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CAPTIVE-BREEDING AND CONSERVATION OF THE EUROPEAN MAMMAL DIVERSITY

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ABSTRACT - Under the biological species concept, the intraspecific variability and true species richness of Palearctic mammals has often been overlooked, and therefore the need to conserve it. Recovery projects of endangered European mammals in Western Europe rely mainly upon translocation of conspecifics from viable populations in Central or Eastern Europe. From a wildlife management and restoration ecology point of view, many such recovery projects have been successful. However, from a biodiversity perspective it could be argued that they could have failed to protect the original European biodiversity. The increasing evidence of a complex phylogeographic pattern in many European mammals – especially in the Mediterranean region - has led to a reconsideration of the conservation unit and highlights the need for species-specific programmes for assuring the survival of threatened, distinctive populations. Such programs should also include captive breeding. It is therefore suggested that a two-level classification of captive breeding programmes is needed according to the degree of threat of concerned taxa, to maximise available resources without jeopardising *in situ* conservation. It is proposed to distinguish between a) level I captive breeding programmes, which are part of the conservation strategy for seriously threatened taxa and need to be financed by state or federal agencies, and b) "prophylactic" level II for vulnerable taxa or populations, and for which funds may be available mainly from the private sector. Available evidence suggests that given adequate husbandry techniques and prerelease training, even captive-bred carnivores can be successfully reintroduced to the wild. However, a closer collaboration among zoological gardens, zoologists and agencies involved in wildlife conservation is needed to avoid ill-conceived, potentially dangerous captive-breeding and re-introduction projects.

Key words: captive breeding, Europe, mammals, re-introductions, zoological gardens

RIASSUNTO - ***La riproduzione in cattività e la conservazione della diversità dei mammiferi europei***. Il numero di specie e la variabilità intraspecifica dei Mammiferi paleartici è stata generalmente sottostimata nei decenni in cui il Concetto Biologico di Specie è stato adottato. Ciò ha portato a sottovalutare le minacce ai Mammiferi europei e a basare l'attività di conservazione principalmente sulla traslocazione di individui da popolazioni vitali dell'Europa orientale. Molti di questi progetti hanno effettivamente portato al ritorno di alcune specie scomparse localmente e quindi al ripristino di una migliore funzionalità ecologica, ma non alla protezione della diversità dei Mammiferi europei. Il presente lavoro si avvale dei risultati di un numero sempre crescente di ricerche filogeografiche che hanno evidenziato complessi modelli di distribuzione e di differenziazione genetica in Europa. L'esistenza di Unità di Conservazione finora criptiche e a volte severamente minacciate, deve portare a riconsiderare il ruolo dei programmi di riproduzione in cattività per i

Mammiferi europei. Al fine di massimizzare l'utilizzo delle risorse disponibili, si propone di suddividere tali programmi in due categorie. I programmi di riproduzione in cattività Livello I fanno pienamente parte della strategia di conservazione di taxa seriamente minacciati, come *Lynx pardinus* o *Ursus arctos marsicanus*. Questi programmi devono essere finanziati da agenzie pubbliche e devono essere realizzati sia in strutture ad hoc che eventualmente in qualificati giardini zoologici. I programmi Livello II interessano taxa non in immediato pericolo ma potenzialmente vulnerabili per intrinseche caratteristiche biologiche. Tali programmi devono essere finanziati dal settore privato e dovrebbero essere realizzati esclusivamente in giardini zoologici, allo scopo di non distogliere fondi dalla conservazione 'in situ'. Una serie di studi dimostra che la reintroduzione anche di carnivori nati in cattività è possibile seguendo una serie di linee guida sul mantenimento in cattività e il *training* degli individui destinati al rilascio. Sembra al momento cruciale, però, stabilire una più effettiva collaborazione tra il mondo scientifico, gli enti governativi e privati e i giardini zoologici per evitare che siano effettuati costosi progetti di riproduzione in cattività e di reintroduzione che non contribuiscono alla conservazione della biodiversità ma anzi la compromettono.

