Terrestrial Mammal Conservation

Global evidence for the effects of interventions for terrestrial mammals excluding bats and primates

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Cover image: Cape mountain zebra (*Equus zebra zebra*), De Hoop Nature Reserve, South Africa. Photograph by Rebecca K. Smith, CC-BY.

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14. Species management

Background

Most of the chapters in this book are aimed at minimizing threats, but there are also some interventions which aim specifically to increase population numbers by increasing reproductive rates and by introducing individuals. This chapter describes interventions that can be used to increase population size by translocating wild mammals from one area to another, by breeding or rearing mammals in captivity (ex-situ conservation) to release back into the wild or by enhancing resources available for mammals in ways that can be used to address multiple threats (such as by providing artificial dens or nest boxes).

14.1. Cease/reduce payments to cull mammals

https://www.conservationevidence.com/actions/2349

- **One study** evaluated the effects of ceasing or reducing payments to cull mammals. This study was in Sweden and Norway[1].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (1 STUDY)

- **Survival (1 study):** A before-and-after study in Sweden and Norway[1] found that fewer brown bears were reported killed after the removal of financial hunting incentives.

BEHAVIOUR (0 STUDIES)

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Background

Financial incentives for hunting particular species of mammal may be awarded for a variety of reasons, including agricultural protection, disease control and human safety. Whilst the intention of making such payments is to increase hunting of focal species, hunter motivations are varied (e.g. Gigliotti & Metcalf 2016) and may include more than financial reward. Hence, removal of payments may or may not have the desired consequence of reducing hunting pressure on species.

Gigliotti L.M. & Metcalf E.C. (2016) Motivations of female black hills deer hunters. *Human Dimensions of Wildlife*, 21, 371–378.

A before-and-after study in 1888–1898 in Sweden and a before-and-after study in 1925–1935 in Norway (1) found that after the removal of financial hunting incentives fewer brown bears *Ursus arctos* were reported killed. In both Sweden and Norway, fewer bears were reported killed during the five years after the removal of financial hunting incentives (Sweden: average 14 bears/county/year; Norway: average 1 bear/county/year) than during the five years before the removal of financial hunting incentives (Sweden: average 25 bears/county/year; Norway: average 3 bears/county/year). Financial incentives to cull bears were eliminated in 1893 in Sweden and in 1930 in Norway. Additionally, in 1930, bear hunting on someone else's property was banned in Norway. Numbers of bears killed were obtained from national harvesting records.

(1) Swenson J.E., Wabakken P., Sandegren F., Bjärvall A., Franzén R. & Söderberg A. (1995) The near extinction and recovery of brown bears in Scandinavia in relation to the bear management policies of Norway and Sweden. *Wildlife Biology*, 1, 11–25.

14.2. Temporarily hold females and offspring in fenced area to increase survival of young

https://www.conservationevidence.com/actions/2351

- We found no studies that evaluated the effects on mammals of temporarily holding females and offspring in a fenced area to increase survival of young.

'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore, we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Survival of new-born mammals can be low, due to a variety of factors including predation. Capturing pregnant females and temporarily holding them and their new-born offspring in fenced areas within their native range (short-term or 'maternal penning'), for the first few weeks of life when young are most vulnerable to predation, may result in increased survival of young. This could help to slow decline, maintain or increase population size.

14.3. Rehabilitate injured, sick or weak mammals

https://www.conservationevidence.com/actions/2352

- **Thirteen studies** evaluated the effects of rehabilitating injured, sick or weak mammals. Four studies were in the UK[3,4,5,8], three were in Spain[6,9,13], two were in Argentina[10,12] and one each was in Uganda[1], Australia[2], the USA[7] and Brazil[11].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (12 STUDIES)

- **Survival (11 studies):** Five studies, in the UK[3,4,5,8] and Spain[9], found that varying proportions of European hedgehogs released after being rehabilitated in captivity survived during

post-release monitoring periods, which ranged from two weeks[3] to 136 days[9]. Five studies, in Australia[2], Spain[6,13], the USA[7] and Brazil[11], found that four koalas[2], an Iberian lynx[6], a gray wolf[7], a puma[11] and two brown bears[13] released following rehabilitation in captivity survived for varying durations during monitoring periods, which ranged in length from three months[6] to up to seven years[13]. A study in Argentina[10] found that over half of released rehabilitated and captive-reared giant anteaters survived for at least six months.

- **Condition (2 studies):** A study in Uganda[1] found that a snare wound in a white rhinoceros healed after treatment and rehabilitation. A study in the UK[3] found that two of three rehabilitated European hedgehogs lost 12–36% of their body weight after release into the wild.

BEHAVIOUR (1 STUDY)

- **Behaviour change (1 study):** A controlled study in Argentina[12] found that released wild-born rehabilitated giant anteaters were more nocturnal in their activity patterns than captive-bred individuals.

Background

Mammals that are injured, sick or found in a weak condition are sometimes taken in by wildlife rehabilitators, to be treated and released back into the wild. Often, this is done more for animal welfare reasons than for species conservation though, for rare species, release of such animals may provide opportunities for choosing where to augment populations. The success of such programmes can be difficult to judge, without benchmark data for survival of wild-reared mammals. It is also important to note that the majority of studies summarised below have very small sample sizes, and that unsuccessful attempts are less likely to have been reported.

A study in 1965 in a grassland site in West Nile District, Uganda (1) found that after rehabilitation, a snare wound in a white rhinoceros *Ceratotherium simum simum* healed. One day after an operation to retrieve a deeply embedded snare from a leg, the adult female white rhinoceros was walking and grazing. Three weeks after the operation, the wound appeared nearly healed and, after six weeks, the rhinoceros was not limping anymore. Five months after the operation, the rhinoceros produced a calf. In July 1965, a white rhinoceros found limping due to a snare wound was immobilised and the snare was cut out with a hacksaw. The wound was swabbed with alcohol, smeared with intramammary penicillin and dusted with penicillin powder. A rough bandage was applied and, during the operation, the rhinoceros was injected with dimethylchlortetracycline.

A study in 1988–1989 in a woodland site in Queensland, Australia (2) found that four injured and rehabilitated koalas *Phascolarctos cinereus* each survived for between at least 20 days and four months after release. Two males moved 2.8 and 3.5 km and left the study area within one month. One settled 6 km from the release site (duration not stated). The other could not be relocated after last being recorded 1.4 km from the release site. Two females moved 0.9 and 1.3 km in 30 days. One female was recaptured after two months (suffering from disease). The other was recaptured after four months (due to collar-induced injuries). Four koalas, rehabilitated after minor road accident injuries, were released in September–November 1988 at adjacent localities (precise spacing not stated). Koalas were monitored daily by radio-tacking for 30 days after release, then twice weekly.

A study in 1989 in a forest and grassland site in Yorkshire, UK (3) found that three of four European hedgehogs *Erinaceus europaeus* that had been treated for injuries and released back into the wild survived over two weeks, but two of the three surviving hedgehogs lost weight. Three of four released hedgehogs survived for at least two weeks in the wild, built nests, and established home ranges (total area 6–17 ha). The other hedgehog (a male) died three days after release. After two weeks, two of the three surviving hedgehogs had lost significant body weight (12–36%). Two female and two male hedgehogs were released in June 1989 following treatment in captivity for injuries. Hedgehogs were radio-tracked for 15 nights after release and were located at least once

every hour throughout the night until they nested. Hedgehogs were captured and weighed at release and every 1–2 nights throughout the study.

A study in 1991 in a farmland site in Suffolk, UK (4) found that over one third of rehabilitated European hedgehogs *Erinaceus europaeus* survived more than seven weeks after release into the wild. At least three out of eight (38%) rehabilitated hedgehogs survived over seven weeks post-release, though one then drowned and one was killed in a road accident. Contact was lost with four animals, but authors report that they were probably still alive at least five weeks after release. One hedgehog died due to illness within two weeks. Eight hedgehogs, rehabilitated after being found injured, ill or underweight, were released in a mosaic of pasture, hay meadow and arable land in July 1991. Animals were radio-tagged and followed nightly during the first three weeks post-release and sporadically until the eighth week post-release.

A study in 1993 in pasture on a farm in Devon, UK (5) found that 40% of rehabilitated juvenile European hedgehogs *Erinaceus europaeus* survived for at least nine weeks after release back into the wild. Of 10 hedgehogs monitored, four were still alive at the end of the nine-week monitoring period, three had been predated by European badgers *Meles meles*, two had been killed on roads and one sick animal had been euthanized. Two further animals survived for at least three and four weeks before losing their radio transmitters. Twelve hedgehogs (6 male, 6 female) were released on or shortly after 2 April 1993. They were wild-born, but had been taken into captivity at a wildlife hospital as underweight juveniles the previous year. Hedgehogs weighed 82–312 g when taken into captivity and 560–1,106 g at time of release. Survival and movements were monitored by radio-tracking.

A study in 1991–1992 in a shrubland and grassland site in Sierra Morena, Spain (6) found that a rehabilitated Iberian lynx *Lynx pardinus* survived at least three months after release back into the wild. The lynx was still alive at least 93 days after release, and radio-collar fixes suggested it had established a 220 ha territory. On 6 July 1991, a wounded male Iberian lynx kitten (approximately four months old, weighing 2 kg) was brought into captivity with superficial wounds and a fractured femur. The wounds were treated and the animal was

kept in a small cage with padded walls. After 43 days, it was moved to a 5 × 5-m outdoor enclosure where it was fed European rabbits *Oryctolagus cuniculus* for 112 days. After this, the animal (weight 4.9 kg) was fitted with a radio-collar and moved to a 1-ha enclosure with natural vegetation and wild rabbits. After 83 days in this enclosure, on 2 March 1992, the animal (weight 6.0 kg) was released in a pine stand, 9 km from where it was originally found. It was monitored daily until the radio-collar fell off.

A study in 1995–1999 in a forest and wetland site in Wisconsin, USA (7) found that a gray wolf *Canis lupus* treated for a leg injury subsequently survived in the wild for at least 4.5 years. The young adult (>1 year) male wolf sustained torn ligaments and an elbow dislocation to a front leg, following capture in a leg-hold trap on 21 May 1995. The dislocation was repaired using artificial ligaments. The wolf was transferred to a holding pen, but escaped on 23 May 1995. Roadkill deer were supplied for six months following the animal's escape. The wolf was monitored primarily by locating tracks, and was still alive on 24 September 1999. The escape site was a 36-km^2 wildlife area, enclosed in a 3-m high deer-proof fence. No other wolves were present at the time of escape though two subsequently entered and the three were observed travelling together.

A controlled study in 2004 in suburban gardens in Bristol, UK (8) found that most rehabilitated European hedgehogs *Erinaceus europaeus* survived over eight weeks after release back into the wild. The probability of rehabilitated hedgehogs surviving more than eight weeks after release into the wild was 73%. However, over the same period, resident wild hedgehogs in the same study area had a survival probability of 95%. Body weight decline in rehabilitated hedgehogs (13%) was similar to resident hedgehogs (5%). However, the night range of rehabilitated hedgehogs (0.58 km^2) was smaller than that of resident hedgehogs (1.67 km^2). Between May and June 2004, twenty rehabilitated hedgehogs were released, one each in 20 suburban gardens. Food was provided during the first week. Rehabilitated hedgehogs and 20 wild hedgehogs inhabiting the same gardens were radio-tracked over eight weeks. Hedgehogs were weighed every 10 days. No details about the rehabilitation are provided.

A study in 2006–2008 in four forest and farmland sites in a protected area near Barcelona, Spain (9) found that more than half of rehabilitated European hedgehogs *Erinaceus europaeus* released back into the wild survived over 20 days and one hedgehog survived for at least four months. Ten of 15 released hedgehogs survived for at least 9–136 days in the wild before their radio-tags were lost. Eight of them survived for at least 22–58 days, and one survived for at least four months. The other five hedgehogs died within two months of release due to predation (two hedgehogs), accidents (two hedgehogs) or unknown causes (one hedgehog). In 2006–2008, seven male and eight female rehabilitated hedgehogs were released across four sites in Collserola Natural Park. No details about rehabilitation are provided, but all individuals were considered healthy at the time of release. The released hedgehogs were radio-tagged and their locations were recorded 9–42 times over 5–136 days between July 2006 and June 2008.

