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Management of Alpine Marmot populations

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Abstract. Phylogenetic and geological aspects of marmot distribution in Europe are considered. Historical relations between people and marmot populations are examined explaining the current distribution of Alpine marmots. At the end of the 20th century, Alpine marmot populations are in expansion. This fact is related to changes in anthropogenic pressure and to the creation of protected areas in the mountains. Technical, biological, ethical and legal aspects of translocation of marmots in Europe are examined. Recommendations are made for management of marmot populations.

Key words: *Marmota marmota*, natural resource, re-introduction, translocation, protected areas, European mountains

Introduction

Among the thirteen species of marmots generally recognized by taxonomists (Corbet and Hill 1986), eight are Eurasian and only two inhabit in Europe (Bibikov 1989, 1991): *Marmota bobak* (Müller, 1776) and *Marmota marmota* (Linnaeus, 1758). These rodents have interacted with human populations since prehistoric times. In modern societies, new relations between wildlife and humans have developed. The change of use of wildlife needs to define new rules of management of natural populations of indigenous animals such as marmots.

Management is required because of the fragility of the Alpine environments where European marmots live. It is also necessary to consider the management of marmot populations as the management of an element of the biodiversity and as a natural renewable resource. Another reason is the strong interactions, often cultural, existing between marmots and humans which imply strong current economic aspects.

