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SETTLEMENT AND SUCCESSFUL BREEDING OF REINTRODUCED SPANISH IMPERIAL EAGLES *AQUILA ADALBERTI* IN THE PROVINCE OF CADIZ (SPAIN)

ASENTAMIENTO Y REPRODUCCIÓN CON ÉXITO DE ÁGUILAS IMPERIALES IBÉRICAS *AQUILA ADALBERTI* REINTRODUCIDAS EN LA PROVINCIA DE CÁDIZ (ESPAÑA)

Roberto MURIEL[1] *, Miguel FERRER[1], Eva CASADO[2], Agustín MADERO[3] and Cecilia PÉREZ CALABUIG[1]

SUMMARY.—A project to reintroduce the Spanish imperial eagle in the province of Cadiz (Andalusia, Spain) began in 2002. The aim was to restore the former breeding nucleus, to encourage subpopulation interconnection and to ensure the long-term persistence of the southern metapopulation of this endemic Iberian species. A population reinforcement programme also began in 2005 at a location in the Doñana area (Andalusia, Spain) to improve the viability of this endangered subpopulation. Between 2002 and 2010, a total of 73 young Spanish imperial eagles were released at four locations by means of hacking. As a result, in 2010 a released male bred successfully with a non-reintroduced female and two young were reared. This was the first successful breeding event recorded in Cadiz province since 1960. An additional territorial pair also settled in the release area in 2010 and four more translocated individuals have made breeding attempts within nearby breeding subpopulations since 2006. The settlement and breeding of reintroduced individuals is the starting point of a future population and constitutes a relevant indicator for the evaluation of the project.

RESUMEN.—En 2002 comenzó un proyecto de reintroducción del águila imperial ibérica en la provincia de Cádiz (Andalucía, España) con el fin de recuperar un antiguo núcleo reproductor, favorecer la conexión entre subpoblaciones e incrementar la persistencia de la metapoblación de esta especie endémica de la península Ibérica. Del mismo modo, en 2005 se puso en marcha un programa de refuerzo en el entorno de Doñana (Andalucía, España) para mejorar la viabilidad de esta amenazada subpoblación. En total, entre 2002 y 2010, 73 jóvenes águilas imperiales se soltaron en cuatro zonas mediante crianza campestre. En 2010 un macho reintroducido crió con éxito con una hembra no reintroducida y sacaron adelante dos pollos, siendo el primer nido exitoso que se registra en la provincia de Cádiz desde 1960. Otra pareja territorial se instaló también en la zona de suelta en 2010 y otros

[1] Department of Ethology and Biodiversity Conservation, Biological Station of Doñana (EBD-CSIC), C/ Américo Vespucio s/n, 41092 Sevilla, Spain.

[2] Migres Foundation, C/ Inca Garcilaso 1, Edificio REE, 41092 Sevilla, Spain.

[3] Consejería de Medio Ambiente de la Junta de Andalucía, Delegación de Jaén, Spain.

* Corresponding author: muriel@ebd.csic.es

cuatro ejemplares reintroducidos han hecho intentos de reproducción desde 2006 en otras subpoblaciones cercanas fuera del área de reintroducción. El asentamiento y reproducción de individuos reintroducidos supone el punto de partida para una futura población y constituye un importante indicador para la evaluación del proyecto.

The Spanish imperial eagle *Aquila adalberti* is considered one of the most threatened and rarest birds of prey in the World (González and Oria, 2004). It is classified as Vulnerable in the IUCN Red List (BirdLife International, 2008) and as Endangered in the Spanish National Catalogue of Endangered Species and the Red List of Birds (González and Oria, 2004). The species suffered a population decline throughout the first half of the 20th century as a consequence of habitat changes and fragmentation, the population collapse of its principal prey the wild rabbit *Oryctolagus cuniculus* and, in particular, the high mortality caused by electrocution on power lines, poisoning and direct persecution (Ferrer, 2001; González *et al*., 2008). Its situation was critical by the 1970s, when fewer than 40 breeding pairs were recorded and its distribution was limited to the southwestern quadrant of Spain (González *et al*., 1989). However, as a result of the implementation of several conservation measures, the Spanish imperial eagle population has experienced a gradual recovery over the last 30 years (Ortega *et al*., 2009), reaching 282 pairs in 2010 (Spanish Imperial Eagle National Working Group unpublished data, 2010) and returning once more to breed in Portugal (Blanco and Pacheco, 2003).

