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Habitat requirements of the Alpine marmot *Marmota marmota* in re-introduction areas of the Eastern Italian Alps. Formulation and validation of habitat suitability models

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I analyzed the habitat selection of two Alpine marmots *Marmota marmota* (Linnaeus, 1758) populations (A and B) re-introduced in the Friulian Dolomites Natural Park (Eastern Italian Alps) in 1977 and 1983 respectively. Population A showed a higher density of family units than the more recently introduced and still increasing population B. I mapped winter burrows and I conferred proportions of usage of habitat types with their availability by the Jacobs index. Population B positively selected fewer types of habitat than population A, and particularly selected those habitat types more strongly selected by A. Through stepwise discriminant function analysis and oneway ANOVA, I analyzed the characteristics of the winter burrow surroundings, by splitting up the two study areas into sample squares covering 1 ha each. The importance of the alpine meadows and pastures was subordinate to the presence of rocks, especially in the pastures. Comparing the results obtained separately for the two populations, the more recent and less dense population showed a more restrictive habitat and slope selection, in accordance with the ideal free distribution theory. In order to validate the habitat suitability model obtained by discriminant analysis I applied it to two other populations of Alpine marmots present in FDNP and in the Julian Prealps Natural Park.

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Introduction

The Alpine marmot *Marmota marmota* (Linnaeus, 1758) is a social and territorial species (Perrin *et al.* 1993a, b, Armitage 1999, Allainé 2000) living in family units composed of a resident pair, subordinate adults, yearlings and juveniles of the year. All the individuals in a family groups hibernate together in the same winter burrow or *hibernaculum* (Arnold 1990, Perrin *et al.* 1993b, Allainé 2000, Lenti Boero 2001). The number of winter burrows therefore reflects the number of family units. Together with adequate nutritious food (Massemin *et al.* 1996, Blumstein and Foggin 1997), hibernacula are a limiting factor to the expansion of marmot population (Arnold *et al.* 1991, Armitage 2000, Lenti Boero 2001).

In spite of the copiousness of studies on the Alpine marmot, studies of the way the species selects its habitat are lacking (Allainé *et al.* 1994). The results of these studies are often contradictory because simple data regarding habitat use are explained as habitat selection, without any analysis of utilisation-availability data (Ferri *et al*. 1988, Grimod *et al.* 1991, Bassano *et al.* 1992, Macchi *et al.* 1992, Sala *et al.* 1992). Moreover, the habitat preferences of Alpine marmots have been investigated by examining the influence of single variables. As emphasized by Allainé *et al.* (1994), a single factor is probably not the only determinant of Alpine marmot habitat preferences: as for all other animal species, it is necessary to analyze the simultaneous effects of several habitat factors.

At present the Alpine marmot occupies the entire Italian Alpine chain, from the Ligurian to the Julian Alps, and some areas of the Northern Apennines. The species is autochthonous in the entire Alpine chain and allochthonous in the Apennines (Cagnolaro and Spagnesi 1981). In Friuli-Venezia Giulia (the most eastern of the northern Italian regions) the species was extirpated in prehistory (Toschi 1954, 1965), but many finds document the presence of marmots in the Holocene fauna in Friuli-Venezia Giulia (Dal Piaz 1929, Toschi 1954, Bressan 1988, Tonon 1989). In some areas of the Eastern Alps (Cadore and Alto Adige-Südtirol) the Alpine marmot was not extirpated, and original and autochthonous populations exist. These data suggest that the translocation of Alpine marmot in the Italian Eastern Alps is a re-introduction, while it is an introduction in the Apennines (Cagnolaro and Spagnesi 1981, Bon *et al.* 1995, Amori and Lapini 1997). The National Institute for Wildlife Biology accepts this view and authorizes and encourages the re-introduction of Alpine marmot in suitable areas in the Eastern Alps.