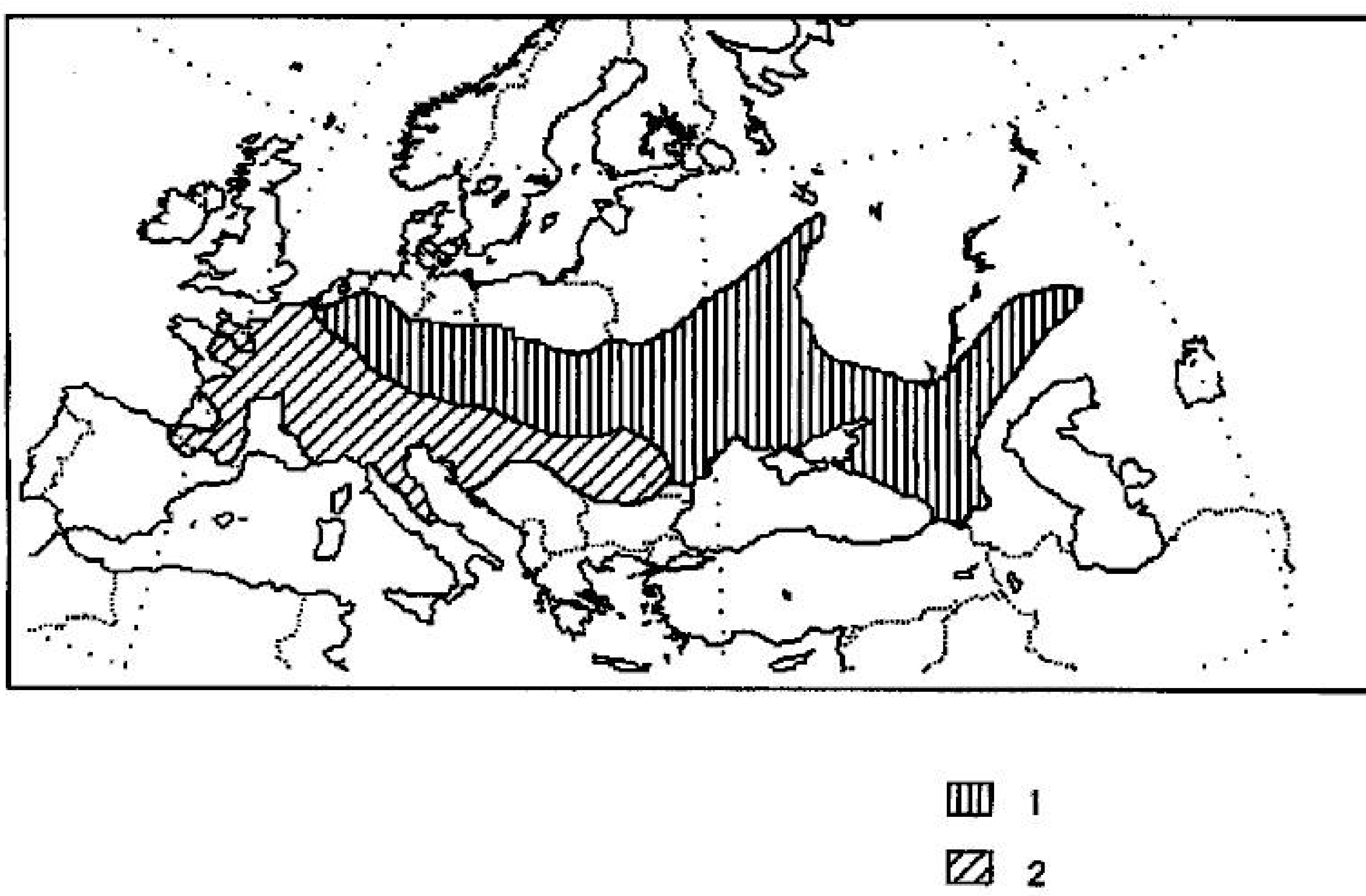

Fig. 1. Areas covering fossiliferous sites of species related to *Marmota bobak* (1) and species related to *Marmota marmota* (2). Sources of distributional data: Chaline 1972a; Couturier 1955; Jean 1981; Lyapunova *et al.* 1992; Pictet 1853; Zimina and Gerasimov 1973.