A study in 2007–2014 in a grassland reserve in Corrientes Province, Argentina (10; same experimental set-up as 12) found that over half of released rehabilitated and captive-reared giant anteaters *Myrmecophaga tridactyla*, some of which were kept in holding pens and provided with supplementary food, survived for at least six months. At least 18 of 31 released giant anteaters survived for a minimum of six months. Long-term survival and the fate of the other 13 anteaters is not reported. In 2007–2013, thirty-one giant anteaters (18 males, 13 females; 1–8 years old) were released into a 124-km^2 private reserve. Hunting within the reserve was prohibited and livestock were absent. Three anteaters were wild-born but rehabilitated in captivity from injuries, 22 were wild-born but captive-reared and six were from zoos (origin not stated). Of the 18 surviving anteaters, six had been released after a short period in a 0.5-ha pen at the release site and 12 after 7–30 days in a 7-ha pen. Supplementary food was provided for several weeks after release. In 2007–2014, thirteen anteaters were tracked for less than six months, and 18 were tracked for 6–46 months.

A study in 2009–2012 in a forest area in São Paulo, Brazil (11) found that a rehabilitated puma *Puma concolor* released back into the wild survived for 14 months. Fourteen months after release, the rehabilitated puma was run over and found dead by a highway. The puma was healthy and the death resulted from the collision. A young male puma

(approximately 12 months old) was rescued in September 2009 after being hit by a vehicle. It was kept and treated in a recovery enclosure (15 × 3 × 3 m). After 542 days, the puma had fully recovered and was transferred to a pre-release enclosure (35 × 30 × 5 m) in a forested mountainous area, 28 km from where it had been hit. It was radio-tagged and released after 34 days in the pre-release enclosure. The puma was tracked every 1–3 days from an ultra-light aircraft between February 2011 and April 2012.

A controlled study in 2007–2012 in a grassland reserve in Corrientes, Argentina (12; same experimental set-up as 10) found that wild-born rehabilitated giant anteaters *Myrmecophaga tridactyla* released into the wild were more nocturnal in their activity patterns than captive-bred individuals. Wild-born rehabilitated giant anteaters were proportionally more active at night than captive-bred animals (70% vs 43% of activity records were at night). During 2007–2012, four wild-born and three captive-bred adult giant anteaters were released into a 124-km^2 private reserve. Wild-born animals were rehabilitated after being injured by hunters or in road accidents. Six anteaters (all wild-born and two captive-bred anteaters) were released after spending a short period of time in a 0.5 ha acclimatisation pen. The remaining 12 anteaters spent 7–30 days in a 7 ha holding pen at the release site prior to release. Supplementary food was provided in the holding pen and for several weeks after anteaters were released. Each of the seven anteaters was fitted with a radio-transmitter and tracked for 1–2 x 24 h periods/month in 2007 and 2011. The released anteaters were further monitored using 14 baited camera traps for an average of 336 days/trap during 2008–2012.

A study in 2008–2013 in two forested, mountainous areas of north-west Spain (13) found that after treating three young female brown bears *Ursus arctos* for injuries and releasing them back in to the wild, one was recaptured 21 days after release and two survived for at least 4–7 years. One cub was recaptured 21 days following release after repeatedly entering villages during the day. The other cub was monitored for 239 days, then seen seven years after release. One female sub-adult was monitored for 292 days, then seen four years after release with a dependent cub. The two bears remaining in the wild both established home ranges (90% of cub's home range: 182 ha; 90% of sub-adult's

home range: 2,816 ha). In 2008–2013, three young bears were taken into captivity for 41–145 days to be treated for injuries and were then released to one of two sites, 3–14 km from where they were captured. One was monitored daily by radio-tracking for 239 days and two were monitored hourly by GPS for 21 and 292 days until they were recaptured, or the collar was lost.

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(3) Morris P.A., Munn S. & Craig-Wood S. (1992) The effects of releasing captive hedgehogs (*Erinaceus europaeus*) into the wild. *Field Studies*, 8, 89–99.

(4) Morris P.A., Meakin K. & Sharafi S. (1993) The behaviour and survival of rehabilitated hedgehogs (*Erinaceus europaeus*). *Animal Welfare*, 2, 53–66.

(5) Morris P.A. & Warwick H. (1994) A study of rehabilitated juvenile hedgehogs after release into the wild. *Animal Welfare*, 3, 163–177.

(6) Rodriguez A., Barrios L. & Delibes M. (1995) Experimental release of an Iberian lynx (*Lynx pardinus*). *Biodiversity & Conservation*, 4, 382–394.

(7) Thiel R.P. (2000) Successful release of a wild wolf, *Canis lupus*, following treatment of a leg injury. *The Canadian Field-Naturalist*, 114, 319–319.

(8) Molony S.E., Dowding C.V., Baker P.J., Cuthill I.C. & Harris S. (2006) The effect of translocation and temporary captivity on wildlife rehabilitation success: an experimental study using European hedgehogs (*Erinaceus europaeus*). *Biological Conservation*, 130, 530–537, https://doi.org/10.1016/j.biocon.2006.01.015

(9) Cahill S., Llimona F., Tenés A., Carles S. & Cabañeros L. (2011) Radioseguimiento post recuperación de erizos europeos (Erinaceus europaeus Linnaeus, 1758) en el Parque Natural de la Sierra de Collserola (Barcelona). *Galemys*, 23, 63–72.

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seasonality and experience. *Mammalia*, 81, 11–21, https://doi.org/10.1515/mammalia-2015-0088

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14.4. Hand-rear orphaned or abandoned young in captivity

https://www.conservationevidence.com/actions/2358

- **Six studies** evaluated the effects of hand-rearing orphaned mammals. Two were in the USA[3,4], one each was in Australia[1], South Africa[2] and India[6] and one was in six countries across North America, Europe and Asia[5].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (5 STUDIES)

- **Reproductive success (1 study):** One study in India[6] found that three hand-reared orphaned or abandoned greater one-horned rhinoceroses gave birth in the wild.
- **Survival (5 studies):** Five studies (including one controlled and one replicated) in Australia[1], the USA[3,4], India[6] and in six countries across North America, Europe and Asia[5], found that some hand-reared orphaned or abandoned ringtail possums[1], white-tailed deer[3], sea otters[4], bears[5] and greater one-horned rhinoceroses[6] survived for periods of time after release.

BEHAVIOUR (1 STUDY)

- **Behaviour change (1 study):** A study in South Africa[2] found that a hand-reared, orphaned serval established a home range upon release.

Background

Young mammals believed to be orphaned or abandoned are sometimes taken in by wildlife rehabilitators, to be reared and released back into the wild. Often, this is done more for animal welfare reasons than for species conservation though for rare species, release of such animals may provide opportunities for choosing where to augment populations. Success of such programmes can be difficult to judge, without benchmark data for survival of wild-reared mammals.

This intervention includes studies where mammals are hand-reared. See also *Place captive young with captive foster parents* and *Place orphaned or abandoned wild young with captive foster parents*.

A controlled study in 1990–1994 in a park in New South Wales, Australia (1) found that ringtail possums *Pseudocheirus peregrinus* released following hand-rearing, or relocated from elsewhere, survived for a shorter time than did resident possums. The average survival of released possums was 101 days and for resident possums was 182 days. There was no difference in survival between hand-reared or relocated possums. Deaths were mostly due to predation by mammals, reptiles and birds. For possums for which their fate was known, predation accounted for 98% of released and 81% of resident animals. Possums were monitored in a 4-km^2 park, adjoining a suburban area. Released possums (112) included hand-reared orphaned animals (81) and those relocated from potentially dangerous situations (21). Resident possums (41) were wild animals that had not been moved or held in captivity. Possums were monitored by radio-tracking ≥twice/week.

A study in 1998–1999 in KwaZulu-Natal, South Africa (2) found that a hand-reared, orphaned, female serval *Felis serval* established a home range upon release. The serval settled in intensive farmland, suggesting elevated habituation to humans. It established a 6-km^2 home range. The core area of this range was 1.5 km from the release point. The serval was moved 3 km away, following poultry depredation, but returned within six days. Two wild servals (1 male, 1 female) were orphaned

after birth and hand-reared for an unknown period. In October 1998, they were placed in a holding pen and were released on 14 December 1998 (with continued access to the holding pen). Radio-telemetry was used to monitor activity. The male serval disappeared after release and no movement data were collected. Precise duration of monitoring of the female was not reported, but spanned at least seven weeks.

A study in 2000–2002 in a forest reserve in Missouri, USA (3) found that less than one third of orphaned and captive-reared white-tailed deer *Odocoileus virginianus* fawns released into the wild survived for more than one year. Twelve of 42 (29%) captive-reared white-tailed deer fawns survived more than one year after release. The other 30 fawns died (22 within 30 days of release) due to predation, accidents, poaching or legal harvesting. Forty-two orphaned fawns were rehabilitated in a wildlife rescue centre and two private residences. Sick or injured fawns received medical treatment. Fawns were released at >10 weeks old into an 8,700-ha forest reserve. Twenty-three fawns (13 males, 10 females) were released in September and October 2000. Nineteen (10 male, nine female) were released between August and September 2001 after two weeks in a 0.8-ha holding pen at the release site. All 42 fawns were fitted with radio-collars and located daily for 14 days post-release, then 3–4 times/week for four months, and weekly for one year in 2000–2002.

A study in 1986–2000 in an aquarium in California, USA (4) found that approximately one-third of rehabilitated sea otter *Enhydra lutris* pups released back into the wild survived for at least one year. Eight of 26 (31%) rehabilitated sea otter pups reared in captivity survived for at least one year after release. The other pups died (16 pups; 11 of which died within one month of release) or had to be permanently returned to captivity (two pups). In 1986–2000, twenty-six stranded new-born sea otter pups were brought into captivity and rehabilitated. Pups were raised primarily in isolation (60–80% of their time during rehabilitation) but were introduced to other sea otters at 9–18 weeks old. Before release, pups were implanted with a radio-transmitter and individually tagged. After release in 1987–2000, rehabilitated otters were monitored daily from shore during the first month and then twice weekly for up to 12 months.

A replicated study in 1991–2012 of 12 programs in the USA, Canada, Romania, Greece, South Korea and India (5) found that following

release, approximately half of orphaned and captive-reared American black bears *Ursus americanus*, Asiatic black bears *Ursus thibetanus* and brown bears *Ursus arctos* survived over one year. Of 141 known mortalities, 54% occurred during the first year after release when bears were 1 to 2-years old and at least two bears lived for more than 10 years in the wild. Average annual survival rates for released captive-reared bears were 73% for American black bear, 75% for brown bear and 87% for Asiatic black bear. A minority of all American (6.1%) and Asiatic black bears (9.7%) released demonstrated persistent problem behaviours and required removal, but none were reported for brown bears. Captive-reared females from all species reproduced in the wild. Orphaned American black bears were released in the USA and Canada (424 individuals, 7 programs), Asian black bears released in India and South Korea (62 individuals, 2 programs) and brown bears were released in Romania, Canada and Greece (64 individuals, 3 programs). Cubs were <1 year old when taken into captivity and were kept for 2–14 months. All bears were released (aged 11–23 months) in areas with suitable habitat. Bears were ear-tagged and/or equipped with telemetry collars. Collared bears were monitored until the collar dropped or malfunctioned. Overall, 30% of bears were not observed after release and so are not included in survival estimates.

A study in 2006–2013 in a grassland reserve in Assam, India (6) found that most orphaned or abandoned greater one-horned rhinoceros *Rhinoceros unicornis* calves survived for at least 6 or 7 years after release and gave birth in the wild. Three of four orphaned or abandoned female rhinoceroses were still alive 6–7 years after release into the wild, and all three gave birth to calves in 2013. The fourth animal died eight months after release, in October 2008. Four female rhinoceroses aged 1–5 months old were rescued in Kaziranga National Park, and hand-reared at the Centre for Wildlife Rehabilitation and Conservation. In January and February 2006–2008, at two or three years of age, the calves were moved to the 519-km^2 Manas National Park, and held in a 600-acre fenced enclosure before release (further details not provided).

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14.5. Place orphaned or abandoned wild young with wild foster parents

https://www.conservationevidence.com/actions/2343

- **Three studies** evaluated the effects of placing orphaned or abandoned wild young with wild foster parents. One study was in the USA[1], one was in South Africa[2] and one was in Botswana[3].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (3 STUDIES)

- **Survival (3 studies):** Two studies (one controlled) in the USA[1] and Botswana[3], found that orphaned young black bears[1] and African wild dogs[3] had greater[1] or equal[3] survival compared to animals released alone[1] or young of wild mammals with their biological parents[3]. A study in South Africa[2] found that an orphaned cheetah cub was not accepted by a family of cheetahs.