The re-introduction of the Alpine marmot in Friuli-Venezia Giulia started in 1960. Marmots have been released in many isolated areas since then, but introduction was only successful in a few of them. The principal cause of failure seems to have been the unsuitability of the areas. The Eastern Italian Alps are disadvantaged by a major lack of studies on the habitat requirements of the Alpine marmot even though they are particularly necessary because of the extinction and re-introduction of the species in this area. Therefore I studied two populations re-introduced at different times in the Friulian Dolomites Natural Park, in order to better understand the habitat requirements of the species in the Eastern Italian Alps. The aim of the study was to elaborate a predictive model of habitat suitability, which could provide a useful instrument for species management in order to improve the success of re-introduction by objectively weighing the feasibility of new re-introductions, and of the expansion of re-introduced populations.

The ideal free distribution theory (Fretwell and Lukas 1970, Fretwell 1972) suggests that habitat selection may be modified as the population density increases. According to this theory, a species colonizing a new area occupies and selects firstly the optimal habitats, and then the suboptimal habitats. In fact, as population density grows, the suitability of the optimal habitats drops because of the competition for settlement in them. Thus settling in habitats initially avoided can become more attractive. In this way, habitats avoided at first and considered as suboptimal may be selected and required at a later time. By studying the habitat selection in populations re-introduced at different times and at different growth levels, I can verify if it was possible to identify optimal and suboptimal habitat types according to the ideal free distribution theory.

Aspect, altitude and slope are the habitat factors most frequently examined by authors in order to explain the occurrence of marmots, although the importance (mostly trophic) of the vegetation characteristics of the home range has been suggested elsewhere (Carey 1985, Allainé *et al.* 1994, Massemin *et al.* 1996, Blumstein and Foggin 1997). I considered the selection by Alpine marmot populations of the different vegetation types in winter burrow (*hibernacula*) digging and their influence on the probability of settlement by marmot families.

Study area

I conducted this study from 1999 to 2002 in the Friulian Dolomites Natural Park (FDNP, centre in 46°17'00''N, 12°29'00''E). The FDNP is located in the Eastern Italian Prealps. Altitude ranges from 500 to 2600 m, and precipitation averages 1400 mm/year and is concentrated in spring and autumn. Average yearly temperature (at 682 m a.s.l.) is 9.3°C (January –1.9°C and July 19.9°C). Woods cover 56.7% of the Park, rocky areas 10.2%, and grasslands only 7.4%. The grasslands are characterized by their small size (0.5–3 km^2) and high isolation, showing a patchy distribution among the woods and scrubs.

I surveyed the two largest marmot populations in the FDNP. The oldest population (A) originated from a re-introduction in 1977 and, at the time of this study, showed increased population density while the number of family units appeared to be stable. The population B was re-introduced in 1983. The area occupied by it was still expanding and its population density increasing. Slopes in study area A ranged between 10 and 125% (average: 59.7%), and between 20 and 100% (average: 52.5%) in study area B. Aspects of the two areas were similar, ranging between southern and eastern. In area A (151 ha in area; altitude range: 1750–2228 m), grasslands covered 50.9%, deciduous scrubs (*Alnus viridis, Salix* spp.) 11.1%, evergreen scrubs (*Pinus mugo*) 17.6% and rocky areas 12.5%. In area B (164 ha; altitude range: 1560–2295 m) grasslands covered 65.1%, deciduous scrubs 4.8%, evergreen scrubs 12.9% and rocky areas 8.6%. Both areas have remained ungrazed by domestic livestock for the last forty years, but both were previously grazed by cows in summertime. Therefore the secondary pastures were abandoned pastures, with tall grass during summertime. In fact, in the absence of livestock grazing the vegetation height in the primary meadowland in the study area generally does not exceed 40 cm, whereas in abandoned secondary pastures it can reach 80–100 cm.

I also mapped the vegetation cover in two other areas (C and D), in which I validated the habitat suitability model formulated for population A. In area C (423 ha; altitude range: 1800–2440 m), grasslands covered 32.5%, deciduous scrubs 1.3%, evergreen scrubs 15.2% and rocky areas 35.8%. In area D (1005 ha; altitude range: 1430–2587 m), grasslands covered 13.2%, deciduous scrubs 2.0%, evergreen scrubs 4.8% and rocky areas 66.4%.

