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Dynamics of the colonization process in reintroduced populations of the Alpine marmot

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The project of marmot reintroduction in the Dolomiti Bellunesi National Park started in 2006. In May 2006 and May 2007, 80 ear-marked (by sex and family) marmots were released in two separate areas (20 ind./year/area). In summer 2008 the populations produced 36 and 39 individuals, respectively; the animals born in the areas exceeded the number of released animals that survived. Only one pair bred successfully in the year of release; 87.5% of the surviving pairs bred the following year, including the pair breeding the previous year. We recorded the reproduction of a single female, and the acceptance of the litter by the male who later joined her. Mortality of the animals released in 2006 was 39% before the first winter and increased to 53.6% after the second summer. The first summer mortality of animals released in 2007 was higher, probably because of greater predation by golden eagles. The population density increased in late summer 2008 to 13.5 and 22.2 family units/100 ha, respectively in the two areas. In 2006, when both areas were uninhabited, the mean dispersion distance from the release site to settlement sites was greater in males than in females. Sixty-one per cent of the settlements consisted of pairs; 33%, a single male; and 6%, of a trio (marmots from different families). The single males settled more distantly than paired males. Of all the possible "same-family composed " pairs, 77.6% occurred.

KEY WORDS: *Marmota marmota*, reintroduction, Dolomites, colonisation, mortality.

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INTRODUCTION

In the south-eastern portion of the Alpine chain (the southern Dolomites and the pre-Alpine Veneto-Carnic belt) the marmot has been extinct since the beginning of the Atlantic period. The bone and fur remnants which came to light in those areas during palaeontology excavations (Dal Piaz 1929, Bressan 1988, Tonon 1989, Bon et al. 1995, Cappato et al. 2006, Gurioli et al. 2006) testify that, locally too, the species was actively hunted since prehistory. Probably the extinction of the species from this area was in great part the consequence of hunting activities, together with the low altitude post-glacial climate dynamics. The recolonisation of the extinction areas in the south-eastern Alps was probably prevented by the progressive reduction in size and increase in isolation of the meadow patches, which occurred during the later post glacial warming period. The reduced size and greater isolation of the eastern Alpine populations resulted in a progressive loss in genetic diversity (Kruckenhauser & Pinsker 2004), which might have negatively affected the vitality of the populations. Today, hunting, one of the main reasons for marmot extinction, has effectively disappeared. But the problem of the isolation and reduced size of the populations in the south-eastern part of the Alpine arc is still present (Lapini & Borgo 2004), with the consequent problem of possible high inbreeding rates.

The project to reintroduce the marmot into the Dolomiti Bellunesi National Park started in 2006. The reintroduction significantly contributes to the conservation of the species, and expands its distributional area in the southern part of the eastern Alpine arc. We consider that the marmot reintroduction could positively affect the populations of other species. For example, the reintroduction of the marmot increases the habitat quality for the golden eagle (*Aquila chrysaetos*) (Borgo & Mattedi 2003a). We expect also that the availability of marmots could result in a decrease in the importance of summer predation on grouse and alpine mountain hare (*Lepus timidus*), species with a higher conservationist importance.

In this paper we present data concerning the colonisation process of animals released in two new areas. See Borgo & Vettorazzo (2008) for details about the project.

METHODS

The reintroduction project started with the analysis of habitat suitability following the guidelines of the Istituto Nazionale per la Fauna Selvatica (Borgo 2007). In

order to evaluate habitat suitability of the meadows of the Park, we applied two habitat suitability models (Borgo 2003, Borgo & Mattedi 2003a) carried out in the nearby Dolomiti Friulane Natural Park, where the alpine marmot was reintroduced in 1977. The areas suitable for marmot reintroduction were located by sub-dividing the entire Park territory into the 100 hectare squares of the UTM network, and by applying a first habitat suitability model. The model gives each UTM square a probabilistic value of suitability included between 0 (no suitability) and 1 (maximum suitability), in relation to its elevation, exposure, slope, and availability of meadows. Two main areas suitable for reintroduction (A: Vette Feltrine, B: Erera-Cimonega-Agnelezze) were individualized and then subdivided into 1 ha squares, inside of which the surface percentages occupied by the different vegetation typologies (also considering the presence and abundance of rocks) were calculated. The second habitat suitability model was applied to give each 1 ha square a probabilistic value of suitability for hibernacula.

An estimate of the number of potential family units was obtained by multiplying the number of suitable squares (1 ha) by the average (0.337) saturation index (SI), which had emerged from the study of the Friuli reintroduced populations. The SI is equal to the ratio between the number of family units present in a single area and the number of squares (1 ha) suitable for occupancy by the species (Borgo 2003).