BEHAVIOUR (0 STUDIES)

Background

Young mammals believed to be orphaned or abandoned are sometimes taken in by wildlife rehabilitators, to be reared and released back into the wild. Often, this is done more for animal welfare reasons than for species conservation though for rare species, release of such animals may provide opportunities for choosing where to augment populations. An alternative to captive rearing may be to attempt to foster young into existing wild families. If this can be achieved, it may improve their ability to find food in the wild and reduce the extent to which they become imprinted on humans and could, thus, improve the prospects of longer-term survival in the wild. However, the success of such programmes can be difficult to judge, without benchmark data for survival of wild-reared mammals.

See also *Place orphaned or abandoned wild young with captive foster parents.*

A controlled study in 1973–1983 in temperate forests in Idaho and Pennsylvania, USA (1) found that orphaned black bears *Ursus americanus* released to wild females with cubs had higher short-term survival than did orphaned bears released alone. Ten days after release, 23 of 45 (51%) orphaned bears placed with females with cubs were seen to be in good condition, but only five of 39 (13%) cases in which orphans were released in the wild alone were deemed successful. In 1973–1983, twenty-nine cubs were released directly into dens of females with young, 11 cubs were released after chasing females and causing their young to climb trees and five cubs were placed with female bears and their young that were caught in culvert traps and then released. In seven cases, females were immobilized while the cubs were introduced. Thirty-nine orphaned bear cubs were held in captivity before being release alone into the wild. Reintroductions were regarded as successful if orphaned bears were observed with the foster mother at least 10 days after reintroduction or, for solo introductions, if animals survived for at

least 30 days and did not become a nuisance to humans. Survey methods were unclear.

A study in 1994–1998 in a savannah reserve in North West province, South Africa (2) found that when an orphaned female cheetah *Acinonyx jubatus* cub was put in a holding pen with a family of cheetahs, the orphaned female was not accepted by the group and was removed after two weeks. The orphaned female was prevented from accessing food by male cubs and the adult female was hostile towards her, although did not cause physical harm. The orphaned female cub was fed separately as a result and was relocated to a captive breeding facility after two weeks. An 8-month-old orphaned female cub was placed in a holding pen with one adult female and three 18-month-old dependent male cubs in a 60,000 ha game reserve. The orphaned female cheetah had been captured on a farm, the family group were from a rehabilitation facility.

A study in 2000 and 2003 at three savannah sites in Botsawana (3) found that orphaned African wild dog *Lycaon pictus* pups released in the vicinity of wild dog packs were readily adopted into the pack and had survival rates similar to those of wild pups. A six-week-old pup was adopted into a pack of 24 adults and yearlings in August, and survived to at least October, but not to the year end. Four 10-week-old pups were adopted into a pack of seven adults and eight pups in August. Two pups survived at least to the year end. Three 10-week-old pups were adopted into a pack of three adults and four pups in August but did not survive to the year end. Where pups died before the year end, no pups born into those packs survived either. One orphaned pup was adopted within 24 hours of capture, the others after three weeks of quarantine. Four pups required moving to re-join their adoptive pack, which moved 7 km during the first night following interactions with lions *Panthera leo*.

(1) Alt G.L. & Beecham J.J. (1984) Reintroduction of orphaned black bear cubs into the wild. *Wildlife Society Bulletin*, 12, 169–174.

(2) Hofmeyr M. & van Dyk G. (1998) *Cheetah introductions to two north west parks: case studies from Pilanesberg National Park and Madikwe Game Reserve*. Proceedings of a Symposium on Cheetahs as Game Ranch Animals, Onderstepoort, 23 & 24 October 1998, 60–71.

(3) McNutt J.W., Parker M.N., Swarner M.J. & Gusset M. (2008) Adoption as a conservation tool for endangered African wild dogs (*Lycaon pictus*). *South African Journal of Wildlife Research*, 38, 109–112, https://doi.org/10.3957/0379-4369-38.2.109

14.6. Place orphaned or abandoned wild young with captive foster parents

https://www.conservationevidence.com/actions/2364

- **Two studies** evaluated the effects of placing orphaned or abandoned wild young with captive foster parents. One study was in Canada[1] and one was in the USA[2].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (1 STUDY)

- **Survival (1 study):** A controlled study in the USA[2] found that stranded sea otter pups reared in captivity by foster mothers had higher post-release survival than did unfostered pups reared mostly alone, and similar survival to wild pups.

BEHAVIOUR (2 STUDIES)

- **Behaviour change (2 studies):** A study in Canada[1] found that a captive white-tailed deer adopted a wild orphaned fawn. A controlled study in the USA[2] found that stranded sea otter pups reared in captivity by foster mothers began foraging earlier than did unfostered pups reared mostly alone.

Background

Young mammals believed to be orphaned or abandoned are sometimes taken in by wildlife rehabilitators, to be reared and released back into the wild. Often, this is done more for animal welfare reasons than for species conservation though for rare species, release of such animals may provide opportunities for choosing where to augment populations. If such mammals can be fostered in captivity by parents of the same species, it may reduce the extent to which they become imprinted on humans and could improve the prospects of post-release survival in the wild. However, the success of such programmes can be difficult to judge, without benchmark data for survival of wild-reared mammals.

See also *Hand-rear orphaned or abandoned young in captivity* and *Place captive young with captive foster parents*.

A study in 1993 in a captive facility in New Brunswick, Canada (1) found that a captive white-tailed deer *Odocoileus virginianus* adopted a wild orphaned fawn. The fawn was around one week old when rescued and was initially hand-fed. After five days, a captive white-tailed deer doe gave birth to a stillborn fawn. The following day, the orphaned fawn was placed with the doe. It was initially ignored, and hand-feeding continued. One day later, the hide of the stillborn fawn was wrapped around the orphaned fawn. The doe proceeded to lick the hide and nursed the fawn thereafter, even after the hide became detached after five hours, due to vigorous licking. The study took place in a captive research facility to which the orphaned fawn was delivered on 9 June 1993. Attachment of the hide, and adoption by the doe took place on 15 June 1993.

A controlled study in 1986–2004 at an aquarium and coastal site in California, USA (2) found that stranded sea otter *Enhydra lutris* pups reared in captivity by foster mothers began foraging earlier and had greater survival in the wild than unfostered pups, and similar survival to wild pups. Fostered sea otter pups began foraging independently on live prey at younger ages (average 8–19 weeks old) than unfostered pups reared mostly alone (average 11–22 weeks old). A greater proportion of fostered pups survived at least one year after release (5 of 7 pups; 71%) than unfostered pups (8 of 26 pups; 31%), and survival was similar to wild pups (9 of 12 pups; 75%). In 2001–2003, seven stranded sea otter pups were brought into captivity and reared with adult female sea otters. In 1986–2000, twenty-six stranded sea otter pups were reared in captivity without foster mothers (mostly alone). All pups were rehabilitated at the same aquarium. Before release, pups were implanted with radio-transmitters and individually tagged. After release in 1987–2004, the rehabilitated otters were monitored daily during the first month and then twice weekly for up to 12 months. Twelve wild juvenile male sea otter pups were observed during a field study prior to 2003 (date not reported).

(1) Greaves T.A. & Duffy M.S. (1994) Adoption of a white-tailed deer, *Odocoileus virginianus*, fawn by a captive doe. *The Canadian Field-Naturalist*, 108, 239.

(2) Nicholson T.E., Mayer K.A., Staedler M.M. & Johnson A.B. (2007) Effects of rearing methods on survival of released free-ranging juvenile southern sea otters. *Biological Conservation*, 138, 313–320, https://doi.org/10.1016/j.biocon.2007.04.026

14.7. Provide supplementary food to increase reproduction/survival

https://www.conservationevidence.com/actions/2367

- **Twenty-four studies** evaluated the effects on mammals of providing supplementary food to increase reproduction/survival. Nine studies were in the USA[1,2,3,8,11,12,16,17,20], two were in Canada[5,13], two were in South Africa[10,22], two were in Poland[4,24], and one each was in Sweden[6], the Netherlands[7], Swaziland[9], Spain[14], Portugal[15], Slovenia[18], Austria[23], Norway and Sweden[19] and one was across North America and Europe[21].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (18 STUDIES)

- **Abundance (8 studies):** Four of eight studies (incuding four controlled, two site comparisons and five before-and-after studies) in the USA[1,2], Canada[5,13], South Africa[10,22], Poland[4] and Austria[23] found that supplementary feeding increased the abundance or density of bank voles[4], red squirrels[5], striped mice[10], brown hyena[22] and black-backed jackals[22]. One study found a temporary increased in prairie vole abundance[1]. The other three studies found supplementary feeding not to increase abundance or density of white-footed mice[2], northern flying squirrels[13], Douglas squirrels[13] or Eurasian otters[23].
- **Reproduction (8 studies):** Four of five controlled studies (three also replicated) in the USA[1], South Africa[10], Norway and Sweden[19], Sweden[6] and Spain[14], found that supplementary food increased the proportion of striped mice that were breeding[10], the number of arctic fox litters[6,19] and the size of prairie vole litters[1]. However, there was no increase in the number of arctic fox cubs in each litter[6] or the proportion of female Iberian lynx breeding[14]. One of two replicated studies (one site comparison and one controlled), in the Netherlands[7] and the USA[16], found that supplementary feeding increased the number of young wild boar produced and recruited in to the population[7]. The other study found that the number

of mule deer produced/adult female did not increase[16]. A review of studies across North America and Europe found that supplementary feeding increased ungulate reproductive rates in five of eight relevant studies[21].

- **Survival (9 studies):** Four of eight studies (including seven controlled studies and two before-and-after studies) in the USA[3,8,11,16,17], Canada[13], Poland[4] and Spain[14], found that supplementary feeding increased survival of mule deer[3], bank voles[4], northern flying squirrels[13] and eastern cottontail rabbits[17]. Five studies found no increase in survival for white-tailed deer[8], Douglas squirrels[13], mule deer[16], Rocky Mountain bighorn sheep lambs[11] or Iberian lynx[14]. A review of studies across North America and Europe found that supplementary feeding increased ungulate survival in four out of seven relevant studies[21].
- **Condition (4 studies):** One of three studies (including two controlled and two before-and-after studies) in Poland[4], the USA[12], and Canada[13], found that supplementary food lead to weight gain or weight recovery in bank voles[4]. One study found no body mass increase with supplementary feeding in northern flying squirrels and Douglas squirrels[13].The third study found mixed results, with supplementary feeding increasing weight gains in some cotton rats, depending on their sex, weight and the time of year[12]. A review of studies from across North America and Europe found that different proportions of studies found supplementary feeding to improve a range of measures of ungulate condition[21].

BEHAVIOUR (6 STUDIES)

- **Use (2 studies):** A replicated, controlled study in Sweden[6] found that supplementary food increased occupancy of Arctic fox dens. A replicated study in Portugal[15] found that artificial feeding stations were used by European rabbits.
- **Behaviour (4 studies):** Two of three replicated studies (two also controlled), in Swaziland[9], Slovenia[18] and the USA[20], found that supplementary feeding led to reduced home range sizes or shorter movements of red deer[18] and elk[20]. The

third study found home ranges and movement distances to be similar between fed and unfed multimammate mice[9]. One replicated study in Poland[24] found that supplementary feeding of ungulates altered brown bear behaviour.

Background

Many mammals have long gained a proportion of their diet as a direct result of human activities (Oro *et al*. 2013). Many of these are cases where by-products of production, harvesting or consumption are exploited. However, in some cases, food is provided specifically for mammals. This is often to increase survival and condition of hunted animals, such as deer. In some other cases, food may be provided to aid the conservation status of rare species. Some studies are less directly conservation-motivated but are included here if the findings can help to inform conservation actions.

Studies that provide supplementary food as part of translocation or reintroduction programmes are discussed in: *Provide supplementary food during/after release of translocated mammals* and *Provide supplementary food during/after release of captive-bred mammals*.

Oro D., Genovart M., Tavecchia G., Fowler M.S. & Martínez-Abraín A. (2013) Ecological and evolutionary implications of food subsidies from humans. *Ecology Letters*, 16, 1501–1514.