In spite of this recovery, the population is still unstable and its long-term persistence, unless conservation efforts are sustained, is threatened by the small population size, a restricted geographical distribution and population fragmentation into five main subpopulations each of 40-60 pairs, between which there is limited interchange (González and Oria, 2004; Martínez-Cruz *et al*., 2007). In addition, the Spanish imperial eagle is a long-lived species with slow demography, facultative philopatry and conspecifics attraction, characteristics that reduce the likelihood of a natural recolonisation of former breeding areas and the occupation of new areas of optimal quality (Ferrer, 1993). Hence, the observed population expansion in recent decades has not been accompanied by establishment within new areas, but has instead involved a slow expansion of the periphery of existing subpopulations (González *et al*., 2006b; González *et al*., 2008). This recovery has not been homogeneous in time or throughout the geographical range. The continuous population increase slowed temporarily during the 1990s due to poisoning. The Doñana subpopulation was the most affected due to its small size and apparent demographic isolation (Ferrer, 2001; Martínez-Cruz *et al*., 2007), decreasing from sixteen to a minimum of seven occupied territories with a noticeable reduction in productivity (Ferrer and Penteriani, 2008; Ferrer *et al*., 2009).

Although conservation actions involving this species have usually deal with habitat management, productivity increase and the reduction of non-natural mortality, the restoration of former breeding populations has been also considered as a way to accelerate and consolidate the recovery process (Parque Nacional de Doñana, 1992; Ferrer, 2001; Ministerio de Medio Ambiente, 2001). Therefore, in 2002 a programme to reintroduce the Spanish imperial eagle was started in the Andalusian province of Cadiz (southern Spain) with the aim of restoring a traditional breeding population, encouraging interconnection and exchange between subpopula-

tions and increasing the overall long-term viability of the southern metapopulation. Cadiz province is a former breeding area of the species, where a habitat availability study (Madero and Ferrer, 2002) based on nesting habitat selection analysis (González *et al*., 1992) has shown that there is suitable habitat and sufficient prey density to support a population of at least 19-30 breeding pairs. In addition, a specific conservation plan was started in 2005 in the Doñana area, including a reinforcement programme in order to increase the number of breeding pairs, to reverse the population aging process and to correct the detected preponderance of males (Ferrer and Penteriani, 2008; Ferrer *et al*., 2009). Both projects were developed by the Environmental Department of the Andalusian Government under the scientific supervision of the Biological Station of Doñana (CSIC) and they were based on previous comprehensive studies on genetics, habitat availability, population/metapopulation dynamics, impact on donor populations and viability analysis (see e.g. Ferrer and Calderón, 1990; González *et al*., 1992; Madero and Ferrer, 2002).

We here briefly summarise and evaluate the main results currently achieved (2010) by the reintroduction and reinforcement programmes of the Spanish imperial eagle in Andalusia with especial emphasis on the settlement and reproduction of the first breeding pair in Cadiz province.

Between 2002 and 2010, 58 young Spanish imperial eagles were released by means of hacking techniques in three neighbouring locations in the La Janda area in Cadiz province (mean 6.44 ± 2.3 individuals/year, range = 4-12) and 15 in the Doñana area (mean 3 ± 1.23 individuals/year, range = 2-5), with an overall sex ratio close to 1:1 (table 1, fig. 1). Most of the hacked birds were wild-hatched chicks and only a few came from wild-laid eggs hatched in captivity. They were translocated from the Andalusian subpopulation of Sierra Morena (Jaen 67.1%, Seville 20.6%, Cordoba 11%) and most of them were rescued chicks subject to a high death risk due to disease, nest collapse, siblicide or parental desertion. These management measures, together with supplementary feeding and collaboration with landowners to avoid disturbance in the nesting areas, have previously been shown to be useful to encourage chick survival and to increase in the productivity of low-quality territories (González *et al*., 2006a; Consejería de Medio Ambiente, 2009; Madero and Pacheco, 2009). Nestlings were translocated when 47.8 ± 6.1 days old on average (range = 36-64 days, N = 58) to the hacking facilities, where they spent 28.8 ± 6.2 days before fledging (range = 15-42 days, N = 57). Prior to release, all nestlings were equipped with conventional back-pack radio-transmitters (models TW-3, Biotrack Ltd., UK; and 5/XOB 17-04, Wagener Telemetrieanlagen, Germany) to enable monitoring during the post-fledging and dispersal periods. A further eight nestlings were tagged with satellite transmitters (Microwave Telemetry Inc., USA; and North Star Science and Technology, USA). Transmitters were fixed on the nestlings using a harness (Kenward, 2001) and did not exceed a maximum of 2.5% of the body weight at fledging. Nestlings were marked with a metal ring from the Spanish Environmental Department and a colour ring allowing identification at a distance. Biometric measurements and blood samples were also taken for subsequent sex determination and analyses.