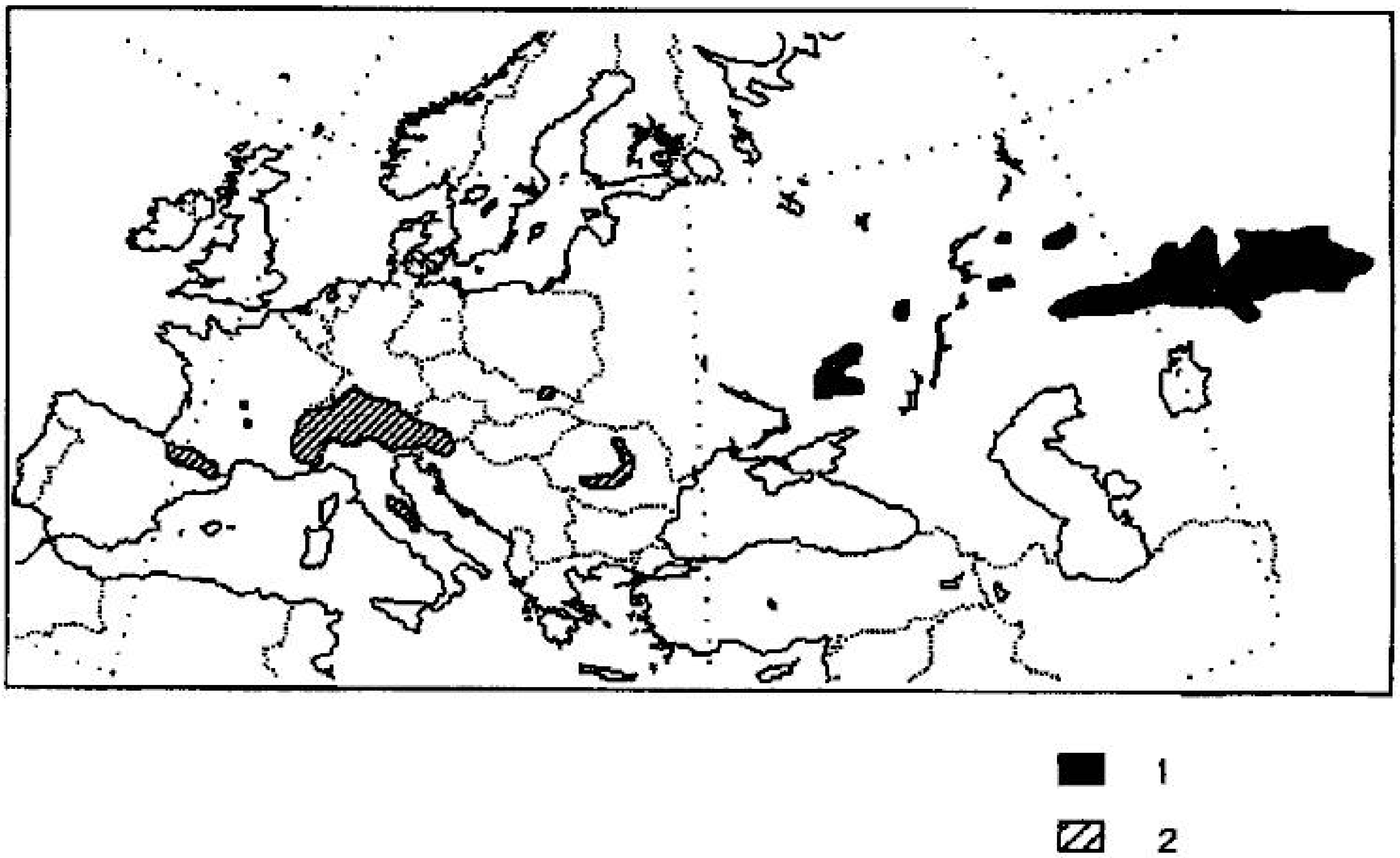

Fig. 2. Present distribution of *Marmota bobak* (1) and *Marmota marmota* (2). Sources of distributional data: Arlagno 1984; Almasan 1981; Bibikov 1991; Dobroruka and Berger 1987; Ferri *et al.* 1987; Garcia-Gonzalez *et al.* 1985; Jean 1981; Kratochvil 1961; Magnani *et al.* 1990; Michelot 1991; Neet 1992; Panteleiev *et al.* 1990; Penel *et al.* 1984; Ramousse *et al.* 1992; Schilling *et al.* 1986; Spagnesi *et al.* 1979.

In this paper we shall first consider the distribution of marmots at a geological scale, then some historical data about relations between men and marmots will be considered. The present management strategy will be considered through the problem of reintroductions and translocations, in Europe and mainly in France. We shall finish with some recommendations concerning management based on scientific knowledge of the Alpine marmots.

Geological aspects of space occupation by marmots

Eurasian marmots are morphologically and karyologically similar, indicating their recent phylogenetic origin (Lyapunova *et al.* 1992). The isolation of North America from Eurasia by the opening of the Bering Strait at the end of the Eocene and the beginning of the Oligocene (40 million years B. P.) allowed the emergence of the ancestors of *Marmotini* (35 million years B. P.) and then the differentiation of both genera *Marmota* and *Citellus* during the Miocene. At this time (end of Miocene: 10 million years B. P.), communication between North America and Eurasia was re-established and marmots started to penetrate Eurasia, reaching Europe during the Pleistocene (1 million years B. P.). Late Pliocene marmots are rare in Eurasia, but occured in Ukraine (Zimina and Gerasimov 1973).

Late Pleistocene marmot fossils are the rodents most frequently found in Western Europe whatever the relief, even in flat areas (Fig. 1) (Pictet 1853, Chaline 1972a). They are known from Belgium in the north, but did not reach England. In the south they went as far as the Cantabrian Mountains in Spain and in the whole peninsula of Italy. Westwards, they stopped near Brittany and towards the south-east they expanded as far as Hungary (Chaline and Mein 1979). Chaline (1972a, b) characterized two fossil sub-species: *Marmota marmota primigenia* Kaup in Würm deposits and *M. m. mesostyla* Chaline in Riss deposits. Fossil forms present a mixture of characters which are found now in two species *Marmota marmota* and *M. bobak*. Partition between these two species results from an allopatric speciation, linked to alternating periods of glaciation and warming.

Fossil burrows with associated marmot skeletons suggest that marmots were already social animals (Meyer 1847 in Pictet 1853; Chaline 1969; Aimar 1992). About 100,000 years ago, when the major extension of marmots culminated, Neanderthal Man appeared, and marmots were already part of their economy (Rebeyrol 1991). The fauna associated with marmot fossils indicates that climatic conditions were harsher than at present and that marmots were better adapted to periglacial conditions (Zimina and Gerasimov 1973). During the Atlantic period with post-Würm reheating they found refuge in mountains in Europe.