A controlled study in 1975–1976 in a grassland site in Illinois, USA (1) found that where supplementary food was provided, prairie vole *Microtus ochrogaster* numbers were temporarily higher and litter size was larger than in an area with no supplementary food. Voles reached higher densities in the food supplemented area (135 voles/ha in April 1976) than in the area with no supplementary feeding (90 voles/ha in October 1975). However, 16–18 months after supplementary feeding commenced, vole numbers were similar in fed and unfed areas (<5/ha). Voles in the fed area had a longer life expectancy and were more likely to breed in winter than voles in the unfed area (data expressed as model results). Average litter size was larger in the fed area (5.1) than in the unfed area (4.3).A 1.5-ha abandoned pasture was divided into two

live-trapping grids of 0.80 and 0.55 ha, separated by a 10-m-wide mown strip. On the 0.55-ha grid, 210 feeding stations (200-ml bottles, filled with rabbit pellets, replenished as required) were placed 5 m apart. No supplementary food was provided on the other grid. Voles were surveyed using 60 wooden traps in the supplementary feeding grid and 72 in the unfed grid. Every three weeks from May 1975 (supplementary food grid) and August 1975 (unfed grid) to November 1976, traps were set for three days and checked twice daily. Traps were baited for two days before setting.

A before-and-after study in 1975–1976 in a woodland in Illinois, USA (2) found that supplementary feeding did not increase white-footed mouse *Peromyscus leucopus* densities. Monthly densities varied seasonally but were not higher in supplementary feeding plots than in plots without supplementary food provision. After supplementary feeding commenced, the highest numbers were 5–9 months later, with 20–26 mice/ha in supplementary feeding plots and 22–29 mice/ha in plots without supplementary food. Four plots, 0.36 ha each, were established within a 9-ha live trap grid, with 20-m trap intervals. Traps were operated across the grid over three days/month, from January 1975 to July 1976. Additional trapping took place fortnightly on grid points within and immediately surrounding plots, from March–December 1976. Supplementary feeding, using mouse chow at 10-m intervals, commenced in two plots in January 1976. No food was provided in the other two plots.

A controlled study in 1984 on three areas of a predominantly grassland site in Colorado, USA (3) found that supplementary feeding of mule deer *Odocoileus hemionus hemionus* increased overwinter survival. Mortality was lowest for deer provided with as much supplementary food as they could consume (24%), intermediate for deer given fixed quantities of supplementary food (33%) and highest for deer not provided with supplementary food (53%). Three study areas (≥5 km apart, 660–1,000 ha extent) were monitored. Supplementary food consisted of wheat middlings, brewer's dry grain, cottonseed hulls and alfalfa formed into wafers. It was provided daily, from 7 January to 10 April 1984, in equal or greater quantities than deer consumed in one study area and at 0.9 kg/deer/day in another study area. No supplementary food was provided in the third area. Biweekly aerial deer counts were conducted

from 27 January 1984 and mortality was assessed by ground surveys for carcases, during 1–15 June 1984, of randomly selected sample plots from each study area.

A before-and-after study in 1966–1969 and 1973–1974 on a forested island in Lake Beldany, Poland (4) found that when supplementary food was provided, the abundance, body weight and survival of bank voles *Clethrionomys glareolus* was higher. Annual peak vole abundance was higher in years when food was provided (835–1,068 individuals) than when no food was provided (157–368 individuals). The average body weight of young voles (3–9 weeks old) was higher in years when food was provided (17.2 g) than when they were not fed (13.9 g). The survival of individuals to autumn in the year they were born was higher in years when food was provided (49%) than when voles were not fed (8–42%). Voles were live-trapped every six weeks from spring to autumn 1966–1969 and 1973–1974, in five 10–14-day trapping sessions/year. Two to five traps baited with oats were set at each of 159 trapping locations and checked twice daily. From spring 1973 to autumn 1974, a total of 159 boxes with 3 kg of oats each were distributed 15 m apart across the 4-ha island, next to trapping sites. Boxes were replaced when half the oats had been consumed, but were removed during trapping.

A replicated, paired sites, controlled, before-and-after study in 1983–1986 in four mixed spruce and pine forest sites in British Columbia, Canada (5) found that providing supplementary food increased the abundance of red squirrels *Tamiasciurus hudsonicus*. After two years, squirrel abundance in sites with supplementary food was higher (41–53 squirrels/site) than in unfed sites (9–15 squirrels/site). One year after supplementary feeding ceased, squirrel numbers declined in previously fed sites (23–31 squirrels/site) but not in unfed sites (11–12 squirrels/site). A 9-ha grid, with 100 stations at 30 m intervals, was established in each of four forest sites (two each in two forests). Sunflower seeds (83–90 kg/month) were provided in cans nailed to trees distributed across two sites (50 cans/site), from September 1983 to September 1985. No food was provided at the other two sites. From June 1983 to June 1986, squirrels were captured and measured using one Tomahawk live trap at alternate stations. Traps were set for two days, every 3–4 weeks in summer (April–September) and 4–10 weeks in winter (October–March). Cans were refilled after each trapping period.

A replicated, controlled study in 1979–1990 in four mountainous grassland areas in northern Sweden (6) found that providing supplementary food increased occupancy of Arctic fox *Alopex lagopus* dens and the number of fox litters born, but not the numbers of cubs in each litter. Where supplementary food was provided, a higher proportion of dens were occupied (35%) than where no supplementary food was supplied (6%). Over five years, 17 of 65 dens (26%) where food was provided contained a litter while only three of 103 dens (3%) where no food was provided contained a litter. However, there was no significant difference in average litter size (supplementary food: 5.2 cubs; no food: 5.7 cubs). During January–April of 1985–1989, reindeer *Rangifer tarandus* and moose *Alces alces* meat was placed 50–200 m from 168 dens which showed signs of Arctic fox activity. In some cases, meat was buried in the snow. About 50–100 kg of meat/den/year was provided. Dens were surveyed for presence of foxes and offspring in June–August of 1979–1990.

A replicated, site comparison study in 1988–1992 of forest and heathland across nine management areas in the Netherlands (7) found that when supplementary feed was provided, wild boar *Sus scrofa* annual population recruitment rates were higher. No statistical analyses were performed. In seven areas, where boar were fed, annual recruitment (number of piglets >2 months old/ adult female) averaged 2.2–2.5, compared to 0.0–2.5 at a site where supplementary feeding ceased in the year before the study began. At a further site, where supplementary feeding ceased two years into the study, recruitment averaged 2.0–2.4 over those first two years and 1.5–1.7 in the subsequent three years. Recruitment data were obtained from nine boar management areas, based on spring counts at feeding locations.

A controlled study in 1986–1989 of a forested area in Wisconsin, USA (8) found that supplementary feeding of white-tailed deer *Odocoileus virginianus* did not increase their overall survival. The average annual survival of winter-fed deer (78%) or summer-fed deer (53%) did not differ significantly from that of unfed deer (64%). Summer-and winter-fed deer had higher over-winter survival during a single severe winter only (summer-fed: 96%; winter-fed: 100%; not fed: 79%), but not during other periods. From October 1986 to July 1989, deer were fed shelled corn or commercial deer food from mid-April to mid-December

(summer-feeding — 53 deer), 1 December to 30 April (winter-feeding — 66 deer) or were not fed (48 deer). All deer, except 24 that were winter-fed, occupied a 15 × 30-km area. No deer was winter-fed and summer-fed in the same year. Survival was monitored through radio-tracking. Deer use of feeders was determined by direct observations.

A replicated, controlled study in 1995–1996 in a grassland in Middleveld, Swaziland (9) found that multimammate mice *Mastomys natalensis* provided with supplementary food had similar home range sizes and distance between captures to unfed mice. The average home ranges of 66 multimammate mice provided with supplementary food (600–923 m^2) did not differ significantly from those of nine unfed mice (838–960 m^2). Similarly, average distances between captures of mice provided with supplementary food (20–21 m) did not differ significantly from those of unfed mice (25–28 m). In May 1995, three 100 × 100-m plots were established in a natural grassland. Supplementary food (4 kg of rolled oats and 4 kg of rabbit pellets) was provided monthly, from July 1995 to May 1996, in two plots. No supplementary food was added to the third plot. From June 1995 to May 1996 mice were surveyed monthly using 100 Elliot and Sherman live traps/plot. Traps were set 10 m apart, on three consecutive nights/month. Mice were individually toe-clipped and weighed when captured. Only individuals captured at least five times were used to calculate home range sizes.

A controlled study in 1995 on a grassland in KwaZulu-Natal, South Africa (10) found that providing supplementary food increased striped mouse *Rhabdomys pumilio* density and the proportion of the population that was breeding. Three to six months after feeding began, there were more striped mice in the plot with supplementary food (30) than in the plot with no supplementary food (21). Over the same time period, a higher proportion of adult mice were reproductively active in the plot with supplementary food (85%) than in the plot with no supplementary food (38%). In one of two plots (>60 m apart) 25 trays, each with 1 kg of oat seeds, were filled weekly. The second plot had no supplementary food. In each plot, mice were monitored at 49 stations, in a 7 × 7 grid, at 10-m intervals. Each station was surveyed for two consecutive nights/month with one baited and insulated Elliot or Sherman live trap, from January–June 1995.

A randomized, replicated, controlled study in 1991–1995 in two mountain ranges in Colorado, USA (11) found that supplementary winter feeding of Rocky Mountain bighorn sheep *Ovis canadensis canadensis* did not increase lamb survival. Average annual recruitment did not differ between herds provided with food (0.5–0.7 lambs/adult female) and herds where no food was provided (0.6–0.7 lambs/adult female). Adult bighorn females of four herds were captured in February–March 1991–1995 and were marked and radio-collared. Between 1991 and 1995 the herds were either fed from mid-December for 8–10 weeks with 2 kg/individual/day of alfalfa hay and 1 kg/individual/day of apple pulp, or not given any supplementary food. Each year, one herd under each feeding regime was additionally medicated for lungworm using fenbendazole, while the other was not medicated. Treatments were rotated annually under a predetermined, randomly selected scheme. Lamb survival for 11–18 marked adult females/herd was assessed every two weeks between May and October the following year.

A replicated, controlled study in 1990–1992 in a forest reserve in Kansas, USA (12) found that cotton rats *Sigmodon hispidus* had different growth rates after the provision of supplementary food, depending on their size and sex, and the time of year. In winter, the growth rate of small cotton rats provided with supplementary food was significantly higher than that of small rats not provided with food, but the opposite was true for larger rats. In spring, males on supplemented grids grew faster than males on control grids, but the opposite was true in females. In summer, there was no difference in growth rates between supplemented and non-supplemented grids. In autumn, males were the same as in winter, but larger females grew faster with supplementary food (data presented as model results). Additionally, seven reproductive cotton rat females had a higher growth rate when provided with food (2.5 g/day) than did 14 non-supplemented females (2.0 g/day). Seven litters born to females on food supplemented grids had higher growth rates in their first month of life (1.4 g/day) than 23 litters born on non-supplemented grids (0.94 g/day). Between June 1990 and May 1992, supplementary food was distributed along two out of four trapping grids. Food (50 g each of sorghum seeds, millet seeds and commercial rabbit chow) was provided in cans that were refilled every two weeks. Grids contained 64–99 trapping stations, 15 m apart, each with two Sherman traps baited

with scratch grain. Traps were set for three consecutive days/month, and checked twice daily. Rats were individually marked and weighed when captured. In June 1991, one of the food supplemented and one of the non-supplemented grids were switched.

A replicated, randomized, paired sites, controlled, before-and-after study in 1996–1999 in three forest sites in British Columbia, Canada (13) found that supplementary feeding did not alter the abundance and body mass of northern flying squirrels *Glaucomys sabrinus* and Douglas squirrels *Tamiasciurus douglasii*, but it did increase survival of northern flying squirrels. Between June 1997 and April 1999, the survival rate of northern flying squirrels was higher in plots with supplementary feeding (0.93) than without supplementary feeding (0.79). Survival did not significantly differ between plots before feeding began (plots to be fed = 0.84; control plots = 0.92). The survival of Douglas squirrels was similar between fed (0.72) and unfed (0.80) plots. The abundance and body mass of squirrels did not differ significantly between plots with supplementary food (northern flying squirrel abundance: 11.8/ha; body mass: 131 g; Douglas squirrel abundance: 14.2/ha; body mass: 200 g) and plots without supplementary food (northern flying squirrel abundance: 7.7/ha; body mass: 128 g; Douglas squirrel abundance: 20.1/ha; body mass: 207 g). From April 1997 to May 1998 and from September 1998 to April 1999, supplementary food was provided at 90 feeding stations, 60 m apart in a 9×10 grid, in each of three 30-ha forest plots. Stations were filled with 7 kg of sunflower seeds at 5–6-week intervals or when seed was depleted. Three other 30-ha plots had no feeding stations. In each plot, squirrels were trapped every 5–6 weeks (when snow-free), from June 1996 to March 1999, using 80 baited Tomahawk live traps, at 40-m intervals in an 8×10 grid.