Marmots for the release were captured by using string traps in the Stelvio National Park (Passo dello Stelvio, BZ) and in the Northern Dolomites (Passo Pordoi and Cherz plateau, BL), two areas more than 100 km distant from each other. In each reintroduction area (A and B) we released animals from both capture sites, in order to maximize the genetic diversity of the founder pool.

At the time of capture, each animal was marked with colored labels identifying its family group on the left ear, and sex on its right ear. In the first year (2006), in both reintroduction areas all animals were released together in a single site. In the second year (2007), the releases were more scattered in order to increase the number of settlements and to give a partner to the single individuals already settled. The animals were released in suitable but unoccupied sites, or directly one by one in the burrows occupied by single individuals.

The monitoring of the new populations was carried out from May to September without differences in methods and effort between years and between areas. All the reintroduction areas were systematically explored searching for marmots.

RESULTS AND DISCUSSION

In May 2006 and May 2007 40 marmots (20 ind./year, sex ratio 1:1) were released in each area A and B. Marmots released in the second year had a different origin from those released in the first year.

Dispersion and group composition

We consider dispersion and settlement data concerning marmots released in only 2006, because habitat and spatial choice of the animals added in the following year could be affected by the distribution of the first settled animals and by the release method. The mean dispersion distance from release sites to settlement sites was 904 m and was greater in males (mean 1047 m, range 0-3300) than in females (mean 665 m, range 0-1295).

In June 2006, 61% of settlements were represented by pairs of different sexes, and 33% by solitary animals. In only one case (6%) was a group of more than two animals (a pair and a young male) formed; the three individuals originated from three different families. Single males settled more distantly (1619 m) than paired males (665 m). Was their greater dispersion distance the cause of their solitude, since females settled at lower distances, or was their distance the consequence of not finding available females? The first hypothesis seems more probable, also keeping in mind that, as the distance from the spot of release increases, the probabilities of an encounter diminish.

By individually identifying animals we could verify whether there was a tendency by individuals of the same family to join together. In the entire group of two populations, 77.6% of the homo-familiar couples that might potentially have joined did settle together.

Mortality

In a population of marmots, the two main causes of mortality are predation during spring and summer and death during hibernation in winter. The winter survival increased with the number of individuals hibernating together (ARNOLD 1990). Mortality rates by predation increase with the dispersal distance (FREY-ROOS 2003). Predation of newly released animals may be easier because of the lack of social organization, the scantiness of shelters, and the marmots' exploring activities.

In accordance with ARNOLD (1990), the mortality during the first winter after release was greater in solitary (47.1%, N = 17) than in not solitary animals (6.4%, N = 31).

Mortality of the animals released in 2006 was 39% before the first winter, increasing to 53.6% at the end of the second summer. The first summer mortality was higher in population A (42.8%, Fig. 1) than in population B (25%, Fig. 2). This difference is due, at least in part, to the predation by a female fox (*Vulpes vulpes*) who settled with her cubs in a marmot burrow after killing its occupants (remains founded). From June to August the fox was frequently observed to lie in ambush at the entrance of the other burrows.

The first summer mortality of animals released in 2007 was 55%, with little differences between areas (50% in area A, Fig. 1; 60% in B, Fig. 2). After the first winter, their mortality raised 72.5%. The first winter mortality was higher in area B (80%, Fig. 2) than in area A (55%, Fig. 1), because of the greater number of solitary animals (62.5% in B, and 20% in A) settled in this area.

The higher summer mortality of the animals released in the second year seems to be a consequence of greater predation by the golden eagle. In summer 2007, the frequency of observations of golden eagles in the reintroduction areas greatly increased in comparison to 2006, becoming daily in 2008. In 2007 we observed three attacks on marmots and we observed a golden eagle preying on an adult marmot. Considering that the monitoring effort and method did not differ among the years, we suggest that after the first year of reintroduction, the territorial eagles learned to exploit the newly available prey.