Parole chiave: riproduzione in cattività, Europa, mammiferi, reintroduzione, zoo

INTRODUCTION

To assure the survival of an increasing number of species in a changing world, measures of active protection and management, other than habitat conservation, have sometimes to be taken by wildlife authorities. Some of these measures include repatriation, augmentation (or re-stocking), and reintroduction. All of these techniques involve the intentional movement of individuals from one place to another and are commonly referred to as translocations (IUCN, 1987a; Griffith *et al*., 1989; Gogan, 1990; Smith and Clark, 1994). Generally, the use of free-ranging, wildborn individuals is preferred, both for economic and biological reasons (Griffith *et al*., 1989; Wilson and Stanley Price, 1994; Miller *et al*., 1999), even if high post-release mortality is sometimes unavoidable (Wauters *et al*., 1997).

In some cases, translocation cannot involve movement of free-ranging individuals, mainly for two reasons: i) lack of any viable (safe) wild population of the species ii) the detection, through biomolecular techniques, of considerable genetic differences between the original population and the supposed donor population(s). In such cases, the only option may consist in the relocation of all or part of the surviving individuals and the creation of a viable managed captive population.

Translocations of animals are a commonly employed tool in the conservation and management of wildlife populations in Europe, North America, Middle East and Australia (Boitani, 1976; Griffith *et al*., 1989). However ill planned initiatives can result in the undesirable introduction of genetically different populations or in the transmission of diseases (Wirth, 1990; Woodford and Rossiter, 1994), reducing, instead of increasing, the chance of survival of wildlife populations.

Captive breeding has been extensively used to save and re-establish endangered taxa in the Nearctic region, with some formidable success. The black-footed ferret*Mustela nigripes* and the 'red wolf' *Canis rufus*, have been saved from complete extinction by captive-breeding, and then repatriated into their original range (cf. Stanley Price, 1989; Ebenhard, 1995; Reading *et al*., 1997). In contrast, very few examples of this approach exist for threatened European mammals, although the European bison *Bison bonasus* was the first example of a species saved by an international captive-breeding program (Pucek, 1991) and the Alpine ibex *Capra ibex ibex* was reintroduced early in the XX century into its former range using captive-bred individuals (Stuwe and Nievergelt, 1991). Mammal species in Western Europe have been reintroduced or augmented using individuals from wild free-ranging populations of Central and Eastern Europe origin, as in the case of the Euroasian lynx *Lynx lynx* reintroduction in Slovenia, Switzerland and France, the brown bear *Ursus arctos* reintroduction in the Pyrenees or various restocking of ungulate species (Arquillière, 1998; Breitenmoser *et al*. 1998; Lovari, 1993).

The aim of the present paper is not to review the general value of translocations and reintroductions (cfr. Stuart, 1991; Stanley Price and Fairclough 1997; Fischer and Lindenmayer, 2000), but to analyse the value and shortcomings of scientifically managed captive-breeding programmes for the conservation of European mammal diversity.

WHY CAPTIVE-BREEDING?