Material and methods

I mapped the vegetation cover of the two areas (1:5000 scale) through direct surveying. Twenty habitat types were detected (Appendix 1). I divided the grasslands into alpine (primary) meadowland (*Seslerio-Caricetum sempervirentis*) and secondary abandoned pastures (*Molinio-Arrhenatheretea,* *Festucetum calvae, Poion alpinae, Rumicion alpini*), according to their origin, natural or anthropic (because of wood or sub alpine bushy belt cutting). By a rough visual estimate I separated both grassland types on the basis of the presence and abundance of large stones (0.50 m or more in diameter), in three categories: without stones, with stones covering less than 30% of the surface area, and with stones covering more than 30%.

From 1999 to 2002, winter burrows were located in early May, when the marmots emerged from hibernation and the soil was still snow-covered (Durio *et al.* 1987, Lenti Boero 2001) and recorded on a 1:5000 scale map. I located winter burrows by observing marmots digging out and tracks in snow showing their departure from burrows. In accordance with Arnold (1990), Perrin *et al.* (1993b) and Allainé (2000) I considered each winter burrow as occupied by one family unit.

The density of family units in the two populations A and B was calculated in 1999 and 2002 using the nearest neighbor distance (NND) method (Newton *et al.* 1977) applied to the winter burrows. Following this method, I calculated the average distance between nearest neighbor winter burrows, and then I drawn around each winter burrow a circular plot with diameter equal to this distance (NND); finally I drawn a minimum convex polygon on the most external plots.

I analyzed habitat requirements at two different levels: the first to define the pattern of habitat selection, the second to analyze the relationship between the winter burrows occurrence and the habitat characteristics. Habitat selection was analyzed using the Jacobs index (Jacobs 1974), considering the principal openings of the winter burrows located in 1999. This method compares use and availability of each feature and supplies an index that varies between –1 and +1 and assumes positive values if the habitat type is selected, negative values if it is avoided. The analyses were carried out on the combined populations and on each population separately.

I analyzed the relationship between the winter burrows occurrence and the habitat characteristics, by dividing the areas A and B into 1-hectare squares (100 m side). In each 1-hectare square (area A: n = 150; area B: n = 168) I determined the presence or absence of the winter burrows in 1999, and I measured the percentage of area covered by each habitat type by means of a graphic tablet. I selected this square size because it approached the nearest neighbor distance recorded among the winter burrows in the two populations. One-Way ANOVA and stepwise discriminant function analysis (DFA) (Magnusson 1983, Massolo and Meriggi 1995) were performed to evaluate the differences between squares with and without winter burrows, and to identify to what extent each habitat variable contributed to the differentiation of the two types of squares. I performed ANOVA and DFA on the A and B areas separately, in order to analyze the differences in habitat requirements between populations with different age and density characteristics. I applied the habitat suitability model formulated by DFA in the older and denser population A on each area, A and B, to predict the suitability of each 1-hectare square for the presence of winter burrows. Considering the ratio between the number of squares with winter burrows in 1999 and the number of squares classified as suitable by the model, I compared the habitat saturation by each population. My purpose in this analysis was to investigate the influence of habitat suitability and of the time elapsed since re-introduction on population density. The saturation ratio does not represent the absolute saturation of the A and B areas by populations, but was only an index of the relative degree: the more saturated area would have a greater ratio of occupied squares to total suitable habitat.

The applicatory purpose of the habitat suitability model formulated for the older population (A) was the creation of a tool for evaluate the suitability of potential areas for future re-introductions. I validated the model on populations C and D. Therefore the C and D study areas were subdivided in 1-hectare squares (C: n = 472, D: n = 1005) in which the percentage of each habitat type was measured as described for study areas A and B. Populations C and D, established in 1995 and 1997 respectively, were very recent and still increasing at the time of the study. In fact, population C was composed of 11 family groups in 1999, 13 in 2001 and 16 in 2002 (A. Borgo, unpubl.). This rapid increase was also the result of re-stocking in 2001. Population D was composed of 11 family groups in 2000 and 2001 and 12 in 2002 (A. Borgo, unpubl.). The model validation was performed by comparing the distribution of the suitable areas proposed by the model in areas C and D and the winter burrow distribution surveyed in 2001.