Distribution

Two species (*Marmota bobak* and *M. marmota*) are presently well distributed in Europe, but their range no longer overlap (Panteleiev *et al.* 1990; Fig. 2). Kratochvil (1961) characterized two subspecies:

Marmota marmota marmota, the Alpine marmot and *M. m. latirostris*, the Carpathian marmot. The local history of the species is difficult to assess because travellers were not always naturalists and mountainous areas were difficult to approach until the last century (Raverat 1872).

History of marmot distribution

The Alpine marmot was first known by Pliny the Elder (1952) as *Mus alpinus*, in the Alps. Marmots, still present in the southern Carpathian mountains in 1868, disappeared by the end of the last century (Almasan 1981). In Switzerland, marmots were abundant in the Grisons, Uri, and Glaris Cantons, present in Tessin, Bern Oberland, and Valais Cantons, but had already disappeared under hunting pressure in Appenzell and Toggenbourg Cantons (Tschudi 1859). Hunting was still important in Switzerland in 1980 (officially 8,000 marmots were shot per year between 1976-1978; decreasing since, Wieser 1990). However, as in the Uri Canton, local rules were observed to protect the marmot resource (Sacc 1858).

Buffon (1761), Bomare (1768) and Bonnier (1922) quoted, probably falsely, the presence of *Marmota marmota* in Apennines, Germany and the Pyrenees. In the Pyrenees, Trutat (1878) did not find it, and Astre (1946) concluded that it was not actually present and probably had never been present during historic times. In the French Alps, Dénarié (1902) quoted decreasing populations following intensive poaching, and Marié (1936) indicated that marmot-digging was forbidden in the natural reserve of Lauzanier. However, the presence of marmots in pre-alpine massifs is more difficult to assess. During the last centuries marmot populations decreased in most European countries or even disappeared as a result of a prominent anthropic pressure (agriculture, man and sheepdogs).

Present distribution of Alpine marmots

Both subspecies live between the limit of forests and the bared rocks in Western Alps, in Eastern Alps, in Carpathian Mountains, Apennines, Central Massif, and Pyrenees (Fig. 2). They may be found at lower altitudes: 990 m in Germany (Müller-Using 1954) or even 800 m in France (Couturier 1963). In the Alpine valleys, the subalpine stage is almost absent due to clearings to exploit pastures which represented 28% of the total surface in Savoie (Guicherd 1930). These habitats, less exploited now, open a new possible colonisation area for marmots. In Italy and Switzerland, marmot populations are stationary or slightly increasing where they are not hunted and stationary or slightly decreasing in the areas where they are still hunted (Spagnesi *et al.* 1979). In France, the recent expansion of the range of marmots (Magnani *et al.* 1990) may be explained by the increase in translocation programs (86 programs since 1931; about 2,000 individuals translocated; Ramousse *et al.* 1993).

Historical use of marmots by people

Two main periods can be considered in the relations between marmots and people: first a period of traditional use of marmots, corresponding to a low density of people in the mountain areas; second a period during which marmot populations have been protected and related to new use of mountain areas, by the increase of exogenous people using mountains during the whole year.

Marmots provided mountain people the main meat and fat resources, especially for shepherds (Guérin 1837). This use declined with the economic development of the Alpine regions but showed a revival during World War II. The medical use of oil persisted longer and is still practised in European communities all over the world (Wieser 1990, Janiga 1993, personal communication). Furs of Alpine marmots were not as valuable as Russian marmots. During the Middle Ages, trade of Russian marmot furs and their contaminated fleas might have been the cause of the big plague outbreak (1347-1348; McEvedy 1988). Skins and furs were used for clothes or handcraft but an important craftsman's trade never developed (Guérin 1837, Bossu 1858, Bonnier 1922). Young animals, which tame easily, were often kept as pets by savoyard chimney-boys who popularized this animal in all towns even far from Alps (in Paris, Bomare 1768). Now, marmot hunting is decreasing in all countries. Hunting is now forbidden or limited. Marmot flesh is no longer so highly regarded. And lastly, growing interest by tourists in wildlife may have given the marmot a valuable economic image. This image is exploited as cuddly toys but also in promoting tourism (postal cards, posters), foods (sweets and infusions), motel networks, and even in advertising films (Tetra Pack). Marmots were also used in physiological research, especially on hibernation and parasitism (Mangili 1807, Dubois 1894, Blanchard and Blatin 1907). This use has recently been encouraged by the discovery of an hepatitis virus similar to human hepatitis in the woodchuck *Marmota monax* (Chomel *et al.* 1984).