A replicated, controlled study in 1985–2008 in two shrubland areas in southern Spain (14) found that supplementary feeding did not increase the breeding rate of Iberian lynx *Lynx pardinus* or survival of offspring. The proportion of female lynx that reproduced in areas where supplementary food was provided (66%) did not differ significantly from that in areas where it was not (83%). Similarly, survival of lynx offspring did not significantly differ (supplementary food: 100%; no supplementary food: 88%). In 2002–2008, six lynx breeding territories were each supplied, throughout the year, with live domestic rabbits at

approximately three feeding stations. An unspecified number of other territories were not supplied with rabbits. Fifteen adult female lynx were fitted with radio-collars and were monitored in 1985–2007. Data on breeding were obtained in March–May of 1993–2008, by tracking females to locate dens. Lynx were also monitored by sightings, camera-trapping, and radio-tracking.

A replicated study in 2007–2009 in six agroforestry sites in Alentejo and Algarve, Portugal (15) found that European rabbits *Oryctolagus cuniculus* used most available artificial feeding stations. Rabbits used almost 70% of 48 feeding stations surveyed. Rabbit numbers were higher in areas where a higher proportion of feeding stations was used (data presented as a correlation). Over the course of the study, which included providing artificial shelters and waterholes, the number of rabbit latrines increased from 16 to 25 latrines/km (no statistical analysis conducted). Between July and September in 2008 and 2009, wheat, oat and alfalfa were made available through 120 artificial feeding stations in six agroforestry. Each station was protected by a fence, aimed at excluding large animals. However, 60% of feeding stations were destroyed by deer or wild boar, so data for 48 feeding stations were analysed. These were surveyed monthly and considered to be used if rabbit droppings were detected. Rabbit abundance was estimated based on the number of latrines/km counted along paths at each site.

A replicated, randomized, controlled study in 2001–2006 in eight forest, grassland and shrubland sites in Utah, USA (16) found that providing supplementary food over winter did not increase mule deer *Odocoileus hemionus* survival or reproductive success. The average annual survival of deer with supplementary feeding (80%) did not differ significantly from that of deer without supplementary feeding (73%). Similarly, the average reproductive success of deer with supplementary feeding (0.58 fawns/female deer) did not differ significantly from that of deer without supplementary feeding (0.57 fawns/female deer). In 2001, eight sites known to host winter concentrations of mule deer were randomly selected. Supplementary food (corn, alfalfa and protein pellets, 0.9 kg/deer/day) was provided over winter (December–March 2001–2005) at four sites. No food was provided at the other four sites. Sites with and without supplementary food were >3 km apart. Fifty-two female mule deer receiving supplementary food and 38 that were

not fed were radio-collared between January and March 2001–2005. They were monitored 2–3 times/week, from May 2002 to January 2006.

A replicated, randomized, controlled study in 2009–2010 in 23 mixed wetland, scrubland, and wasteland sites in New Hampshire, USA (17) found that supplementary feeding increased survival of eastern cottontail rabbits *Sylvilagus floridanus*. After two months, rabbit survival in sites where supplementary food was provided was higher (9 of 15 animals; 60%) than in sites where no food was provided (5 of 13 animals; 38%). In November 2009–March 2010, twenty-eight rabbits were trapped and fitted with radio-collars and ear tags. Between December 2009 and March 2010, commercial rabbit food was provided every three days (450 g) at some sites and no food was provided at other sites. The number of sites where food was provided is unclear.

A replicated study in 1997–2003 in forest, meadows and farmland in a mountain range in central and southern Slovenia (18) found that in areas where supplementary food was provided, the home-range of red deer *Cervus elaphus* was smaller. Red deer had smaller home ranges in areas where more supplementary feeding occurred (data expressed as model results). Between 1997 and 2003, twenty-five adult female and 17 adult male red deer were caught across a 2,100 km^2 study area. Deer were radio-collared and released, and were relocated at least once a week, during all daylight hours, for at least one year. Annual home range size was estimated for each individual for each full year that it was monitored (total = 73 deer-years from 42 animals). Information on the location of supplementary feeding sites, and the type and quantity of food provided, was collected from a national register of feeding sites and used to model deer home-ranges alongside other relevant variables.

A replicated, controlled study in 1999–2011 in 10 tundra sites in Norway and Sweden (19) found that the number of artic fox *Vulpes lagopus* litters increased after supplementary winter feeding at den sites, along with control of red foxes *Vulpes vulpes.* At two sites where an average of 11–13.5 dens were fed, both the number of active arctic fox dens in winter, and the number of litters produced in summer, increased more than at sites where no feeding or a low level of feeding was undertaken (data reported as statistical model results). During winter 1999–2011, commercial dog food or remains from slaughtered reindeer *Rangifer tarandus* was provided to a large number of arctic fox

dens (11–13.5) at two sites, where red foxes were also intensively culled in winter. At four other sites, low numbers of arctic fox dens (1–3) were provided with food, and low numbers of red foxes were culled (0–7). At the remaining four sites, no food was provided and no red foxes were culled (3 sites) or intensive culling was conducted (92 animals, 1 site). The number of arctic fox litters was counted in known arctic fox dens during July and August 1999–2011.

A replicated, controlled study in 2007–2013 in four forested mountain areas in Wyoming, USA (20) found that elk *Cervus canadensis* provided with supplementary food migrated shorter distances and spent less time on their summer feeding grounds than unfed elk. Elk provided with supplementary food in winter migrated shorter distances (35.4 km) than did unfed elk (54.6 km). Fed elk arrived at their summer range an average of five days later and left 10 days earlier than did unfed elk. More fed elk used stopover sites on spring (56% of elk) and autumn (49% of elk) migration than non-fed elk (48% and 42% of individuals). Two hundred and nineteen adult female elk were caught and fitted with GPS radio-collars between January and March 2007–2011 at 18 sites where supplementary food was provided and at four sites with no supplementary food. Sites were located in four mountain areas within elk winter ranges. Supplementary feeding began when elk started to congregate at feeding sites and ceased once most elk had departed. GPS locations were taken from the elk every 30–60 minutes, for 1–2 years. Fed and unfed elk were monitored for 164 and 116 elk-years, respectively. The precise number of fed and unfed elk monitored is not detailed.

A review of evidence within studies looking at effects of feeding wild ungulates in North America (48 studies), Fennoscandia (25 studies) and elsewhere in Europe (28 studies) (21) found that supplementary feeding increased ungulate survival, reproductive rates or condition in varying proportions of studies. Ungulate survival rates increased in four out of seven relevant studies. The reproductive rate increased in five of eight relevant studies. Birth mass increased in one of three relevant studies. Loss of mass in winter was reduced or winter condition improved in five of seven relevant studies. Autumn mass increased in three of 11 relevant studies. Autumn mass or condition of offspring was improved in four of six relevant studies. Carrying capacity was increased in all

three relevant studies. The review reported evidence from 101 studies that met predefined criteria from an initial list of 232 papers and reports.

A before-and-after, site comparison study in 2007–2013 of a conservation park and a game park in South Africa (22) found that when carrion was provided at a vulture feeding station, there were more brown hyaena *Hyaena brunnea* and black-backed jackal *Canis mesomelas* scats in that area. At the vulture station site, there were more hyaena scats in the final year of carrion provision (5.0 scats/km) than before carrion provision (2.6 scats/km) and over the two years after carrion provision ceased (1.5–2.0 scats/km). Scat counts remained more stable over this period at a site without a vulture feeding station (3.2–4.3 scats/km). Similarly, there were more jackal scats at the vulture feeding station in the final year of carrion provision (3.3 scats/km) than before (0.5 scats/km) or over two years after (1.5–2.0 scats/km) carrion provision. Scat counts remained low (0.2–1.4 scats/km) at a site without a vulture feeding station. A vulture restaurant was operated at a conservation park from March 2008 to August 2011. Predator density at this park, and on a game park where carrion was not provided, was monitored by annual scat transects from 2007–2013.

A site-comparison study in 2011 along two rivers in Austria (23) found that on a river stocked with fish for angling, densities of resident adult Eurasian otters *Lutra lutra* were not higher than those on an unstocked river. No statistical analyses were performed. Resident adult otter density on the stocked river (0.23 otters/km) was similar to that on the unstocked river (0.22 otters/km). However, including juvenile and non-resident otters, a slightly higher density was found on the stocked river (0.37 otters/km) than on the unstocked river (0.33 otters/km). Two river stretches, with similar hydromorphology, were studied. One (21.5 km long) was stocked with fish from a hatchery in April–September each year. The other (18.3 km long) was not stocked. Otter spraints were collected daily for five days during three visits from February–April 2011. Individual otters were identified by genetic analysis of faeces. Forty-eight faeces were successfully used to genetically identify individuals from the stocked river and 33 from the unstocked river.

A replicated study in 2008–2015 in a mountain forest and grassland site in the northeast Carpathians, Poland (24) found that supplementary feeding of ungulates altered brown bear *Ursus arctos* behaviour. Bears

encountered feeding sites more frequently (GPS-tracked bears: 0.15 sites/km; snow-tracked bears: 0.93 sites/km) than expected at random (0.05 sites/km). From 2008–2010, a complete inventory of 212 ungulate feeding sites in the 1,500 km^2 study area was compiled through interviews with land managers and field inspections. Feeding occurred regularly, often year-round but especially in autumn and winter, and usually in the same location for decades. In spring and autumn 2008–2009 and 2014–2015, nine bears were captured and fitted with GPS collars. Bear locations were recorded every 30 minutes for five days at the start of each month, and used to create 49 GPS-tracks (average 34 km long). From December–March 2010–2012, 40 snow tracks of unmarked bears longer than 500 m were recorded (average 6 km long). To determine what would be expected if movements were at random, for each of the 49 GPS tracks recorded, 100 random tracks were created using the same start point and number of locations, and by randomly choosing the distance travelled and angle turned between points.

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(2) Hansen L.P. & Batzli G.O. (1979) Influence of supplemental food on local populations of *Peromyscus leucopus*. *Journal of Mammalogy*, 60, 335–342.

(3) Baker D.L. & Hobbs N.T. (1985) Emergency feeding of mule deer during winter: tests of a supplemental ration. *The Journal of Wildlife Management*, 49, 934–942.

(4) Banach K. (1986) The effect of increased food supply on the body growth rate and survival of bank voles in an island population. *Acta Theriologica*, 31, 45–54.

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(6) Angerbjörn A., Arvidson B., Norén E. & Strömgren L. (1991) The effect of winter food on reproduction in the arctic fox, *Alopex lagopus*: a field experiment. *The Journal of Animal Ecology*, 60, 705–714.

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14.8. Provide supplementary water to increase reproduction/survival

https://www.conservationevidence.com/actions/2396

- **Six studies** evaluated the effects on mammals of providing supplementary water to increase reproduction/survival. Two studies were in Australia[2,6] and one each was in Oman[1], Portugal[4], Saudi Arabia[5] and the USA and Mexico[3].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (5 STUDIES)

- **Abundance (2 studies):** A replicated study in the USA and Mexico[3] found that providing supplementary water was associated with increases in desert bighorn sheep population size. A study in Oman[1] found that a released captive-bred Arabian oryx population initially provided with supplementary water and food increased over 14 years.
- **Reproduction (2 studies):** A study in Saudi Arabia[5] found that released captive-bred Arabian gazelles initially provided with supplementary water and food after release into a fenced area started breeding in the first year. A study in Australia[6]

found that most female released captive-reared black-footed rock-wallabies provided with supplementary water after release into a large predator-free fenced area reproduced in the first two years.

- **Survival (2 studies):** A controlled, before-and-after study in Australia[2] found that most released captive-bred hare-wallabies provided with supplementary water, along with supplementary food and predator control, survived at least two months after release into a fenced peninsula. A study in Australia[6] found that over half of released captive-reared black-footed rock-wallabies provided with supplementary water after release into a large predator-free fenced area survived for at least two years.

BEHAVIOUR (1 STUDY)

- **Use (1 study):** A replicated study in Portugal[4] found that artificial waterholes were used by European rabbits and stone martens.

Background

In arid environments, artificial water sources may be provided to aid survival or population expansion for species of conservation concern (e.g. West *et al*. 2017). This may be done as part of translocation or reintroduction programmes and also for securing existing populations of threatened species.