Results

Habitat selection

In 1999, the older population A contained 23 family units, with a density of 28.4 family units per km^2, and a nearest neighbor distance of 107 m. In the same year, population B contained 13 family units, with a density of 13.8 family units per km^2, and a nearest neighbor distance of 117 m. In 2002 the number of family units in population A was unchanged, whereas in population B 18 family units were located, also as a consequence of re-stocking (12 animals delivered) in 2001. Therefore, I can affirm that in 1999 area A was saturated whereas area B was sub-saturated.

In both study areas, A and B, marmots occupied a larger area during the summer than in winter, colonizing all the slopes as far as the crest (from 1700 to 2300 m a.s.l.). The presence of the winter burrows was limited to a lower part of the slopes (1700–2000).

Both populations strongly preferred the alpine meadows and the secondary pastures with more than 30% of the surface covered by stones, but they differed in the use of some other habitat types. The alpine meadows without stones and the secondary abandoned pastures with less than 30% of surface area covered by stones

Table 1. Availability (% area covered) of the different habitats and selection (Jacobs index) by Alpine marmots in two surveyed populations A and B.

Habitat types	Availability (%)		Jacobs index	
	A	B	A	B
Secondary abandoned pastures without stones	11.7	8.2	–1	–1
Secondary abandoned pastures with stones < 30%	1.8	1.7	0.69	–1
Secondary abandoned pastures with stones > 30%	3.2	0.6	0.74	0.92
Raspberry	0.5	0.4	–1	–1
Primary alpine meadow without stones	14.1	6.6	0.06	–1
Primary alpine meadow with stones < 30%	7.8	20.2	0.46	0.07
Primary alpine meadow with stones > 30%	3.5	15.7	0.64	0.55
Discontinuous alpine meadow	0	0.9	–	–1
Primary alpine meadow with stones < 30% with *Rhododendron*	0	8.9	–	–1
Primary alpine meadow with stones > 30% with *Rhododendron*	0	3.4	–	–1
Closed evergreen scrub	21.7	8.4	–1	–1
Open evergreen scrub	0.5	4.5	–1	–1
Closed deciduous scrub	8.7	1.4	–1	–1
Open deciduous scrub	5.8	3.4	0.46	–1
Rocky areas	6.7	8.6	–1	–1
Scree and landslips	0.4	1.1	–1	–1
Woodland	7.4	4.8	–1	–1
Secondary abandoned pastures with Larch	6.0	1.2	–1	–1

were avoided by population B and were used by the older population A in proportion to their availability. Similarly, the deciduous open scrub was selected by population A but avoided by population B (Table 1). The denser population (A) used a wider range of slopes (from 21–30% to 71–80%) selecting classes between 21–30% and 51–60%, and avoiding greater or lesser slopes. Population B, on the other hand, used a more limited range of slopes (from 21–30% to 51–60%), selecting only the 21–30% and 31–40% classes, and avoiding greater or lesser slopes (Fig. 1).

Factors affecting winter burrows occurrence

The discriminant function analysis formulated on population A correctly classified 87.6% of the sample squares: 87.0% of the squares (n = 23) with winter burrows, and 87.7% of those (n = 127) without any. The variables discriminating the two types of sample squares were the percentage of alpine meadow with and without stones, the percentage of secondary abandoned pastures with stones, and the percentage of open deciduous scrub. In particular, meadowland and pastures were of greater importance when the coverage of stones exceeded 30% of the surface of the habitat patch (Table 2). The one-way ANOVA showed that all the habitat types selected in the discriminant function were significantly more abundant in the squares with winter burrows than in squares without winter burrows (Table 3). These squares were also characterized by a lower percentage of rocky areas and of closed evergreen scrub (mountain pine *Pinus mugo*). The average slope differences between squares with and without winter burrows were not significant (Table 3).