The exact definition of the role of captive-breeding programmes (CBP's) in the conservation of threatened species is open to debate in the conservation and scientific community. The Conservation Breeding Specialist Group (CBSG) of the World Conservation Union/Species Survival Commission (IUCN/SSC) does evaluate the need of scientifically managed captive-breeding programmes worldwide by a taxon by taxon approach through its Conservation Assessment and Management Plan (CAMP) and Global Captive Action Plan (GCAP) processes. At a regional/continental level, recommendations are made by so-called TAG's (Taxon Advisory Groups) formed by major zoo associations such as EAZA in Europe and AZA in North America (Foose *et al*. 1995; Hutchins *et al*., 1995). The final aim of captive-breeding programmes is the reintroduction of captive-bred individuals in the species' former range (Soulé *et al*., 1986; Seal, 1991; Ebenhard, 1995). The IUCN had approved a policy statement (IUCN, 1987b) and prepared technical guidelines (IUCN, 2002a) concerning the validity of captive breeding as a support to *in situ* conservation. However, captive breeding is sometime considered ineffective as a conservation strategy, and especially costly (Rabheck, 1993; Schaller, 1993; Balmford *et al*., 1995). Furthermore, CBP's are sometimes seen as "a technological fix that merely prolongs rather than rectifies problems" (Snyder *et al*., 1996), diverting attention (and funds) from *in situ* activities. Some authors argued that, if possible, captive-breeding programmes for threatened species should be based in *ad hoc* monospecific centres located in the natural range of the taxon (Snyder *et al*., 1996, see below). However, it seems that with all their shortcomings, zoos presently represent the best places for siting captive-breeding programmes (Conway, 1995; Gippoliti and Carpaneto, 1997), as financial constraints do not permit the development of "ad hoc" facilities for every threatened taxa, particularly in developing countries. For the less glamorous, unspectacular species, CBP's are often the only (or first) concrete conservation initiatives taken (e.g. European mink *Mustela lutreola*, Maran 1996). Zoos have the facilities, expertise and scientific competence to work with many endangered species. It is true however, that the majority of international breeding programmes are devoted to exotic tropical species. In Europe, only a few Palearctic species have been included in the EEP's (European Breeding Programmes) of EAZA (European Association of Zoos and Aquaria), mainly through the energetic initiative of a few individuals/institutions (e.g. Blomqvist and Larsson, 1990; Maran, 1996). The European mammal *taxa* presently included in EEP's (EAZA, 2003) are: *Canis lupus signatus, Lutra lutra, Gulo gulo, Mustela lutreola, Bison bonasus* and *Ovibos moschatus*.

An increasing number of governmental agencies and public and private organisations are involved in local breeding and re-introduction programs. An increase of collaboration and communication between the zoo community and other environmental organizations in Europe should result in a more optimal allocation of resources for the conservation of threatened mammals. This should be one of the objectives of the newly formed IUCN/CBSG Europe (Holst, 2003). Hopefully, this may lead to a clearer view about the value of captive breeding programmes and of existing captive populations. In Italy, for instances, specimens of the highly threatened Appennine brown bear *Ursus arctos marsicanus* are currently held in captivity in the Abruzzo National Park, without contributing to any direct conservation goal.

SYSTEMATIC AND CONSERVATION UNITS

A possible explanation for the scarce interest in captive-breeding programmes for Western Palearctic species is the perceived vast range of many native species, with a consequent low risk of endangerment at a global level. However, biomolecular techniques (sometimes coupled with more traditional taxonomic techniques), evidence the presence of notable intraspecific variability, sometimes overlooked because of unclear taxonomy (Taberlet and Bouvet, 1994), or the existence of true "sibling species" (Lovari, 1987). With a few exceptions (e.g. Iberian lynx *Lynx pardinus*, European mink), most European mammals are threatened at the subspecific or populational level (Tab. 1). Mitochondrial DNA studies revealed the presence of three different lineages in European *Ursus arctos*, (Taberlet and Bouvet, 1994) but lack of a ready source make inevitable the use

Tabella 1 - Threatened mammal subspecies and populations in Europe and category of threat (IUCN, 2002b). LR = Lower risk; cd = conservation dependent ; VU = Vulnerable; EN = Endangered; CR = Critically endangered.

SUBSPECIES	CATEGORY OF THREAT
Canis lupus Spain, Portugal	LR/cd
Canis lupus Italy	VU
Felis silvestris grampia	VU
Vormela peregusna peregusna	VU
Halichoerus grypus NE Atlantic	EN
Phoca hispida botnica	VU
Phoca hispida saimensis	EN
Genetta genetta isabelae	VU
Cervus elaphus corsicanus	EN
Capra aegagrus cretica	VU
Capra pyrenaica hispanica	LR/cd
Capra pyrenaica pyrenaica	CR
Capra pyrenaica victoriae	VU
Ovis orientalis musimon	VU
Rupicapra pyrenaica ornata	EN
Rupicapra rupicapra cartusiana	CR
Rupicapra rupicapra caucasica	VU
Rupicapra rupicapra tatrica	CR
Microtus oeconomus arenicola	CR
Microtus oeconomus méhelyi	VU

of bears from Slovenia (belonging to the "Balkan refugium" lineage) to restock the Pyrenean population which instead belong to the now endangered "Iberian refugium" lineage (Arquillière, 1998). One can question if the survival of one population takes precedence over the maintenance of distinct phylogeographic lineages. A CBP for the Iberian bear, if started some years ago should have avoid the need to mix these two lineages.