During the second half of 20th century, in Italy, Switzerland and France, marmot populations have also taken advantage of the decline of mountain agriculture and of the creation of protected areas. Marmot protection began in Switzerland in 1883 (Musy 1925) and in France in 1936 with the creation of a nature reserve in the Queyras mountains (Southern Alps, Marié 1936).

Introductions, reintroductions and translocations

Introduction is the creation of a new population for one species in a natural habitat where this species never existed. Re-introduction is an attempt to reconstitute a population, with a genetic patrimony close to the aboriginal population, in an area from which the species became extinct in historical times. These distinctions are not always clear. When a species has died out in an area during historical times, we are not sure whether any ecological changes have occurred since that time. Many introductions achieved pest status, for example, nutria *Myocastor coypus* Molina in France (Abbas 1988) while re-introductions have seldom achieved pest status, probably because animals are soon subject to the environmental factors which previously regulated their numbers (Price 1989). But re-introduction is only an initial stage and re-inforcement by subsequent releases is a normal second stage.

Marmots are game in their native range, e.g., Western Alps in Italy, some Cantons in Switzerland and Alpine departments in France. They are protected in parks, reserves and in areas where they have been introduced. In France, the law of 10th July, 1976 specifies re-introductions but the list of animal re-introductions authorized is still not published. France ratified only in 1990 the Bern convention (1979) providing a general attitude of the signatory countries about re-introductions. But no application texts have been defined to date. The only direct indications must be found in the rural code. Generally, capture and transportation of game is regulated (DDAF departmental Direction of Agriculture and Forests of the capture site). Promoters of re-introduction should at least follow international recommendations (Council of Europe 1985, IUCN 1987). Four distinct phases must be respected: (1) A feasibility study indicating the likelihood of a successful re-introduction. (2) A preparation phase. (3) A phase of release planning. (4) A post-release phase monitoring the range or dispersal and the causes of possible mortality of animals released as well as any adverse effects on the ecosystem.

Principal reasons invoked in favour of these operations are ecological. Maintenance or increase of frail populations especially in island-zones limit the probability of disappearance of the species. Marmots supply prey for rare species such as the golden eagle allowing its development and restricting its hunting pressure on other decreasing species, such as the black grouse in the Alps and the chamois and hares in Pyrenees, and enhancing local biodiversity. Fossorial activities of marmots create particular microecosystems where a special entomofauna of high altitude survives (Marié 1937). The natural landscape, seemingly in harmonious equilibrium with its physical environment, is strongly affected by the grazing activities of animals. A moderate level of marmot activity reduces the dominance of common species and thereby enhances community diversity (Del Moral 1984). In under-used areas marmots substituting for domestic cattle may limit brush-wood and changes in vegetation cover such as increase of long herbs which create surfaces more conducive to avalanches (Delpech 1975). Marmots eat Orthoptera reducing their proliferation (Voisin 1986). But now the main motive supporting re-introductions is socio-economic, linked to summer tourism and recreation development. Presence of easily observable species improves the attraction of a region to tourists. Lastly, most of the introduction programs of marmots are justified by the Pleistocene distribution for marmots (Fig. 1), which seems highly inappropriate because ecological conditions have been clearly altered through climatic as well as anthropogenic changes.

Since the end of World War II the Alpine subspecies (*M. m. marmota*) has been introduced successfully in the Eastern Alps (Germany: Bade-Würtemberg, Baviere; Austria; Münch 1958), in Slovenia (Dobroruka and Berger 1987), in Italy (eastern Alps, Lecco pre-Alps, Apennines; Lenti Boero 1987, Ferri *et al.* 1988), in the French Pre-Alpine mountains (Bauge, Chablais, Vercors, Grande Chartreuse), in French Pyrenees (Couturier 1955) from where it colonized the Spanish side (Garcia-Gonzalez *et al.* 1985) and in the Central Massif (Ramousse *et al.* 1992). There have been unsuccessful attempts in Vosges (Boithiot 1979), Jura (Fayard, Rolandez, and Roncin 1979), and Côte d'Or (Chaline 1972a). Successful reintroductions of *M. m. marmota* took place as early as 1883 in Switzerland (Valais Canton; Musy 1925), and since then in several valleys in Jura (Neet 1992), and in Romania (Almasan 1981). *M. m. latirostris* was reintroduced in Ukraine and in Slovakia in the eastern part of the Low Tatras probably in the 19th century (Jamnický 1977), but also in the Apennines of Italy (Ferri *et al.* 1988).