The eagles improved their flight techniques such as soaring and performed short exploratory flights out of the reintroduction area during the course of the post-fledging period before dispersal. They left the hacking area and started dispersal at a mean age of 143.4 ± 15.5 days (range = 112-178 days, N = 57). Released individuals showed the usual juvenile dispersal behaviour with medium-long range movements, the use of

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TABLE 1

Total number of released Spanish imperial eagles distributed by year and sex in the province of Cadiz and the area of Doñana between 2002 and 2010.
[Número total de águilas imperiales ibéricas reintroducidas según año y sexo en la provincia de Cádiz y el entorno de Doñana entre 2002 y 2010.]

	Cádiz			**Doñana**			**Total**			
Year *[Año]*	**Males** *[Machos]*	**Females** *[Hembras]*	**M+F** *[M+H]*	**Males** *[Machos]*	**Females** *[Hembras]*	**M+F** *[M+H]*	**Males** *[Machos]*	**Females** *[Hembras]*	**M+F** *[M+H]*	**Accumulated** *[Acumulado]*
2002	3	2	5	0	0	0	3	2	5	5
2003	2	4	6	0	0	0	2	4	6	11
2004	4	2	6	0	0	0	4	2	6	17
2005	1	4	5	0	3	3	1	7	8	25
2006	3	4	7	0	3	3	3	7	10	35
2007	3	1	4	2	0	2	5	1	6	41
2008	4	3	7	0	2	2	4	5	9	50
2009	3	3	6	4	1	5	6	4	11	61
2010	6	6	12	0	0	0	6	6	12	73
Total	29	29	58	6	9	15	34	38	73	