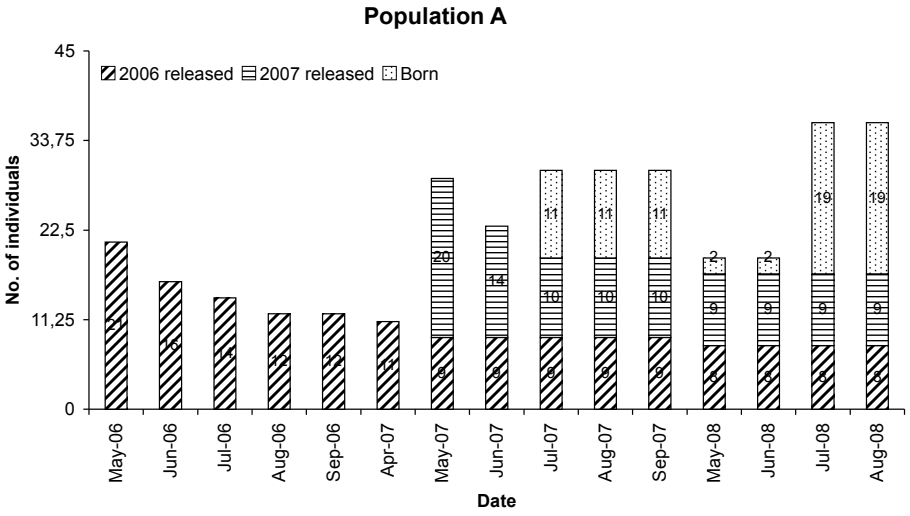

Fig. 1. — Number of individuals observed in the reintroduction area A (Vette Feltrine) from the first release (May 2006) to the late summer 2008.

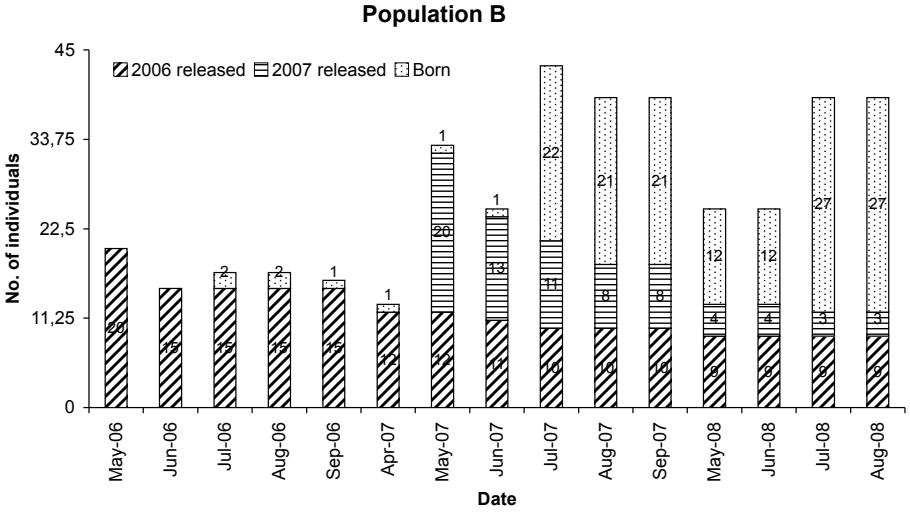

Fig. 2. — Number of individuals observed in the reintroduction area B (Erera-Cimonega-Agnelezze) from the first release (May 2006) to the late summer 2008.

The mortality of young individuals (born in 2007) during their first year was 56.2%, higher in area A (81.8%, Fig. 1) than in area B (42.9%, Fig. 2). The winter 2007-2008 was characterized in the study area by a high deepness and persistence of the snow cover in the spring, after the coming out from hibernation.

Population and density

In late summer 2008, in population A we censused 36 marmots distributed in 8 family units, and in population B 39 marmots distributed in 7 family units (Table 1). Two of the family units in population B were solitary animals, therefore, the number of pairs was greater in area A (8) than in area B (5). The average size of the family units was 4.5 in population A and 5.7 in population B (Table 1).

In population A the animals colonized an area (MCP on winter burrows) 162 ha wide, with no differences among the 3 years. The population density was 7.4 family units/100 ha in autumn 2006, 18.5 in 2007, and 22.2 in late summer 2008 (Table 1).

In population B the occupied area changed among years because two distant settlements disappeared: 650 ha in 2006, 549 ha in 2007 and 289 ha in 2008. The population density was 2.5 family units/100 ha in autumn 2006, 7.1 in 2007 and 13.5 in 2008 (Table 1). The two populations were similar in the number of individuals, but differed in the number of pairs and in the density of family units.

Breeding

Only one pair (homo-familiar) bred successfully in the year of release. In 2007, 87.5% of the survived pairs bred (mean litter size 4.6, range 3-7), including the pair breeding the previous year. In 2008, 72.7% of the pairs bred (mean litter size 4.1, range 3-6). One female bred consecutively in all 3 years; at least 50% of the females bred consecutively in 2007 and 2008. In 2007 we also recorded the reproduction of a single female who mated with a neighbour male, and the acceptance of the cubs by the male who settled with her in June 2007, after the second release.

In late summer 2008, the number of individuals born in the area represented the 52.8% of the population A (Fig. 1), and the 69.2% of the population B (Fig. 2).

Table 1.

Parameters of the two new populations recorded at late summer 2008.

Parameter	Population A	Population B
No. individuals	36	39
No. family units	8	7
No. individuals / family unit	4.5	5.7
Colonized area (MCP)	162 ha	289 ha
Density (No family units / MCP)	22.2	13.5

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