In the younger population B, the most important variables discriminating the squares with and without winter burrows were the percentage of alpine meadows with stones, and the percentage of secondary abandoned pastures with stones

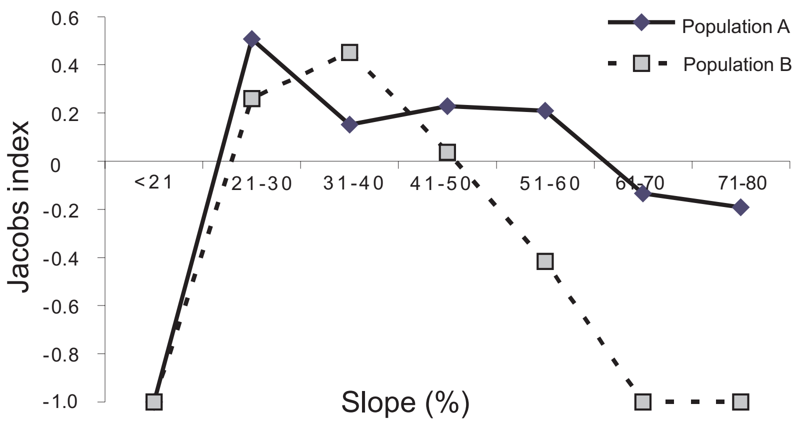

Fig. 1. Comparison of the slope selection (Jacobs index) in the two A and B populations of Alpine marmots.

Table 2. Results of the discriminant function analysis (DFA) comparing squares with (n = 23) and without (n = 127) winter burrows of Alpine marmot in study area A.

Habitat variables	Standardized coefficients	Coefficients of correlation with DF
% primary alpine meadow with stones > 30	0.688	0.471
% secondary abandoned pastures with rocks > 30	0.707	0.421
% primary alpine meadow with rocks < 30	0.570	0.356
% open deciduous scrubs	0.457	0.242
% primary alpine meadow without rocks	0.351	0.040
% secondary abandoned pastures with rocks < 30	0.338	0.154
Eigenvalue = 0.646 Canonical Correlation = 0.626	χ^2 = 69.762	p < 0.0001

Table 3. Average values (SE) of percent cover of habitat variables in squares (1 ha area) with and without winter burrows in study area A and significance of the differences (one-way ANOVA).

Habitat variables	Absence (n = 127)	Presence (n = 23)	F	p
% slope	69.3 (2.4)	58.4 (3.9)	3.55	0.062
% rocky areas	14.2 (1.9)	3.2 (1.4)	5.82	0.017
% closed evergreen scrubs	25.9 (4.3)	0.1 (0.1)	7.16	0.009
% open deciduous scrubs	4.3 (1.2)	13.3 (6.5)	5.15	0.025
% secondary abandoned pastures with rocks > 30%	1.3 (0.6)	12.7 (5.8)	16.13	< 0.0001
% secondary abandoned pastures with rocks < 30%	1.4 (0.6)	3.9 (2.7)	2.05	0.155
% primary alpine meadow with rocks > 30%	2.0 (1.1)	11.1 (4.5)	8.20	0.005
% primary alpine meadow with rocks < 30%	5.8 (1.9)	18.1 (5.2)	6.37	0.013
% primary alpine meadow without rocks	12.7 (2.7)	21.6 (7.0)	1.63	0.205

covering more than 30% of the surface of the habitat patch (Table 4). The discriminant function correctly classified 79.3% of the sample squares: 64.3% of the squares with winter burrows (n = 14) and 80.7% of those without (n = 154). The squares with winter burrows were also characterized by significantly lower (42.7%) average slopes than the squares without winter burrows (53.4%; Table 5).

Habitat saturation

The habitat suitability model formulated on population A identified 37 suitable sample squares in study area A and 73 in area B. The saturation ratio (used squares/suitable squares) in May 1999 was 0.62 in population A, and 0.19 in population B. In May 2002 the saturation ratio in population A was the same as in 1999 (0.62), whereas in population B was 0.28.

Table 4. Results of the discriminant function analysis (DFA) applied to squares with (n = 14) and without (n = 154) winter burrows of Alpine marmot in study area B.

Habitat variables	Standardized coefficients	Coefficients of correlation with DF
% secondary abandoned pastures with rocks > 30%	0.845	0.670
% primary alpine meadow with rocks > 30%	0.646	0.456
% primary alpine meadow with rocks < 30%	0.479	0.291

Eigenvalue = 0.265 Canonical Correlation = 0.457 $\chi^2 = 37.680$ $p < 0.0001$

Table 5. Average values (SE) of percent slope and cover of habitat variables in squares (1 ha wide) with and without winter burrows in study area B and significance of the differences (one-way ANOVA).