It is questionable whether subspecies (or populations) are a suitable focus for conservation programmes, given financial and technical constraints (e.g. Ryder *et al*., 1988; Maguire and Lacy, 1990; Schaller, 1996) and the confusion surrounding the subspecies concept itself (Ryder *et al*. 1988). However, considering that most European countries are among the most developed and wealthy in the world, conservation of biological diversity in Europe at such finer level seems fully justifiable (Gippoliti, 1996), and is also in agreement with the Convention on Biological Diversity signed by EU states in 1993. National scientific communities and wildlife agencies may be unwilling to reintroduce individuals with a different or unknown origin. Furthermore, local communities can provide greater support to conservation initiatives, if they feel they are protecting a unique natural heritage. It may also be noted that, if the phylogenetic species concept is adopted, many classical subspecies must be considered species (Meffe and Carroll 1997). Ehrlich (1988) rightly emphasised "The loss of genetically distinct populations within species is, at the moment, at least as important a problem as the loss of entire species". At least, as far as European mammals are concerned, loss of populations within species is possibly a more urgent problem than species extinction (see for instance the conservation status of *Capra pyrenaica* sspp., Pérez *et al*., 2002) . It is therefore essential that conservation programs (including CBP's) adopt populations as targets of their action. Former experience with several CBP's evidenced many cases of "outbreeding depression" (breeding incompatibility due to chromosomal arrangement) when individuals of the same "species", but of different origin, were incorporated in the same breeding population (Ryder *et al*., 1988; Schreiber *et al*., 1993; Marshall and Spalton, 2000). The negative effects of gene flow on the fitness of locally adapted populations have received scanty attention from conservation biologists (Storfer, 1999). Traditionally, translocations of free-ranging individuals for conservation purposes usually overlook intraspecific variability, on the assumption that the species range was formerly continuous. The extinct Alpine lynx represents a particular lineage of older origin, and a very close population could still exist in the Pyrenees (Anon., 1987; Hemmer, 1999). Accordingly, translocation of central European lynxes into France may result in the extinction, through competition or hybridisation, of a locally adapted population of great biogeographical and phylogenetic importance. That such deep population structure may exist in the European lynx has been recently demonstrated in Scandinavia by Rueness *et al*. (2003). Intraspecific variability among Palearctic species may be much higher than presently assumed. Waiting for genetic assessment, isolated populations should prudently not be the subject of restocking programmes using individuals originating from elsewhere. This may be the case for Iberian, Italian, Sicilian and Balkan populations of wildcat *Felis silvestris* (Hemmer, 1993), possibly isolated in southern Europe from mainland populations during the last Pleistocene glaciations (Ragni *et al*., 1993). Phylogeographic patterns emerging from several studies indicate the general inadequacy of continental European populations serving as sources for re-stocking or re-introduction operations in Italy and, possibly, in the other southern Europe peninsulas (Gippoliti and Amori, 2002). The continued reintroductions of roe deer *Capreolus capreolus* of central European origin into the Italian peninsula and their increasing number, a success from a wildlife management point of view, resulted in a serious setback for the survival and prospect of the few remaining autochthonous populations of roe deer (Lovari, 1993), whose distinctiveness has been recently confirmed by molecular investigations (Vernesi *et al*., 2002; Lorenzini *et al*., 2002).