Recommendations for management of marmot populations

Economic rules

Marmot re-introductions and re-inforcements are far less expensive than most of other animal re-introductions. First, translocations of wild-caught marmots into another suitable natural site make the least demands, no need of marooning nor of rehabilitation. Secondly, capture and its cost are generally not undertaken by promoters of re-introduction but rather by protected area administrations to limit complaints of hay meadow owners who can no longer bear marmot populations interfering with agricultural activities or by undertakers of large-scale engineering works such as hydro-electric plants, highways and ski pistes to translocate marmots into safer areas. Thirdly, feasibility studies are often insufficient and costs of short and long term surveys are seldom taken into account. A re-introduction program might allow funds to ascertain possible effects on the ecosystem and appreciate socio-economical, administrative and political aspects. The "economical value" of a wildlife species might also be investigated.

Scientific rules

The genetic stock used should be as close as possible to the original population. When marmots became extinct during geologic time, it was an introduction of the species. Introductions must be postponed until we have a better understanding of the ecological consequences of the programs already realised. In the Apennines, the two sub-species *Marmota marmota latirostris* and *M. m. marmota* were released (Ferri *et al.* 1987). When extinction took place during historic times, such as in Romania, the Carpathian sub-species *M. m. latirostris* may probably have been chosen instead of *M. m. marmota* (Almasan 1981). Such a mistake has also been made in Low Tatras, distribution area of the Carpathian sub-species, where *M. m. marmota* was released (Schilling *et al.* 1986). It is better to release marmots of the same sub-species. In France, most of the animals released for re-inforcements came from the same population instead of different origins to reduce insularity effects and genetic drift. It emphasizes the importance of ecological and ethnoecological studies as part of a feasability project (Meilleur 1984).

The release site must be carefully chosen. The nature of the soil and geological structure of the substratum must allow digging deep burrows which are the principal habitat where marmots retire during dark hours and hibernate during the cold season (Moss 1940; Durio *et al.* 1987). The socio-spatial structure of marmot populations have been related to the diversity of plant communities, to the variation of slopes, elevation, sun exposure and hikers' activity (Perrin and Allainé 1991; Rodrigue *et al.* 1992). In relation to thermoregulatory constraints, marmots preferred elevated south-exposed slopes (Türk and Arnold 1988). Food selectivity was observed in yellow-bellied marmots (*Marmota flaviventris* Audubon and Bachman 1841, Armitage 1979; Carey 1985) and in a familial group of *M. marmota* which consumed mainly *Dicotyledon* flowers (Massemin and Ramousse 1993). Leguminosae and graminoids decrease with elevation, but their richness in nutritive elements increases and lignification of cellulose is delayed making the plant more palatable and more easily digestible. The best part of mountain pastures are the most elevated (Guicherd 1930). Marmots concentrate early-season feeding on young leaves as they emerge, this pruning may stimulate herb growth in their foraging area. Salt drive in mammals is a common phenomenon. *M. monax* Linnaeus 1758 licks the road surface for residues of winter-applied sodium chloride and presents a definite seasonal variation in Na drive (Weeks and Kirkpatrick 1978). This spring peak of sodium intake could explain increased traffic mortality at this time and the migration of marmots into alpine meadows chemically fertilized which in turn causes agricultural difficulties. Human impact, high frequency of hikers, requires longer periods in the burrow for the day-active marmots, thus preventing the accumulation of sufficient body fat during the summer to last through hibernation (Neuhaus *et al.* 1992). Nothing is known of the effect of the development of road and touristical infrastructures which might induce a break up of the marmot range. Few integrated approaches, such as population vulnerability analysis (Neet 1992), have been used to deal with such reintroduced populations exposed to habitat insularity, inbreeding, outbreeding and demographic processes that occur in small populations. Such approaches imply that reintroduced populations must be monitored in the short term as well as in the long-range. Short-term surveys are needed to assess trapping and transportation risks but overall to understand the behavioural processes occuring in reconnaisance of the new habitat. Long-range monitoring deals with colonization processes of small populations, their effects on other species and the landscape, their interrelation with socio-economic development of the region and comparison of different strategies.