Habitat variables	Absence (n = 154)	Presence (n = 14)	F	p
% slope	53.4 (1.5)	42.7 (2.7)	4.34	0.039
% secondary abandoned pastures with rocks > 30%	0.1 (0.1)	5.7 (4.2)	19.24	< 0.0001
% primary alpine meadow with rocks < 30%	15.8 (2.1)	38.5 (9.6)	8.89	0.003
% primary alpine meadow with rocks > 30%	18.9 (2.3)	34.5 (9.5)	3.64	0.058

Validation of the habitat suitability model

The habitat suitability model formulated on population A identified 59 suitable sample squares in area C and 80 in area D. The present populations give a saturation ratio of 0.22 for area C and of 0.16 for area D, confirming that both areas were not saturated by the present populations. Some sample squares predicted as suitable by the model may be areas of potential expansion for increasing populations. The animals (10) delivered in 2001 in area C to re-stock the population and to accelerate its expansion settled and dug winter burrows in three sample squares which were all classified as suitable by the model. At the same time, the family units that settled in area B after 1999 dug winter burrows in 5 sample squares classified as suitable by the model.

Discussion

The availability of optimal hibernacula, together with adequate nutritious food (Massemin *et al.* 1996, Blumstein and Foggin 1997), is a limiting factor to the expansion of marmot population (Arnold *et al.* 1991, Armitage 2000 and Lenti

Boero 2001). Winter and early spring seemed to be more important than the summer season in my study areas for limiting the population distribution too. In fact, the area used by the populations during the summer was wider than area used during the hibernation period and early spring time after coming out of the hibernation. In summer marmots also colonized the highest crest characterized by a rocky outcrops and lacking possibilities for digging deep burrows. During the summer, marmots also foraged far from their winter burrows and outside the 1-hectare square with winter burrow presence. Winter burrow areas were not deserted by marmots in summertime, and were the only areas used by marmots all the year long. Moreover, summer burrows were often in vicinity of winter burrows and, in some cases, winter burrows were also used as summer burrows (cf Sala *et al*. 1992 and Lenti Boero 2001).

My study showed that the abundance of stones increases the importance of the grassland in discriminating the squares with winter burrows from those without. But, the alpine meadows provided suitable habitats also in the absence of stones, whereas the secondary abandoned pastures suitability was strictly subject to stones presence. The different height of the grass seems to explain the different suitability of the two habitat types in the absence of large stones. In the absence of livestock grazing the vegetation in abandoned secondary pastures was much higher than in primary meadows (see study area and appendix), making abandoned secondary pastures more dangerous and less suitable (Carey 1985). In habitats with tall vegetation marmots must increase their vigilance time when foraging and reduce the rate of food intake (Carey and Moore 1986). Moreover, the height and density of grass in the abandoned pastures imply lower visibility and slower predator sighting as a consequence (Blumstein *et al*. 2001) and obstruct escape by reducing running speed (Blumstein 1992). In this dangerous habitat the presence of large stones probably permits more effective predator avoidance. The unsuitability of the secondary abandoned pastures without large stones may explain the decrease in or the extinction of some colonies settled in secondary pastures, after the abandonment of livestock grazing. Therefore, the grazing of secondary pastures by domestic animals is an important aspect of Alpine marmot management.

Several studies differ about the suitability of the scrub: some authors affirm that this habitat is avoided (Ferri *et al.* 1988, Grimod *et al.* 1991), others state that it is a regularly used habitat (Cagnolaro and Spagnesi 1981). These differences seem to depend on the lack of an appropriate analysis of utilization-availability data, but they may also depend on the species of scrubs involved (deciduous or evergreen), or on their structure and height, and on the presence of large stones within the scrubs. In my study scrubs with irregular cover and open structures were used and suitable, while continuous and closed scrubs were avoided. Moreover, the evergreen scrubs (*Pinus mugo*) were generally avoided, whereas the deciduous scrubs (*Alnus viridis, Salix* spp.) were selected when open and scattered, and avoided only when closed. These differences between evergreen and deciduous scrubs can depend on the different visibility and predation avoidance possibility in the spring, or on the soil conditions (humidity, fertility, depth). In the study area, the used scrubs were characterized by the presence of stones. In any case, it may be that the suitability of scrubs is subordinate to the presence of large stones as was noted in abandoned pastures.