On the other hand, there is a tendency in some cases to emphasise supposed differences between populations, although definitive scientific evidence is lacking. One such case is represented by the European otter (*Lutra l. lutra*). Some breeders do will not collaborate with the otter EEP owing to the possibility of mixing their pure-bred "Scandinavian", "British" or "French" otters (Vogt 1995), and a genetic study of the "Italian" population(s) has been proposed (Reggiani *et al*. 1997). The otter case seems particularly instructive, being a taxon whose former range extended over the whole of Europe and further east to the Pacific coast, but is now reduced to a few, small, fragmented populations (Robitaille and Laurence, 2002), where genetic drift is encouraged. Like in other "historic" captive-breeding programmes, the exact origin of the founder stock of *Lutra l. lutra* is not always known, and mixing with individuals of south-east Asian origin was suspected – this has been recently confirmed by bio-molecular investigations (Randi pers. comm.). The concern with the recent reintroduction of these mixed-origin otters into northern and central Italy should not lead to a negative attitude towards captive breeding, but to highlight the importance of a deep scientific foundation of any such project. However, if we bring at the extreme a "splitting approach", in the absence of further data, then we must admit that is neither possible nor reasonable to manage CBP's for each national otter population. Interestingly, preliminary mt DNA research on museum specimens and faeces seems to indicate that the otter population of southern Italy is genetically distinct from those of central and northern Italy (Bernardini, pers. comm.; Randi, pers. comm.). Therefore, for precaution reasons, this population should be considered as an indipendent management unit.

CAPTIVE-BREEDING: HOW AND WHERE?

The creation of a viable *ex situ* population for a particular taxon can have two main conservation goals. For highly threatened species it can represent the last chance of survival or, at least, an important component of a conservation strategy. In other instances, the aim can be to build up a secure population of a threatened, declining but still not critically endangered taxon. Clearly CBP's cannot be considered a panacea to wildlife conservation problems, especially when the prime cause of a species regression is habitat destruction, fragmentation and pollution. Too often in the past, great attention has been paid to the genetic and demographic viability of small populations instead of an understanding of the root causes of population decline. This 'small population paradigm' often results in incorrectly prescribing captive breeding as the sole or principal cure to a conservation problem (Caughley, 1994). However, zoos and other facilities may provide an effective temporary relief from risks such as human persecution, disease, genetic introgression through cross-species (or subspecies) breeding, and intra-guild competition or predation by alien or native taxa.

It is opportune here to consider that hybridisation (between different subspecies, with domestic forms or introduced similar species) following translocations is one of the major risks for many native taxa; e.g. wild boar *Sus scrofa* (Apollonio *et al*., 1988), Chartreuse and other chamois subspecies *Rupicapra rupicapra* sspp. (Schroder, 1985), wild goat *Capra aegagrus cretica* (Sfougaris, 1995), red deer *Cervus elaphus* (Lowe and Gardner, 1975; Wirth, 1990), red squirrel *Sciurus vulgaris* (Balciauskas, 1996), European beaver *Castor fiber* sspp. (Nolet and Rosell, 1998), brown hare subspecies *Lepus europeus* sspp. (Flux and Angermann, 1990), wolf *Canis lupus* (Delibes, 1990), and wildcat *Felis silvestris grampia* (McOrist and Kitchener, 1994).

Other native species suffer from competition when alien species are introduced in parts of the continent. The decline of red squirrel *Sciurus vulgaris* in Great Britain and northern Italy is coupled with the spreading of the North American grey squirrel *Sciurus carolinensis* (Bertolino and Genovesi, 2003). The European mink is possibly the most threatened mammal species in Europe. It is rapidly declining in supposed strongholds in Russia and is completely extinct in Estonia, where it is being replaced by the accidentally introduced American mink *Mustela vison* (Maran and Henttonen, 1995). Canadian beaver *Castor canadensis* have been introduced in some European countries and in Finland are known to have dominated and displaced the European beaver *Castor fiber* (Macdonald *et al*., 1995). The Apennine hare *Lepus corsicanus* has been only recently recognised as a distinct species by Palacios (1996) and Pierpaoli *et al*. (1999), but in the meantime its population has been severely reduced on mainland Italy (but not Sicily) by a combination of hunting and possible introduction of brown hare *Lepus europaeus* (and respective diseases) of Central European origin (Angelici and Luiselli, 2001; Trocchi and Riga, 2001).

Intraguild competition between native species is even sometimes advocated as the cause of a species decline or disappearance following the increase of another more eclectic species. In Europe for example, red fox *Vulpes vulpes* may limit the distribution of the arctic fox *Alopex lagopus* and affect the density of pine marten *Martes martes* (Linnell and Strand, 2000).