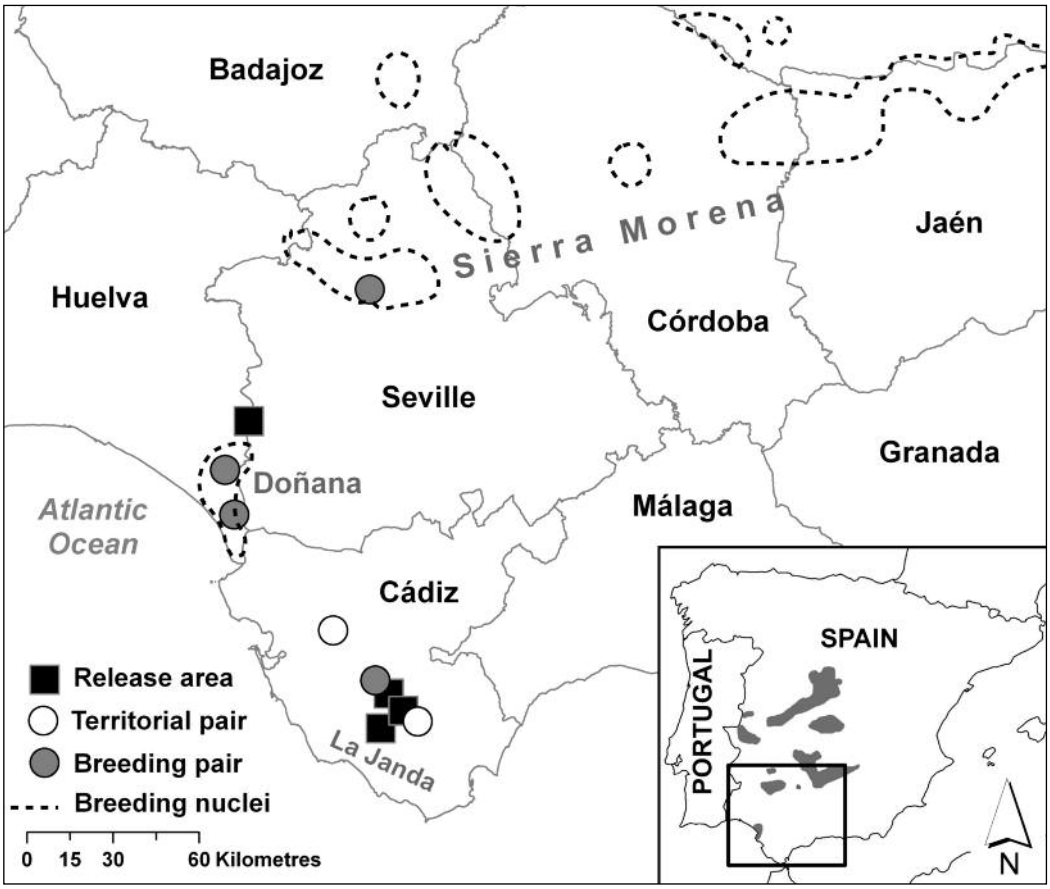

FIG. 1.—Geographical location of release areas in the province of Cadiz and the area of Doñana, and the territorial/breeding pairs with at least one reintroduced member, in Andalusia (SW Spain). A breeding pair was considered when at least egg laying was recorded. Current distribution of breeding subpopulations is showed in the location map. Territories are slightly shifted to avoid their location.
[Localización geográfica de las áreas de reintroducción en la provincia de Cádiz y el entorno de Doñana y de las parejas territoriales/reproductoras con al menos un miembro reintroducido, en Andalucía (SO España). Se consideró pareja reproductora cuando al menos se registró puesta de huevos. La distribución actual de las subpoblaciones reproductoras se muestra en el mapa de localización. Los territorios están ligeramente desplazados para evitar su localización.]

temporary settlement areas, visits to breeding subpopulations and occasional returns to the hacking area (Ferrer, 1993). Despite the proximity of the reintroduction localities to traditional dispersal areas in Cadiz, the juveniles did not restrict their movements and used other dispersal areas beyond Andalusia, such as southern Extremadura, Castilla-La Mancha and southern Portugal.

Following an estimation of survival rates based only on those individuals with known fates ($N_{known\text{-}fate}$), and excluding those with transmitter loss/failure or premature signal loss, we found that 83% of hacked juveniles

survived until six months old ($N_{known\text{-}fate}$ = 54) and 66.7% until their first year ($N_{known\text{-}fate}$ = 45). The main cause of juvenile death, assessed from recovered carcasses (N = 19), was electrocution (79%) with a noticeable sex-biased ratio since females were more likely to die in this manner (73.3% of electrocuted individuals). The remaining deaths were due to poisoning (10.5%), fence collision (5.3%) and natural causes (5.3%).

The first pair that occupied a territory and displayed courtship behaviour and territorial defence was recorded in 2006, only four years after releases began, 30 km from the hacking area in Cadiz (table 2; fig. 1). The pair was formed by a male released in 2003 in Cadiz and an unringed immature female. However, the female disappeared and the male moved to the Sierra Morena breeding area in the north of Seville province, more than 160 km from the hacking area, where he paired with a female released in 2003. They laid eggs and at least one chick hatched but it disappeared, probably because of predation, so the breeding attempt failed. In the following year, the male probably died since it was not relocated in the breeding area. However, the female bred again with a non-reintroduced immature male. Two eggs were laid and abandoned but they were rescued and successfully incubated in the Spanish imperial eagle Captive Breeding Centre (Seville). One of the chicks was hacked in Doñana and the other integrated into the captive breeding stock.

Two other breeding attempts by different hacked individuals were also recorded in the Doñana area. The first was in 2008, between a male released in Cadiz and a non-reintroduced female. Although they did not lay eggs in their first attempt they bred successfully in the following two years (table 2). Another male released in the Doñana area in 2007 made a breeding attempt with an unidentified female in 2009 but the eggs failed to hatch.