See also *Natural system modifications -Provide artificial waterholes in dry season* and *Climate change & severe weather -Provide dams/water holes during drought*.

West R., Ward M.J., Foster W.K. & Taggart D.A. (2017) Testing the potential for supplementary water to support the recovery and reintroduction of the black-footed rock-wallaby. *Wildlife Research*, 44, 269–279.

A study in 1982–1999 of a large desert area in Oman (1) found that a population of released captive-bred Arabian oryx *Oryx leucoryx* initially provided with supplementary water and food increased over 14 years,

but then declined due to poaching. Oryx numbers in the wild peaked at >400 animals, 1–14 years after the release of 40 animals. Poachers (capturing live animals, especially females, for international trade) then removed at least 200 oryx over the next three years. Animals were taken back into captivity to re-establish a captive breeding program. Seventeen years after releases began, the captive population was 40, and approximately 104 remained in the wild, with a high male:female sex ratio. Arabian oryx became extinct in Oman in 1972. Founders for the initial captive herd were sourced from international collections. Forty individually marked oryx were released in 1982–1995. A sample of wild-born animals was individually marked to retain the marked proportion at 20–30%. The original released herd was provided with water and food for seven months after release. Population estimates were derived from sightings using mark-recapture analysis.

A controlled, before-and-after study in 2001 in five shrubland sites in Western Australia (2) found that most released captive-bred banded hare-wallabies *Lagostrophus fasciatus* and rufous hare-wallabies *Lagorchestes hirsutus* provided with supplementary water, along with supplementary food and predator control, survived at least two months after being released into a fenced peninsula. After 1–2 months, 10 of 16 rufous hare-wallabies and 12 of 18 banded hare-wallabies were still alive. Overall both rufous and banded hare-wallabies recaptured had similar body conditions to when they were released, although rufous hare-wallabies lost 12% of body condition while waiting for release in holding pens (data presented as a body condition index; see paper for details). Sixteen captive-bred rufous hare-wallabies and 18 captive-bred banded hare-wallabies were released at five sites in August 2001. Six rufous and nine banded-hare wallabies were placed in separate 3-ha enclosures with electrified fencing for 10–19 days before being released. Remaining animals were released directly into the wild. Supplementary water and food (kangaroo pellets, alfalfa) were made available to all hare-wallabies (those kept in holding pens and those not; duration of feeding not given). Hare-wallabies were monitored by radio tracking (once/week for 1.5 years after release) and live-trapping (at 4 and 8–9 weeks after release). Release areas were within a fenced peninsula where multiple introduced mammals were controlled or eradicated.

A replicated study in 1951–2007 in 10 desert sites in Arizona and New Mexico, USA, and the Gulf of California, Mexico (3) found that providing supplementary water at some sites was associated with increases in desert bighorn sheep *Ovis canadensis* population size. At three out of 10 sites where supplementary water was provided, it was associated with an increase in bighorn sheep populations. However, at one site, provision of water was associated with declines in sheep populations. The remaining six sites showed no association (data not presented). Data were obtained from historical records for ten sites with long-term survey and hunting information. Data included counts of bighorn sheep from both surveys and hunter harvests, and the number of watering sites provided.

A replicated study in 2009 in four agroforestry sites in Alentejo and Algarve, Portugal (4) found that artificial waterholes were used by European rabbits *Oryctolagus cuniculus* and stone martens *Martes foina*. European rabbits used four out of 16 artificial waterholes. At least one waterhole was used by stone martens (number of waterholes used by this species is not stated). In September and October 2009, sixteen artificial waterholes in four agroforestry estates dominated by cork *Quercus suber* (2–6 waterholes/estate) were monitored using camera traps. No description of the waterholes is provided. Waterholes were monitored for 7 or 14 days, using one camera trap/waterhole.

A study in 2011–2014 of a dry dwarf-scrubland site in Saudi Arabia (5) found that released captive-bred Arabian gazelles *Gazella arabica* initially provided with supplementary water and food after release into a fenced area started breeding in the year following the first releases. Seven females gave birth in August–September of the year after the first releases and all calves survived to at least the end of the year. Of 49 gazelles released over three years, 10 had died by the time of the final releases. In 2011–2014, three groups of captive-born gazelles, totalling 49 animals, were released in a 2,244-km^2 fenced reserve. They were moved from a wildlife research centre and held for 23 days to a few months before release in enclosures measuring 500 × 500 m. Water and food was provided for three weeks following release. Released gazelles were radio-tracked from the ground and air.

A study in 2011–2014 in a semi-arid area in South Australia (6) found that over half of released captive-reared black-footed rock-wallabies

Petrogale lateralis provided with supplementary water after being released into a large predator-free fenced area survived for at least two years and most females reproduced. Ten (five males, five females) of 16 rock-wallabies (63%) survived more than two years after being released. All five females that survived reproduced within 2–6 months of release. Over three years, 28 births from nine females were recorded. Between March 2011 and July 2012, sixteen captive-reared black-footed rock-wallabies (eight males, eight females; 1–5 years old) were released in three groups into a 97-ha fenced area. Ten of the 16 rock-wallabies were wild-born and fostered by yellow-footed rock-wallaby *Petrogale xanthopus* surrogate mothers in captivity. Introduced predators, common wallaroos *Macropus robustus* and European rabbits *Oryctolagus cuniculus* were removed from the enclosure. Supplementary water was provided in five 8-l tanks that were monitored with camera traps in 2011–2014. Rock-wallabies were fitted with radio-collars and tracked 1–7 times/week in 2011–2014. Trapping was carried out on seven occasions in 2011–2014.

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(2) Hardman B. & Moro D. (2006) Optimising reintroduction success by delayed dispersal: is the release protocol important for hare-wallabies? *Biological Conservation*, 128, 403–411, https://doi.org/10.1016/j.biocon.2005.10.006

(3) Wakeling BF., Lee R., Brown D., Thompson R., Tluczek M. & Weisenberger M. (2009) The restoration of desert bighorn sheep in the Southwest, 1951–2007: factors influencing success. *Desert Bighorn Council Transactions*, 50, 1–17.

(4) Loureiro F., Martins A.R., Santos E., Lecoq M., Emauz A., Pedroso N.M. & Hotham P. (2011) O papel do programa lince (LPN/FFI) na recuperação do habitat e presas do lince-ibérico no sul de Portugal. *Galemys*, 23, 17–25.

(5) Islam M.Z., Shah M.S. & Boug A. (2014) Re-introduction of globally threatened Arabian gazelles *Gazella arabica* (Pallas, 1766) (Mammalia: Bovidae) in fenced protected area in central Saudi Arabia. *Journal of Threatened Taxa*, 6, 6053–6060, https://doi.org/10.11609/jott.o3971.6053-60

(6) West R., Read J.L., Ward M.J., Foster W.K. & Taggart D.A. (2017) Monitoring for adaptive management in a trial reintroduction of the black-footed rock-wallaby *Petrogale lateralis*. *Oryx*, 51, 554–563, https://doi.org/10.1017/s0030605315001490

14.9. Graze herbivores on pasture, instead of sustaining with artificial foods

https://www.conservationevidence.com/actions/2398

- **One study** evaluated the effects of grazing mammalian herbivores on pasture, instead of sustaining with artificial foods. This study was in South Africa[1].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (1 STUDY)

- **Reproductive success (1 study):** A site comparison study in South Africa[1] found that a population of roan antelope grazed on pasture had a higher population growth rate than populations provided solely with imported feed.

BEHAVIOUR (0 STUDIES)

Background

In highly managed populations of wild mammalian herbivores, locations of enclosures or other constraining features can determine what food is available for animals. Some populations may be maintained on food imported from elsewhere. However, making pasture available might provide a higher quality diet than can be offered with imported food and this might have positive effects on the population.

A site comparison study in 1995 of five conservation areas on a range of veld habitats in South Africa (1) found that in a population of roan antelope *Hippotragus equinus equinus* grazed on pasture, the population growth rate was higher than in populations provided solely with imported feed. The rate of increase of the pasture-fed population was higher than that of four other populations that were not pasture-fed (data presented as mean exponential rates). Population sex ratios, calving rates, population sizes and densities were not correlated with rates of population increase. Five conservation areas (each <3,000 ha)

were studied. Population data were obtained in winter 1995. At one site, antelopes were grazed on pasture and, in the dry season, fed ≥0.5 kg of supplementary food/day (lucerne, antelope cubes and mineral lick). At the other four sites, antelopes solely received the supplementary feed, in varying proportions.

(1) Dörgeloh W.G., van Hoven W. & Rethman N.F.G. (1996) Population growth of roan antelope under different management systems. *South African Journal of Wildlife Research*, 26, 113–116.

Translocate Mammals

14.10. Translocate to re-establish or boost populations in native range

https://www.conservationevidence.com/actions/2397

- **Sixty-four studies** evaluated the effects of translocating mammals to re-establish or boost populations in their native range. Twenty studies were in the USA[5,8,9,11,12,13,19,20,23,26,31,32,34,35,38,42,48,51,52,56], eight in Italy[16,25,30,46,53,59,61,62], four in Canada[2,6,10,41] and South Africa[7,36,44,50], three in the Netherlands[14,33,47] and Spain[35,60,63], two in each of the USA and Canada[3,22], Zimbabwe[4,17], Sweden[15,18], Australia[28,57] and the USA and Mexico[45,49] and one in each of Uganda[1], the UK[24], Brazil[27], France[29], Portugal[39], Africa, Europe, North America[40], Botswana[43], Nepal[54], Chile[55], Slovakia[58], Ukraine, Slovakia and Poland[64] and one global study[21].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (62 STUDIES)

- **Abundance (22 studies):** Two studies (incuding one controlled and one before-and-after, site comparison study) in Spain[35] and Canada[41] found that translocating animals increased European rabbit[35] abundance or American badger[41] population growth rate at release sites. Fourteen studies (one replicated) in South Africa[7,44,50], the USA[9,23,20,31],

the Netherlands[14], Italy[16,46,53,61], France[29] and Spain[60] found that following translocation, populations of warthogs[7], Eurasian beavers[14], red squirrels[16], roe deer[29], Alpine ibex[53], Iberian ibex[60], Cape mountain zebra[50], 22 species of grazing mammals[44], black bears[9], brown bear[61,46], bobcats[31] and most populations of river otters[23] increased. Two reviews in South Africa[36] and Australia[28] found that reintroductions (mainly through translocations) led to increasing populations for four of six species of large carnivores[36] and that over half of translocations were classified as successful[28]. One replicated study in the USA and Mexico[45] found that translocating desert bighorn sheep did not increase the population size. Two studies (one replicated) and a review in USA and Canada[3], the USA[34] and Australia[57] found that translocated American martens[34], and sea otters[3] at four of seven sites, established populations and that translocated and released captive-bred macropod species[57] established populations in 44 of 72 cases. A study in Italy[59] found that following the translocation of red deer, the density of Apennine chamois in the area almost halved. A worldwide review[21] found that translocating ungulates was more successful when larger numbers were released, and small populations grew faster if they contained more mature individuals and had an equal ratio of males and females.

- **Reproductive success (16 studies):** A controlled study in Italy[62] found that wild-caught translocated Apennine chamois reproduced in similar numbers to released captive-bred chamois. Fourteen studies (four replicated) in Canada[2], the USA[5,8,19,20,31,38], Zimbabwe[4], South Africa[7], the UK[24], Italy[46], the Netherlands[33,47] and Slovakia[58] found that translocated black and white rhinoceroses[4], warthogs[7], common dormice[24], European ground squirrels[58], cougars[19], bobcats[31], brown bears[38,46], sea otters[2], river otters[5,8,20] and some Eurasian otters[33,47] reproduced. A study in the Netherlands[14] found that translocated beavers were slow to breed.
- **Survival (39 studies):** Four of five studies (including three controlled, two replicated and one before-and-after, site

comparison study) in the USA[11,19,32], Canada[41] and Chile[55] found that wild-born translocated long-haired field mice[55], female elk[11], cougars[19] and American badgers[41] had lower survival rates than non-translocated resident animals. One found that translocated Lower Keys marsh rabbits[32] had similar survival rates to non-translocated resident animals. Five of four studies (two replicated, four controlled) and two reviews in Canada[10], Canada and the USA[22], the USA[48], Italy[62], Sweden[15] and Africa, Europe, and North America[40] found that wild-born translocated swift foxes[10,22], European otters[15], black-footed ferret kits[48] and a mix of carnivores[40] had higher survival rates than released captive-bred animals. One study found that wild-born translocated Apennine chamois[62] had a similar survival rate to released captive-bred animals. Twenty of twenty-one studies (including two replicated and one before-and-after study) and a review in Nepal[54], France[29], Italy[25,30,59], Portugal[39], Ukraine, Slovakia and Poland[64], Canada[2,6], USA[5,12,13,20,26,38,56], Brazil[27], Uganda[1], South Africa[7], Zimbabwe[4,17] and Botswana[43] found that following translocation, populations of or individual mammals survived between two months and at least 25 years. The other two studies found that two of 10 translocated white rhinoceroses[1] died within three days of release and an American marten[26] population did not persist. A review in Australia[28] found that over half of translocations, for which the outcome could be determined, were classified as successful. Two of three studies (one replicated) and one review in Sweden[18], the UK[24], the Netherlands[47] and the USA and Mexico[49] found that following release of wild-caught translocated and captive-bred animals, European otters[18,47] and common dormice[24] survived three months to seven years. The review found that most black-footed ferret[49] releases were unsuccessful at maintaining a population. A replicated study in the USA[51] found that following translocation of bighorn sheep, 48–98% of their offspring survived into their first winter.