Habitat selection by the two populations showed some differences. In the more recent population B, marmots excavated the winter burrows in a small range of habitats, primarily selecting those most preferred by the less recent and denser population. The same differences also emerged from the analysis of slope selection: the population B showed a stronger selection than the population A, using a narrower range of slopes, and, in particular, only slopes selected by the denser population A. According to other authors (Bassano *et al.* 1992, Allainé *et al.* 1994, Gąsienica-Byrcyn 1994) both populations avoided slopes lower than 20%, set in the study areas at the foot of the slopes.

In accordance with the ideal free distribution theory (Fretwell and Lukas 1970, Fretwell 1972, Kshatriya and Cosner 2002) and with Rosenzweig (1985), the differences recorded in habitat selection can be the consequence of differential habitat saturation by populations A and B. In fact, the increase of density pushes marmots to use and select a wider range of habitat types. With the increase in density and in the area's saturation after the ideal free distribution stage, marmots may settle in habitats that they avoided in lower density conditions. Following the theory, a species colonizing a new area occupies and selects the optimal habitats first, and then the suboptimal habitats. It is therefore possible that the habitats selected by the more recent population living in the subsaturated area represent optimal habitats for the Alpine marmot, whereas the habitat selected only by the denser population should be considered suboptimal. The density-dependent changes in habitat preferences of the Alpine marmot must be considered in order to understand some of the differences between different studies.

I conducted the study of the habitat requirements of the Alpine marmot in the FDNP to improve the success of the re-introduction and re-stocking program. A knowledge of habitat selection in the re-introduction areas allows workers to verify the suitability of the available habitats and to formulate models for evaluating the suitability of other areas for further re-introductions. These aspects are most important in the Eastern Alps, where the Alpine marmot was extirpated in ancient times (Toschi 1965, Amori and Lapini 1997). The model formulated on the population living in the saturated area A performed well and represents a useful planning and management tool in the evaluation of the suitability of an area for the presence (re-introduction) of the Alpine marmot. The model formulated on the more recent population was less predictive, because the population was increasing and was apparently living in a non-saturated habitat. This model can be useful in detecting the sites where the animals choose to settle first, but not for predicting the potential distribution of the species (Milne *et al.* 1989, Johnson and Krohn 2002).

Many authors stress the necessity of model validation before it is to be used (Lancia *et al.* 1982, Cole and Smith 1983, Morrison *et al.* 1992, Van Horne and

Wiens 1991), and suggest the use of more than one test method (Laymon and Barett 1986, Pompilio and Meriggi 2001). The discriminant model formulated on population A resulted therefore valid and reliable, showing a high accuracy in reclassifying the sample squares and, furthermore, a high efficacy in classifying the test areas. Also the re-stocking action carried out by FDNP in test population C in 2001 further validated the model.

Studies of re-introduced populations are useful for species management because they allow the verification of the adaptation of the Alpine marmot to the re-introduction environment, and the latter's effective suitability. The definition of the habitat requirements of the species permits an analysis of the suitability of other areas of potential re-introduction. The alpine meadows in the Eastern Italian Alps are smaller and more fragmented than in the Western and Central Alps because of the lower altitude of the mountain chain. Before re-introducing marmots in any site in the Eastern Alps, it is therefore necessary to evaluate the feasibility of the re-introduction and the future isolation of the new populations. It is also necessary to evaluate the habitat suitability of the area and the potential size of the re-introduced population (Borgo and Mattedi 2003). The habitat suitability models formulated in the Friulian Dolomites Natural Park can represent a useful instrument for the management of the species in the Eastern Alps, so as to assess the possibility of further re-introductions, or to evaluate the saturation ratio of recently re-introduced populations, and program some eventual re-stocking actions.

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