The first stable territorial pair to settle in Cadiz was recorded in 2009, seven years after the reintroduction project began. The male was released in 2007 in Cadiz and returned for the first time to the release area in 2008, when he was observed interacting with released fledglings and perching on the hacking cages and the artificial feeders. An unringed four year-old female appeared in the territory in mid 2009 and both showed courtship behaviour and territorial defence. An artificial platform was installed to encourage their settlement but they built their own nest on a cork oak *Quercus suber* only 2.3 km from the hacking site. First copulations were observed in February 2010 and eggs were laid and incubation began in mid March. Hatching occurred around April 25th and two chicks were later observed in the nest. Access to the nest was difficult so only one female nestling could be ringed and fitted with a conventional transmitter at around 54 days old. As for reintroduced individuals, biometric measurements and a blood sample were taken for subsequent sexing and analysis. Both nestlings developed normally and fledged when around 77 days old. During the post-fledging period they developed their flight skills and the ringed fledgling at least performed exploratory flights up to 15 km away, although always returning to the territory until dispersal at the end of September, when 158 days old. Both fledging and dispersal ages were within the usual ranges recorded for the species (Ferrer, 1992; Ferrer, 1993).

In 2010 another new pair also occupied a territory close to the third release location in Cadiz and showed territory defence. It was formed by a male reintroduced in Cadiz in 2008 and a wild-reared immature female from Doñana.

The behaviour of both the breeding pair and the new territorial pair affected the post-fledging behaviour of the juveniles reintroduced in 2010 in Cadiz. We detected territorial flights over the reintroduction areas and even aggression towards the young eagles,

TABLE 2

Summary of all territorial/breeding Spanish imperial eagle pairs recorded with at least one member from the reintroduction program in Andalusia. Each released individual is identified by a specific code and age in years is provided between brackets.
[Resumen de todas las parejas territoriales/reproductoras de águila imperial ibérica registradas con al menos un miembro procedente del proyecto de reintroducción en Andalucía. Cada individuo reintroducido es identificado con un código específico y se proporciona su edad en años entre paréntesis.]

Id	Year *[Año]*	Male *[Macho]*	Female *[Hembra]*	Area *[Zona]*	Province *[Provincia]*	Status *[Estatus]*	Commentaries *[Comentarios]*
1	2006	**M1** (3)	*Non-released*	North Cádiz	Cádiz	Territorial	
2		**M1** (3)	**F1** (3)	Sierra Morena	Seville	Breeding	Failure
3	2007	*Non-released*	**F1** (4)	Sierra Morena	Seville	Breeding	2 eggs rescued[a]
4	2008	**M2** (2)	*Non-released*	Doñana	Huelva	Territorial	
5	2009	**M2** (3)	*Non-released*	Doñana	Huelva	Breeding	1 nestling rescued[b]
6		**M3** (2)	*Non-released*	La Janda	Cádiz	Territorial	
7		**M4** (2)	*Non-released*	Doñana	Huelva	Breeding	Failure
8	2010	**M2** (4)	*Non-released*	Doñana	Huelva	Breeding	2 fledlings
9		**M3** (3)	*Non-released*	La Janda	Cádiz	Breeding	2 fledlings
10		**M5** (2)	*Non-released*	La Janda	Cádiz	Territorial	

[a] Breeders abandoned incubation. Both eggs were successfully incubated in the Spanish imperial eagle Captive Breeding Centre (Seville). One chick was hacked in Doñana and the other one was integrated in the captive breeding stock.
[Los reproductores abandonaron la incubación. Ambos huevos fueron incubados con éxito en el Centro de Cría en Cautividad del Águila Imperial Ibérica (Sevilla). Un pollo fue reintroducido en Doñana y otro fue integrado en el grupo de reproductores en cautividad.]

[b] Nestling with physical problems, treated in a wildlife rehabilitation centre and subsequently hacked in Doñana.
[Pollos con problemas físicos, tratados en un centro de rehabilitación de vida silvestre y posteriormente reintroducidos en Doñana.]

which led to a premature departure from the reintroduction area by the released individuals and a shorter post-fledging period of 30.5 ± 13.98 days (range = 8-49 days, N = 12) relative to the expected period of 51.5 days (Ferrer, 1992).