- **Condition (3 studies):** Three studies (including one replicated, controlled study) in the USA[37,52] and Italy[46] found that following translocation, populations of elk[37] had similar levels of genetic diversity to non-translocated populations, descendants of translocated swift fox[52] had genetic diversity at least as high as that of the translocated animals and brown bear[46] genetic diversity declined over time.

BEHAVIOUR (9 STUDIES)

- **Use (7 studies):** A study in Italy[53] found that following translocation, Alpine ibex used similar habitats to resident animals. Two of four studies (including one randomized, controlled study) in the USA[13,42], Netherlands[33] and Botswana[43] found that following translocation (and in one case release of some captive-bred animals), most Eurasian otters[33] settled and all three female grizzly bears[13] established ranges at their release site. The other two studies found that most nine-banded armadillos[42] and some white rhinoceroses (when released into areas already occupied by released animals)[43] dispersed from their release site. Two studies (one replicated) in Spain[60,63] found that following translocation, Iberian ibex[60] expanded their range and roe deer[63] increased their distribution six-fold.
- **Behaviour change (2 studies):** A replicated controlled study in Chile[55] found that following translocation, long-haired field mice[55] travelled two-to four-times further than non-translocated mice. A controlled study in Italy[62] found that wild-caught translocated Apennine chamois[62] moved further from the release site than released captive-bred animals.

Background

Translocations involve the intentional capture, movement and release of wild-caught mammals into the wild to re-establish a population that has been lost, or augment an existing population. This can reduce the risk of inbreeding, help safe guard small populations from extinction due to catastrophic events and/or increase the range of a species and therefore the maximum possible population. Translocations can also be used to move mammals to areas where threats have been removed, such as invasive predators on islands. However, translocations are typically expensive and may risk spreading pathogens to previously unexposed areas.

Release techniques vary considerably, from 'hard releases' involving the simple release of individuals into the wild to 'soft releases' which involve a variety of adaptation and acclimatisation techniques before release or post-release feeding and care. This action includes studies describing the effects of translocation programmes that do not provide details of specific release techniques. Studies that describe or compare specific release techniques, such as use of holding pens at release sites, or providing supplementary food, water or artificial refuges/breeding sites are described under each specific action.

This action includes studies where animals were released in groups but not studies where releases of different group sizes were compared, or where animals were released in family or social groups (including groups where social animals have been pre-conditioned together prior to release in holding pens). For those studies, see *Release translocated/captive-bred mammals in larger unrelated groups* and *Release translocated/captive-bred mammals in family/social groups.*

A study published in 1961 on savannah in a national park in Uganda (1) found that after release of 10 translocated white rhinoceros *Ceratoiherium simum cottoni*, two died within three days. One animal died one day after release and the other died three days after release. Both

were adult females. One had a female calf that was taken into captivity. The remainder were all thought to have survived in the short-term, although only four of the seven were resighted by the end of the study. Ten rhinoceroses (four adult females, three half-grown males, one male calf and two female calves) were translocated to the park and released in March 1961. Duration of monitoring not stated.

A study in 1969–1978 in coastal waters close to Vancouver Island, British Columbia, Canada (2) found that a population of translocated sea otters *Enhydra lutris* persisted over nine years and reproduced. Eight and nine years after the translocation of 89 sea otters, a population of at least 67 individuals persisted within the surroundings of the translocation area. Pups (7 individuals), dependent juveniles (4 individuals) and subadult otters (10 individuals) were observed. A total of 89 sea otters were translocated in 1969, 1970 and 1972 from Alaska, USA to the Bunsby Islands along the west coast of Vancouver Island. No details about the translocation procedure are provided. Otters were counted almost daily by boat, scuba diving and aerial census in June-July 1978. Further census details are not provided.

A replicated study in 1965–1981 at seven coastal sites in Oregon, Washington, and Alaska, USA, and British Columbia, Canada (3) found that translocated sea otters *Enhydra lutris* established stable populations at four of the seven release sites. In south-eastern Alaska, where 412 sea otters were released, 479 were counted six years after the last release. In British Columbia, after 89 sea otters were released, 70 (including some pups) were seen five years after the last release. In Washington, 59 sea otters were released at two sites, with 36 (including one pup) counted across these sites 12 years later. In Oregon, 93 were released at two sites, but only one was found 10 years later. Fifty-five were released on the Pribilof Islands, Alaska, but only three were found nine years later. In 1965–1972, a total of 708 sea otters were translocated from Amchitka Island and Prince William Sound, Alaska to seven coastal sites where they had previously been extirpated. Populations were surveyed in 1971–1975 by boat and plane and from land.

A study in 1975–1981 of savannah in a national park and surrounding areas in Zimbabwe (4) found that translocated black rhinoceros *Diceros bicornis* and white rhinoceros *Ceratotherium simum* established populations and started to breed. Five out of seven translocated black

rhinoceroses survived at least six years after release and at least one calf was born. Up to nine out of 10 translocated white rhinoceroses survived at least six years after release, with at least seven calves born. Together with immigrant animals, the white rhinoceros population numbered 23–25 individuals at that time, in widely dispersed locations (movements of 22–130 km from release points were recorded). Black rhinoceroses and white rhinoceroses were translocated from areas of encroaching human activities. Seven black rhinoceroses (four adult males, two adult females and a male calf) were translocated in October–December 1975. Ten white rhinoceroses (one adult male, one adult female, two sub-adult males and six sub-adult females) were translocated and released in two groups, reflecting two areas of capture, in April 1975.

A replicated study in 1982–1986 in two wetland sites in Missouri, USA (5) found that most translocated river otters *Lutra canadensis* survived for at least a year after release and reproduction occurred at both release sites from two years following releases. Of otters whose status could be confirmed one year after release, 15 of 17 were alive at one site and 10 of 14 survived at the second site. Reproduction was confirmed annually at both release sites from the second year after releases. Nineteen wild-caught otters were released at a 4,455-ha wildlife refuge in March–May 1982 and 20 were released at a 2,251-ha wildlife area in April 1983. All otters were implanted with radio-transmitters. Monitoring occurred daily for the first three weeks and then 2–4 times/week until death or transmitter failure (typically at 12–14 months).

A review of studies in 1964–1982 in Newfoundland, Canada (6) found that after translocation, 17 of 22 caribou *Rangifer tarandus* populations persisted for at least 1–20 years. Between 1964 and 1982, a total of 384 caribou were translocated to 22 sites in Newfoundland. Caribou populations at sites were resurveyed using unspecified methods in 1981–1982.

A study in 1976–1990 in a shrubland reserve in Cape Province, South Africa (7) found that translocated warthogs *Phacochoerus aethiopicus* survived, bred successfully and abundance increased over approximately 10 years. Ten to 11 years after the release of 20 warthogs, numbers of warthogs counted increased to 641. Thirteen to 14 years after release, 361 individuals were counted. Separate surveys of dead warthogs found that the population comprised a mixture of age groups,

including juveniles (<1 year: 67–144 individuals), yearlings (1–2 years: 31–62 individuals) and adults (>2 years: 143–204 individuals). The majority of yearling and adult females examined (80–100%) were pregnant. In 1976–1977, twenty warthogs were introduced into a 6,493-ha reserve dominated by dense thorny scrub. Warthogs were surveyed by helicopter in 1981–1990. In 1987–1990, warthogs were shot at random from helicopters in order for carcasses to be examined and population age structure estimated.

A replicated study in 1982–1991 at two riverine sites in Pennsylvania, USA (8) found that translocated river otters *Lutra canadensis* released in areas with no existing otters settled and reproduced in the 6.5–8 years after release. Otter scats were widely found in both release areas, confirming continued otter presence. Two juveniles, live-trapped and released by hunters three years after translocations, provided evidence of breeding at one site. At the other site, four of seven otters killed by trappers, between three and seven years after translocations, were considered to be offspring of released animals. Twenty-two wild-caught otters (11 male, 11 female) were released in Pine Creek in 1983–1984 and four (two male, two female) were released in Kettle Creek in 1982. Follow-up monitoring of scats occurred in September–December 1990 (Pine Creek) and April 1991 (Kettle Creek). Additionally, carcasses were examined and trapping incidents reviewed.

A study in 1985–1993 of forest across two mountain areas in Arkansas, USA (9) found that a translocated population of black bears *Ursus americanus* grew steadily after animals were released. Following release of an estimated 254 bears, the population grew to >2,500 bears 20 years later. Litter sizes in two study areas were 1.6–2.4 and survival to one year was 40–65%. Black bears were extirpated from Arkansas sometime after 1931, apart from a small isolated population. Approximately 254 bears were released in 1958–1968 into three main areas from which bears had been lost. Released animals were wild-caught in Minnesota and in Manitoba, Canada. Bear densities were estimated in two study areas by mark-recapture at bait stations in 1985–1990. Litter sizes were estimated from bears radio-collared in 1988–1990 and monitored through to 1993.

A replicated, controlled study in 1990–1992 at two grassland sites in Alberta, Canada (10) found that translocated, wild-born swift foxes *Vulpes velox* had higher post-release survival rates than did released

captive-born animals. No statistical analyses were performed. Nine months after release into the wild, 12 out of 28 (43%) wild-born translocated swift foxes were known to be alive, compared with at least two out of 27 (7%) released captive-born swift foxes. In May 1990 and 1991, a total of 27 captive-born and 28 wild-born swift foxes were released simultaneously. Wild-born animals had been captured in Wyoming, USA, 4–7 months before release and were quarantined for ≥30 days. Animals were released without prior conditioning in holding pens. Foxes were radio-collared and monitored from the ground and air, for at least nine months.

A controlled study in 1980–1990 in a large mountainous area dominated by coniferous forest in Oregon, USA (11) found that translocated female elk *Cervus canadensis* had a lower survival rate than non-translocated female elk. The average annual survival rate of translocated female elk (77% of 35 individuals) was siginificantly lower than that of non-translocated female elk resident at the release sites (92% of 35 individuals) and also appeared lower than the average annual survival rate of female elk in the whole study area (89% of 184 individuals, this result was not compared statistically to other survival rates). The study area included six national forests and eight state wildlife management districts. In 1980–1990 one hundred and eighty-four resident female elk were released at their capture site. In 1987–1990, 35 female elk were caught, radio-collared and translocated. A further 35 resident female elk were radio-collared in 1988–1989 at the translocation release site. Distances between capture and release sites of translocated elk are not given. Both non-translocated and translocated elk were located 2–4 times/month, mostly from an aircraft.

A study in 1987–1992 in a subalpine coniferous forest in Idaho, USA (12) found that approximately a quarter of translocated woodland caribou *Rangifer tarandus caribou* survived or had stayed at the release site two-four years after release. Fourteen out of 60 (23%) translocated woodland caribou survived two-four years after being released into the wild. Seven translocated caribou left the study area over the five-year study, of which six were during the first year after release. Twenty-seven caribou died during the same period (3 during the release process) and the outcome for 12 animals was unknown due to radio-collar failure. The average annual survival rate was 74%. Between 1987 and

1990, sixty woodland caribou were caught in British Columbia, Canada and released in the Selkirk Mountains, USA after 72 hours. Caribou were radio-tagged and were monitored weekly, from an aircraft, until February 1992.