Successful settlement depends on the number, on the sex-ratio and on the age-class of animals released on a site. In France until the seventies, a mean of ten animals were released each time, then this mean number increased to twenty (Ramousse *et al.* 1993) without affecting significantly the result of these operations. But long-term surveys occured rarely and nothing is known about the dynamics of these reintroduced populations. We hypothesize that these populations increase very slowly and have a low viability. As a matter of fact, marmots constitute familial groups of about nine individuals : a couple of adults and their progeny until three years old (Mann and Janeau 1988, Perrin and Allainé 1991). Moreover Arnold (1990) emphasized the importance of social thermoregulation during hibernation. Also it would be preferable to release whole familial groups rather than individuals. Intra-familial cohesion links may prevent erratic dispersion after release and also problems inherent in recomposition of familial groups neccessary to go through hibernation with success and to enhance demographic processes.

Ethical rules have also to be observed as wild animals must be trapped in a way that respects their welfare and optimizes their ability to settle (Le Berre and Ramousse 1993). Animals must be measured and marked for future recapture and identification. As transportation should be as short as possible to prevent mortality following transportation stress, the moment of capture and of release must be closely linked. Marmots may be trapped in spring time between hibernation emergence and snow melting period and young dropping period or late in summer after weaning. The first period is better for at least five reasons: starving marmots are very active at this time, grass is still short and trampling problem is limited, touristic pressure is still low, heat stress less frequent and overall sex-ratio is equilibrated whereas in summer males are more frequently trapped (Ramousse *et al.* 1992). However a spring release assumes that animals have time to prepare burrows for hibernation, but they also need to relearn how to exploit their new habitat. This may decrease the available foraging time and limit accumulation of a sufficient body fat to go through hibernation in good conditions and reproduction the next year. Artificial burrows have been dug but they were used, at best, only for a few days after release preventing stress dispersion, then abandoned (Vuillet 1988). On the other hand, autumnal release of animals in areas with unoccupied burrows might be more adavantageous, fat marmots would have only to fit out preexisting burrows.

Discussion - Conclusion

Unlike other rodents which are commonly disliked and considered as pests, the marmot is a charismatic species. They seem less vulnerable to local extinctions but we saw that they became extinct locally in many parts of Europe and are still disappearing in some places. Also, the present increase of their range does not mask the fragility of most of the marmot populations outside of protected areas and the problems of management of animal populations in protected areas. Fragility is increased by the extreme sensitivity of mountain ecosystems to man's impact, site destruction and to climatic changes. In the hypothesis of an elevation of ambient temperature (Ozenda and Borel 1991), related to greenhouse effect and global change, the range of Alpine marmots should be reduced dramatically. Marmots must be seen as one element of mountain landscapes which is at the same time the result of mountain farmers' work and the basic "capital" of tourism (Unesco 1988). Future directions for marmot protection seem clear. We must intensify our fact-finding efforts. We need to know more about life histories, population dynamics, genetic and behavioural responses of released animals to a novel habitat. Study of expanding populations such as marmot populations of the Pyrenees could constitute the basis of a better understanding of ecological processes by which mountain ecosystems maintain or adapt to changes and may provide the basis for field experiments (Nebel and Franc 1992). At the same time, it is of great importance to develop criterion for measuring the success of different rehabilitation schemes taking into account the socio-economic backgrounds. Comparison of the policies of different countries will then suggest different conservation strategies. Efficient synthesis and effective dissemination of information derived from research may be increased through cooperative efforts between scientists, protected area managers, official territorial administrators and farmers to develop and implement conservation of marmot populations, restoration of biodiversity of mountain ecosystems interlinked with sustainable development. In this way, creation of Biosphere Reserves (Berchtesgaden and Tatras) as proposed by the Unesco Man and Biosphere international research programme, will be of great interest in order to plan a better management of Alpine natural resources and especially to define the new recreational relations which are developing between people and marmots with the evolution of the socio-economy of European mountainous area.

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