Diseases too are increasingly recognised as further causes of endangerment and extinction, as shown by the canine distemper epizootic which extirpated the last wild population of black-footed ferret *Mustela nigripes* in Wyoming (Thorne and Williams, 1988) or the recent outbreak of a disease of male sexual organs of still unknown origin in free-ranging and captive herds of European bison (Pucek, 1996).

Otherwise, captive populations (especially of so-called "flagship" species) can offer unique opportunities for environmental education programmes (Dietz *et al*., 1994; Gippoliti, 1996). In fact, many mammal species can act as symbols to promote awareness of the conservation problems of European habitats or to elucidate specific issues, such as the negative effects on wildlife of the introductions of exotic organism, straying dogs, unregulated tourism, pollution etc. For example, otters are splendid ambassadors of freshwater ecosystem conservation problems. However, conservation and educational objectives do not always coincide, and the two aspects must therefore be carefully balanced looking at the primary aim of the specific CBP. In an otherwise successful captive breeding program for the Appennine chamois *Rupicapra pyrenaica ornata* in Abruzzo (Mari *et al*., 2001), it seems that the great attention paid to 'faunistic areas' as tourist attractions resulted in sub-optimal genetic and veterinary management. This was probably the result of the excessive spreading of breeding nuclei and greater emphasis on the aesthetic attributes of the enclosures rather than on their functionality for species husbandry and management.

Obviously, goals influence where and how the CBP is managed. Ideally, for highly endangered taxa, the development of an *ad hoc* breeding facility represents the best choice. Such a facility should preferably be situated outside the present range, but in the historic range, of the species. At a later stage, it is advisable to disperse the population among different centres (Lacy, 1994; Maran, 1996), preferably located in the same bioclimatic zone from which the taxon of concern originates. Zoos, which decide to become involved with a CBP, must afford the creation of an off-exhibit facility. Intuitively, the housing of small mammals is much less costly and a small number of institutions can afford the cost of maintaining a whole viable captive population while, in the case of larger mammals, a greater number of institutions are needed. In the case of large mammals, the building of extensive off-exhibit facilities is out of the physical and financial capabilities of most zoos. Limited viewing by public through glass windows or video cameras seems a viable option. The alternative, to have CBP's carried out exclusively in one or more closed mono-specific breeding facilities, has been proposed and advocated (Ciucci and Boitani, 1991; Snyder et al., 1996) and sometimes realised for endangered mammals in the USA (e.g. black-footed ferret, Doncarlos *et al*., 1989) and Canada (e.g. swift fox *Vulpes velox*, Smeeton and Weagle, 2000). However, because the high costs of such programmes, these can be accomplished mainly by national or federal agencies, and probably, only for the most appealing species. In turn, this means diverting funds potentially available for "in situ" conservation to "ex situ" activities, and is criticised by many conservationists. The growing captive populations of black-footed ferret and red wolf (originally in one closed breeding facility) are now dispersed among several U.S. zoos (Moore and Smith, 1990; Reading et al., 1997).

For taxa not immediately at risk, but which present particular biological characters (limited distribution, edge of species range, know susceptibility to disease or to invasion of alien taxa, likelihood of hybridisation etc.), the building up of a viable captive population seems a worthwhile option. However, this must not be considered a higher priority, and must not compete with other conservation options. This "level II" of CBP should be carried out and financed mainly by "traditional" zoological collections, using resources currently allocated to similar, non-threatened species/taxon or conspecifics of unknown origin. Presently, European zoos hold stocks belonging to native species of poorly documented origin (e.g. wild boar, red deer, roe deer, brown bear, wolf) (i.e. Andrén *et al*., 1997). Captive populations may also offer many opportunities for research that can benefit our understanding of species taxonomy, biology and conservation needs, while providing basic information for the captive management itself (i.e. Laikre and Ryman, 1991; Asa and Valdespino, 1998).

There is a tendency to advocate CBP as last-ditch efforts for taxa that are already reduced to low population numbers. At that time, much of the species genetic variability is lost, and if a taxon recovers from very few founders, negative consequences and intensive genetic and demographic management have to be predicted (e.g. European bison, Hartl and Pucek, 1992; black-footed ferret, Reading *et al*., 1997). Therefore it is essential that the conservation community at large recognise the need of implementing a CBP before a taxon reaches an extinction crisis.