The settlement of this first territorial pair in the vicinity of the reintroduction area constitutes a starting point for a future new breeding population and is thus a significant achievement on the way to the eventual success of the reintroduction programme. However, progress is inevitably slow in the case of a long-lived, slow-maturing, territorial species such as the Spanish imperial eagle, particularly when release rates are low. The first successful breeding of the Spanish imperial eagle in Cadiz province in the last 50 years (the last pair of adults was recorded in 1960; González *et al*., 1989), eight years after the project started, is an unquestionable achievement in the process of restoration of a former breeding population by means of reintroductions. Taking into account the annual release rate in Cadiz (table 1) and assuming an age at first breeding of three years (fourth calendar year), a pre-breeding mortality of 82% and an annual mortality of breeders of 7.3% (Ferrer and Calderón, 1990; Ortega *et al*., 2009), the first potential pair would have been expected five years after starting releases and the first two pairs after seven years. Our observed results thus met our prior expectations even considering that this is a simple deterministic approach without considering sexual, demographic or environmental stochasticity, or metapopulation dynamics, and are comparable with those observed in other reintroduction projects involving large territorial raptors with delayed maturity and similar release rates, such as the bald eagle *Haliaeetus leucocephalus* projects in the USA (first success after six years in Oklahoma and Indiana; Castrale, 1991; Jenkins and Sherrod, 2005;), the white-tailed eagle *Haliaeetus albicilla* in Scotland (first success after ten years; Evans *et al*., 2009) or the golden eagle *Aquila chrysaetos* reintroduction in Ireland (first success after six years; Golden Eagle Trust, 2008). However, caution must be taken when comparing reintroduction outcomes since species biology, environmental conditions and release methods differ between projects.

In addition, the breeding recruitment of released individuals into other existing subpopulations and the settlement of non-reintroduced birds in Cadiz also confirm the breeding interconnection and the subsequent gene flow between the incipient nucleus in Cadiz and other subpopulations, especially that in Doñana. The trade off between philopatry and conspecific attraction in this species might also play a relevant role since released individuals may disperse from the release area to other non-saturated breeding subpopulations within the dispersal range (González *et al*., 1992; Doligez *et al*., 2003). Conversely, settled pairs may encourage the recruitment of new individuals and thus speed up the recolonisation process (Ahlering and Faaborg, 2006).

The settlement of territorial pairs in the vicinity of release sites may involve conflicts and alterations in the behaviour and use of space of reintroduced juveniles during the post-fledging period, as already observed in 2010. Hence, in 2011 the hacking sites in Cadiz were moved to two new locations at least 15 km from the nearest territorial pair in La Janda.

In long-lived raptors, mortality tends to be concentrated in the pre-breeding period and mainly during the first year of life (Newton, 1979; Ferrer and Calderón, 1990; McIntyre *et al*., 2006). However, although hacked individuals came from lower-quality or problematic territories, the recorded juvenile survival rate was similar to that estimated for the global population during 1990-2001 (six months: 89.4%, one year: 66.9%; Ortega *et al*., 2009) and noticeably higher than that of

the nearby Doñana subpopulation, which shares similar dispersal areas, during 1986-1989 (six months: 39.2%; Ferrer, 2001). This last difference could be due to reduction of mortality factors over the last 20 years, especially the modification of dangerous power lines in the breeding and dispersal areas (López-López *et al*., 2011). However, electrocution was still the main cause of death among released juveniles, particularly females, which are under a greater risk of electrocution at pylons on account of their longer wingspan (Ferrer and Hiraldo, 1992). This sex-biased mortality, together with higher male philopatry, could be the underlying causes of the higher recruitment rate observed in males: five of the six settled individuals were males.

The final aim of any reintroduction project is to attain a long-term, self-sustaining, population with nil or little human intervention in the release area (Seddon, 1999). Hence, we believe that releases should continue to support the initial breeding attempts at least until natural productivity of settled pairs in Cadiz province achieves the annual average release rate (6.44 ± 2.33 individuals). That would mean attaining a minimum of 4-5 occupied territories with a mean productivity similar to that recorded by Ferrer and Donázar (1996) for non-saturated populations (1.43 fledglings per pair).

The Spanish imperial eagle reintroduction and reinforcement projects constitute clear examples of active management actions that may be undertaken in multiple-approach conservation plans together with more traditional measures. Reintroductions by means of hacking have proved to be especially effective and valuable in birds of prey (Sherrod *et al*., 1981; Cade, 2000; Negro *et al*., 2007) and therefore can be used as potentially useful tools for population restoration with appropriate planning, development and monitoring (IUCN, 1998). Translocations and reintroductions seem likely to be used more extensively in the future, especially in the face of rapid global changes and corresponding distributional shifts of certain species, but also with regard to the favourable socio-ecological conditions that remain within the former ranges of threatened species. Consequently, it is important to improve our understanding of the limitations and applications of these techniques, sharing the results and thus increasing our expertise in wildlife restoration strategies.

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