and piglet protection. Density of vegetation and canopy and understory cover were also important micro-habitat variables, especially in winter when it is difficult for wild boars to find vegetation useful for sheltering and in spring and in summer for the reproductive needs of the species. In summer, grass height increased the probability of a point being an observation of wild boar signs; this is probably due to the requirements of lactating females and to the use of herbaceous vegetation as an alternative food when chestnuts and acorns are no longer available (Howe *et al.,* 1981; Janeau & Spitz, 1984).

Our habitat selection analyses gave results which are substantially in accordance at the three different levels considered in this study, demonstrating the validity of a multi-level approach to outline habitat requirements of a highly prized game species like the wild boar, which is at the same time an economically important pest. Each level of analysis gives support to the preceding one as well as useful new information to explain some previous results.

The evidenced pattern of habitat selection showed the great importance of forest habitat all the year round and of water presence to make a habitat suitable for wild boars. From our results, a high-quality habitat for wild boars should be characterized by a patchy distribution of broad-leaved mature woods for feeding and old coppices and mixed woods for sheltering. Clearings and scrubs can be of importance for feeding and farrowing in some seasons.

Most of the researches carried out so far on wild boar ecology in Europe concern small numbers of radio-tagged individuals caught during several years or tracked for a few months, so that there is a strong influence of individual differences and of seasonality on the pattern of habitat selection. On the contrary, our results may be considered representative of the whole population or at least of a part of it living in the study area. For this reason, this study can be more useful to explain the present trend of wild boar population in southern Europe and for management purposes.

The general trend of wooded areas in northern Italy along the Apennines is nowadays characterized by the abandonment of wood exploitation with an increase in the naturality of forests and surrounding areas. These changes will make the habitat more and more suitable for wild boars, which are presently expanding their range at lower altitudes with an increasing risk of crop damage. The models (MRA and LogRA) employed in this study can be useful for predicting the future presence of wild boars, assessing the quality of habitat for the species, and suggesting management actions aimed both at improving the carrying capacity and at avoiding damage to agriculture.

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APPENDIX I - *Habitat variables measured in sample squares (25 ha) used for the analyses on the macro-habitat level.*

1 BROAD LEAVED MATURE WOODS (%)
2 CONIFER MATURE WOODS (%)
3 COPPICES (%)
4 OLD COPPICES (%)
5 MIXED WOODS (%)
6 WOOD DISTANCE (the distance in m of the square centre from the nearest wood boundary)
7 SCRUBS (%)
8 CROPS (%)
9 WALLOWING SITES (number)
10 WALLOWING SITE DISTANCE (the distance in m of the square centre from the nearest wallowing site)
11 STREAM LENGTH (length of streams crossing the square in km)
12 STREAM DISTANCE (the distance in m of the square centre from the nearest stream)
13 CLEARING DISTANCE (the distance in m of the square centre from the nearest clearing)
14 FARM NUMBER
15 FARM DISTANCE (the distance in m of the square centre from the nearest farm)
16 ROAD LENGTH (the length of roads crossing the square in km)
17 ROAD DISTANCE (the distance in m of the square centre from the nearest road)
18 AVERAGE ALTITUDE (m a.s.l.)
19 CROP DISTANCE (the distance in m of the square centre from the nearest field)
20 AVERAGE SLOPE (in degrees)
21 N EXPOSURE (the percentage of the square exposed to the North)
22 NE EXPOSURE (%)
23 E EXPOSURE (%)
24 SE EXPOSURE (%)
25 S EXPOSURE (%)
26 SW EXPOSURE (%)
27 W EXPOSURE (%)
28 NW EXPOSURE (%)

APPENDIX II - *Micro-habitat variables measured in a 5-m-radius plot on observation and control points.*

1 ALTITUDE (m a.s.l.)
2 EXPOSURE (1 = North West, North, North-East; 2 = East; 3 = South-East, South, South West; 4 = West)
3 SLOPE (slope of the plot in degrees)
4 TREE HEIGHT (height of tree layer: 0 = no trees; 1 = less than 5 m; 2 = 5-10 m; 3 = more than 10 m)
5 BUSH HEIGHT (height of bush layer: 0 = no bushes; 1 = less than 50 cm; 2 = 50-100 cm; 3 = more than 100 cm)
6 GRASS HEIGHT (height of herbaceous layer: 0 = no grasses and forbs; 1 = less than 20 cm; 2 = 20-40 cm; 3 = more than 40 cm)
7 EXPLOITATION TYPE (0 = no wood; 1 = long-trunked wood; 2 = coppice; 3 = old coppice)
8 WOOD STRUCTURE (0 = no wood; 1 = coeval; 2 = uncoeval)
9 WOOD AGE (0 = no wood; 1 = young; 2 = mature; 3 = old)
10 LITTER (litter thickness in cm)
11 BRIGHTNESS 0 (brightness at 0 cm from the ground as a ratio of the Lux measured on the point over the Lux measured in open space; a measure of the cover of canopy, understory and herbaceous cumulated layers)
12 BRIGHTNESS 60 (brightness at 60 cm from the ground; a measure of canopy and understory cover)
13 BRIGHTNESS 150 (brightness at 150 cm from the ground; a measure of canopy cover)
14 VEGETATION DENSITY (density of the vegetation, measured as average percentage of a 2-m graduated pole visible at a distance of 5 m from the four cardinal points; a measure of the horizontal transparency of the vegetation)
15 SOIL TYPE (type of soil: 1 = muddy; 2 = clayey; 3 = stony; 4 = gravelly)
16 SOIL STATE (condition of the soil: 1 = dry; 2 = moist; 3 = slimy; 4 = icy; 5 = snow-covered)
17 WATER PRESENCE (0 = no water; 1 = stream; 2 = pool)
18 WATER DISTANCE (distance of the point from the nearest water in m)
19 WOOD DISTANCE (distance of the point from the nearest wood boundary in m)
20 CLEARING DISTANCE (distance of the point from the nearest clearing boundary in m)