HUSBANDRY PRIOR OF RELEASE

The genetic and demographic viability of captive populations has been the primary goal of zoo managers (see Lacy, 1994 for a review). However, behavioural problems often represent a major challenge to propagation (Wielebnowski, 1998). Inevitably, captivity can alter the capacity of individuals to cope with the natural environment. The captive environment and husbandry regime may select behaviour and genotypes which are maladaptive in the wild. For example, among the cat family, breeding females that successfully rear their offspring in standard captive habitat will be genetically dominant in the next generation, while females that kill the offspring will be not represented in future generations. In this way, captive females are selected for their tameness and adaptability in the choice of a denning site, qualities which may be deleterious in the wild. Ironically, zoo personnel do sometime consider "unnatural" the behaviour of the killing mothers, although there is evidence that in more appropriate social and physical environments, the same females can show the typical maternal behaviour (Gippoliti pers. obs.). Increased docility is one result of captive populations. To counteract the effects of unwanted and unconscious selection, it is necessary that populations are maintained in the most natural social and physical setting, so reducing the effects of artificial selection (Arnold, 1995). It is ever more evident that the success of captive-bred mammal reintroductions is dependent on the husbandry and housing regime they experienced prior to release. Long-term captive breeding programmes may effectively depress the behavioural competence and survival skills, especially of carnivores (Miller *et al*., 1999). However, it appears that little attention has been paid by conservation biologists to the success of introduced species having a long history of domestication, such as the American mink. Generally, wild-caught individuals are considered more successful than captive-bred, and it is usually stated that herbivores reintroductions are easier to conduct than those concerning carnivores (Kleiman, 1996; Woodroffe and Ginsberg, 1999). It is almost clear, however, that given proper husbandry and training methods, carnivore reintroductions can work as well. Successful captive-bred reintroduced carnivores now include a wide array of Holarctic species: wolf, red wolf *Canis rufus* and swift fox among canids, European otter and black-footed ferret for mustelids, and the brown bear among the bear family (Jefferies *et al*. 1986; Moore and Smith 1990; Badridze *et al*., 1992; Carbyn *et al*., 1994; Sjöåsen, 1996; Miller *et al*., 1994). Globally, a wide array of cat species has been successfully reintroduced using captive-bred individuals (Law *et al*., 1997). In Bavaria, a population of wild cat has been re-established through the reintroduction of captive-bred and wild-caught individuals (Nowell and Jackson, 1996), while Rodriguez *et al.* (1995) report the successful reintroduction of a one year-old wild-born, but captive reared Iberian lynx. Prior to release, the lynx was kept in a 1 ha. enclosure with natural vegetation and live rabbits, having therefore the opportunity to develop and improve hunting skills. Exposure to live prey and large naturalistic enclosures seem the key of improved survival of reintroduced captive-bred swift foxes in Canada (Weagle and Smeeton, 1997). Training to learn recognition of predators is another valuable adjunct of reintroductions involving captive-bred mammals (McLean *et al*., 1996; Reading *et al*., 1997; Griffin *et al*., 2000). Prior to reintroduction of black-footed ferrets, Steppe polecats (*Mustela eversmannii*) were studied and released experimentally to test the effects of rearing experience in captivity. Results indicated that prior experience in killing prey, minimal contact with people and maintenance in large enclosures with resident prairie dogs as opposed to cages were the key factors in providing ferrets which were better predators and exhibited more developed predator avoidance behaviours (Reading *et al*., 1997, see also Vargas and Anderson, 1999). It is recommended that individuals for reintroduction programmes be selected on the basis of several factors, including previous history in captivity, age, sex, individual character and health, with the aim of reducing unnecessary losses among released stocks (International Academy of Animal Welfare Sciences, 1992). For example, care must be taken not to select hand-reared individuals or carriers of deleterious genetic traits; younger animals are preferable to adults but if they are too young they may be overconfident and incautious. Specific social systems must carefully be considered. For a reintroduction program, a compatible social group with the appropriate age/sex structure should be assembled prior to release, while in a restocking program (i.e. with an existing wild population in the release area), individuals belonging to one sex (the one more likely to emigrate) may be more easily accepted in existing social groups. Most reintroduction programmes include the maintenance of animals in enclosures or cages in the release site for a short period (i.e. Bright and Morris, 1994; see also Tab. 2). Sometimes, water and food is offered inside the pens after the release took place. Although experimental studies on the utility of such "soft release" approaches are limited, it is likely that it may constitute a critical factor in coping with stress factors (environmental change) if captive-bred individuals perceive the acclimatisation area as familiar. There is evidence of marked corticosteroid elevation when animals are moved to novel environments, but if the same animals can control their exposure to the new environment from their familiar cage by gradually exploring and being accustomed to it, no elevation of steroids is observed (Warburton, 1991). Such facilities can be particularly important with territorial species (Bright, 2000). Perhaps, it may prove desirable that individuals selected for reintroductions have already experienced some social and environmental changes, as they may respond better to stressors associated with return to the wild.

CONCLUSIONS

As more of the complex phylogeographic pattern of European mammals is discovered, captive-breeding programmes assume a potentially greater role in the conservation of biodiversity in Europe. Technically, it is now feasible to carry out controlled breeding programmes for all terrestrial mammals with reasonable hope to successfully reintroduce them back to the wild. However more attention must be paid to the selection of taxa to be cared for, establishing objective criteria that help to prioritise candidate taxa. CBP's are a costly technology and funds must be allocated very carefully. It is proposed to distinguish between CBP's (level I), which are part of the conservation strategy for seriously threatened taxa and need to be financed by state or federal agencies, and "prophylactic" CBP's (level II) for threatened or vulnerable taxa or populations, and for which funds may be available from the private sector (including zoos). In the first case, reintroduction of captive-bred individuals is the primary goal, and captive breeding must take place in *ad hoc* facilities designed to maintain the maximum amount of species-specific behaviours. In level II programs, the primary goal must be the creation of self-sustaining populations in more classical zoo setting and which offer research, education and eventually conservation opportunities. A proper knowledge of the phylogeography of threatened species seems essential for adequate choice of the conservation unit targeted for captive breeding.

Reintroductions must be part of an overall restoration project, following existing conservation guidelines (IUCN, 1995) and they should never be carried out as a problem-solving strategy for surplus captive individuals. Finally, the effective conservation of European mammal diversity will only benefit from a more efficient communication and closer collaboration between national wildlife agencies, zoologists and the zoo community.

Tabella 2 - European mammals reintroduced using captive-bred individuals and used method of release when known. SR = Soft release means holding animals in an enclosure in the reintroduction site for a time prior to release; HR = Hard release, without enclosure.

SPECIES	COUNTRY	RELEASE METHOD	REFERENCE
Felis silvestris	Bavaria -Germany	SR	Nowell and Jackson, 1996
Lynx lynx	Poland	SR	Blomqvist *et al*., 2000
Lutra lutra	England - UK	SR	Jefferies *et al*., 2000
Lutra lutra	Sweden	SR/HR	Sjöåsen, 1996
Mustela lutreola	Hiiumaa Is. - Estonia	HR/SR	Maran, pers. com.
Mustela nivalis	Finland	?	Hellstedt *et al*., 1999
Castor fiber	Poland	HR	Macdonald *et al*., 1995
Castor fiber	Netherlands	SR	Macdonald *et al*., 1995
Castor fiber	Germany	?	Macdonald *et al*., 1995
Muscardinus avellanarius	UK	SR	Bright and Morris, 1994
Glis glis	Poland	SR	Jurczyszyn, 2001
Cricetus cricetus	Netherland	SR	De Vries, 2002
Bison bonasus	Poland, Russia etc.	?	Pucek, 1991
Capra ibex	Switzerland	HR	Stuwe and Nievergelt, 1991
Capra ibex	Austria	HR	Blomquist and Reevers, 1996
Rupicapra pyrenaica	Abruzzo - Italy	HR	Dupré *et al*., 2002

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