A study in 1990–1993 in forests in Montana, USA (13) found that three translocated female grizzly bears *Ursus arctos horribilis* successfully established ranges around the release site and that two survived for at least three years. All three translocated bears established movement and habitat-use patterns similar to those of non-translocated bears (no data reported). Two of the three bears survived for at least three years. Three adult female bears were translocated from the border area of Canada and the USA to the Cabinet Mountains in Montana, USA. Bears were monitored by radio-tracking until their collars failed or to the end of the study period after three years.

A study in 1988–1993 of a freshwater estuary at a national park in the Netherlands (14) found that translocated Eurasian beavers *Castor fiber* increased in number, although were slow to breed. From 42 animals released over four years, the population grew to 47 two years after releases (including 27 animals ≥1 year old). Only in this final year did the number of births exceed the number of animals lost (through dispersal, death or other disappearance). Population Viability Analysis found that the population was unlikely to be viable (80% of simulated populations going extinct within 100 years) unless low breeding productivity was a temporary response to translocation. A total of 42 beavers, translocated from Germany, were released in October or November of 1988–1991. They were monitored by radio-tracking (from boat and plane) and direct observations of marked animals.

A replicated, controlled study in 1989–1993 in two rivers in southern Sweden (15; same experimental set-up as 18) found that wild-born translocated European otters *Lutra lutra* had a higher survival rate than did released captive-bred otters. One year after release, the survival rate of wild-born translocated otters (79%) was higher than that of released captive-bred otters (42%). Between 1989 and 1992, eleven wild-born otters and 25 captive-bred otters were released into two rivers in south-central Sweden. Thirty-four otters were released in one river catchment and two in the other. Wild-born otters were live-trapped along the Norwegian coast. Captive-bred otters were descendants of two captive

females. All otters were around one year old when released. All except one were released between February and June. All were fitted with an implanted radio-transmitter and monitored for one year on 64% of days.

A study in 1986–1996 in a forest and heathland reserve in Lombardy, Italy (16) found that a population of translocated red squirrels *Sciurus vulgaris* increased in size over 10 years and expanded to nearby woodlands. Three to four years after eight translocated squirrels were released, the population had increased to 38–126 squirrels. By ten years after the first release, the squirrel population had further increased and colonized all five woodlands (squirrel abundance in 1996 is not given). Between December 1986 and August 1987, eight red squirrels were translocated to a 3,500-ha reserve containing 800-ha of woodland, from which the species was extirpated in the 1940s. In February 1990, squirrel nests were counted on a 70-ha plot and the population size was estimated based on a mean of 4.5 nests/squirrel. In spring 1990 and 1996, all five woodland blocks at the release site were searched for 30 min to 1 hour for dreys or typical feeding signs.

A before-and-after study in 1996 in a mixed miombo and mopane woodland reserve in the Midlands province, Zimbabwe (17) found that three translocated cape pangolins *Manis temminckii* survived at least a month after release and one established a new home range. During the sixty-five days after release, one translocated pangolin set up a home range covering 0.45 km^2. Of two adult females translocated, one returned to her original home range nine days after translocation and the other moved for 30 days (on average 1.25 km/day), without returning to the capture site or establishing a home range. One pangolin had been retrieved from a poacher and its origin and length of time in captivity were unknown. The two females were caught, radio-tagged and radio-tracked in their original capture location (for an unspecified period) before being moved and released about five and 18 km from their known home ranges within 24 hours of capture. Translocations were carried out to study effectiveness of releasing pangolins confiscated from poachers. Pangolins were monitored by radio-telemetry, and located during daytime by tracking on foot for approximately a month after release.

A study in 1989–1992 at seven lakes in boreal forest in Sweden (18; same experimental set-up as 15) found that following release of European otters *Lutra lutra* (a mix of wild-caught translocated and

captive-bred animals), at least 38% survived for almost a year or longer. Fourteen otters established home ranges and were still alive when last recorded, 362–702 days after release. Eight further otters were monitored until their transmitters failed or they moved out of radio contact, 89–219 days after release. Fourteen were known to have died, 18–750 days after release. Otter origin (wild-caught or captive-bred) did not affect movement distance. In 1989–1992 thirty-six otters (11 wild-caught, translocated animals and 25 captive-bred) were released in lakes and rivers in southern Sweden. Otters were fitted with radio-transmitters. Radio-tracking was carried out at least monthly, in 1989–1992.

A study in 1989–1993 at nine temperate shrubland and coniferous woodland sites in New Mexico, USA (19) found that survival rates of translocated cougars *Puma concolor* were lower than those of resident populations, and two translocated females produced offspring. Nine of 13 cougars (69%) died within four years of translocation. Annual survival rates of translocated female (55%) and male (44%) cougars were lower than of non-translocated resident animals (86%). Two translocated females produced offspring. The main cause of mortality was from aggressive interactions with other cougars. In April 1989, one cougar was released at one site in the Cibola National Forest, New Mexico. From December 1990 to June 1991, thirteen cougars were released in eight sites in the Sangre de Christo Mountains, New Mexico. Released animals were radio-tracked by air or from the ground through to January 1993. Survival rates of translocated cougars were compared to those of 15 radio-tracked cougars that had not been translocated.

A study in 1995–1996 of a wildlife refuge with several wetland habitats in Indiana, USA (20) found that following translocation of North America river otters *Lutra canadensis*, most survived at least one year after release and breeding occurred in the second year post-release. Survival one year post-release was estimated at 71%. Three otter litters were documented in the second year after release. Confirmed mortalities were three otters killed by vehicles, one dying from research-related causes and one dying of an unknown cause. River otters were extirpated from Indiana by 1942. Twenty-five otters (15 male, 10 female) were translocated from Louisiana and released in a 3,125-ha refuge in Indiana, on 17 January 1995. Fifteen otters were radio-tracked five times/week for 16 weeks, and three times/week for up to one year. Field

surveys and visual observations were also used, including to document breeding activity.

A worldwide review of 33 studies (21) found that translocating ungulates (Artiodactyla) to re-establish populations in their native range was more successful when larger numbers of animals were released, and small populations grew faster if they contained more mature individuals and had an equal ratio of males and females. All 10 translocated populations of ≥20 animals increased in number (by an average of 17%), whereas six of 23 translocated populations with ≤20 animals decreased. Small translocated populations (≤20 animals) were more likely to increase if they contained more mature individuals (females ≥3 years of age; males ≥5 years) and had an equal sex ratio (data reported as statistical model results). Analyses included 33 re-introduction studies involving nine ungulate species (including sheep, goats, elk, bison, reindeer and gazelle). Groups of 2–69 wild-caught animals were released within their native range and observed over 3–9 years (locations not reported). Studies were published (between 1959 and 1998) and unpublished (dates not reported).

A review of studies in 1989–1991 in prairie sites in Canada and the USA (22) found that following release, translocated wild-caught swift foxes *Vulpes velox* had higher survival rates than did captive-bred released swift foxes. Over an unspecified time period, 59% of wild-caught translocated swift foxes survived while three of 41 (7%) released captive-bred swift foxes survived. In 1989–1991, thirty-three wild-caught, adult foxes and 41 captive-bred foxes, born the previous year, were released in the spring. Methods used for monitoring animals were unclear from the review.

A study of projects carried out in 1976–1998 across 48 states in the USA (23) found that following translocations, river otter *Lutra canadensis* populations and ranges expanded in most states. Of 21 states with reintroduction programs, 15 reported having growing river otter populations, one reported a stable population and three reported stable to growing populations. Two states reported that it was too soon into their programs to judge population trends. Evidence of reproduction was reported from 18 states (82% of states with reintroductions), and range expansion was reported in 17 states (77%). In 1976–1998, river otter releases totalled 4,018 animals in 21 states. In six states, otters had

been extirpated while in 15, reintroductions took place in parts of the state from which otters were absent. Releases involved an average of 19.6 otters/site. Information was gathered from telephone interviews in August–September 1998.

A replicated study in 1993–2002 in seven woodland sites across England, UK (24) found that following releases of some wild-born translocated but mainly captive-bred common dormice *Muscardinus avellanarius*, populations persisted for at least three months to over seven years and all reproduced. In at least three of seven releases, dormouse populations were stable or increased from 19–57 released individuals to 40–55 individuals between two and seven years later. At one site, only one individual was detected 7–8 years after the release of 52 individuals in two batches. In three populations, the number of released animals is not provided, but populations persisted for at least three months and up to at least three years after release. Animals in all seven populations bred in the wild. Releases took place in 1993–2000 into woodlands in Cambridgeshire, Nottinghamshire, Cheshire, Warwickshire, Buckinghamshire, Yorkshire and Suffolk. Monitoring continued to 2000–2002. Precise numbers and origins of dormice released are not given for all sites. Most were captive-bred, but some were wild-born translocated animals. Some dormice were kept in pre-release holding pens, sometimes for several weeks, before release. Nest boxes and supplementary food were provided at least at some sites (see paper for further details).

A replicated study in 1977–2002 in four alpine shrub and meadow sites in the Eastern Italian Alps, Italy (25) found that translocated alpine marmot *Marmota marmota* populations persisted for at least five years. At the first translocation site, 23 marmot families (28.4 family units/km^2) were counted 22 and 25 years after release. At the second site, 13 marmot family groups were counted 16 years after release (13.8 family units/km^2). After 12 more marmots were added to the second site in 2001, the population increased to 18 family units in 2002. A further two marmot populations were described as persisting for 5–7 years with 11–16 family groups (assisted by some restocking in one site). In 1977, 1983, 1995 and 1997, alpine marmots were released in four sites (150, 168, 472 and 1,005 ha respectively) in the Friulian Dolomites Natural Park. The number of individuals released is not reported. The origin of animals is not

explicitly stated, but releases appear to be of translocated wild marmots. In May 1999–2002, winter burrows were located as marmots emerged from hibernation. Marmots were identified by tracks in the snow and each winter burrow was considered to be occupied by one family unit. Authors state that marmots were released in many isolated areas from the 1960s onward, but introduction was only successful in a few of them.

A study in 1989–1998 in two forest sites in Vermont, USA (26) found that after translocation of American martens *Martes americana*, the population did not persist. One to six years after introductions, there was evidence that 3–4 martens were present in the area but, after seven to eight years, there was no evidence of a marten population. In 1989–1991, a total of 115 martens (88 males, 27 females) were captured in Maine and New York State and released at two sites in southern Vermont. Forty of the martens were held in boxes at the release site for several days before release and 75 were released immediately after transport to the release site. Thirteen martens were fitted with radio-collars and monitored using telemetry until March 1991. In January–February 1990, surveys were carried out for marten tracks in the snow. In October 1994 to January 1995, January–March 1998 and the summers of 1997 and 1998, camera traps were placed at 20–285 locations to survey martens.

A study in 1994–2001 in two forest reserves in Espírito Santo, Brazil (27) found that translocated maned sloths *Bradypus torquatus* survived over 13 months and up to at least 36 months after release. All five translocated sloths survived the whole length of the post-release monitoring period (9–13 or 36 months). Two female sloths gave birth but all young were predated. Moving/resting and feeding time and daily distances travelled were not related to time since release. Between 1994 and 1999, five sloths were translocated from within or close to urban areas into two forests (500–900 ha, encompassing reserves and private forest land). Sloths were radio-collared and monitored 1–3 days/month for 9–13 months (four animals) and 36 months (one animal). Each sloth was observed from 07:00 to 17:00 h for totals of 182–509 hours. Data on activity budgets, home range size and diet were collected.

A review study of 66 translocations of 14 mammal species in Western Australia (28) found that over half of translocations, for which the outcome could be determined, were classified as successful. Out of

20 mammal translocations with a confirmed outcome, 11 (55%) were classed as successful and nine (45%) as non-successful. At the time of the review, the outcome of 46 translocations (68% of all translocations studied) remained uncertain. Species translocated were quokka *Setonix brachyurus*, black-flanked rock-wallaby *Petrogale lateralis*, tammar wallaby *Macropus eugenii*, brush-tailed bettong *Bettongia penicillata*, boodie *Bettongia lesueur*, common wallaroo *Macropus robustus*, numbat *Myrmecobius fasciatus*, southern brown bandicoot *Isoodon obesulus*, western barred bandicoot *Perameles bougainville*, western ringtail possum *Pseudocheirus occidentalis*, greater stick-nest rat *Leporillus conditor*, shark bay mouse *Pseudomys fieldi*, Thevenard Island mouse *Leggadina lakedownensis* and pebble-mound mouse *Pseudomys* sp. In 1993–2002, between 5–188 individuals of each species were translocated to different locations. Invasive mammals were controlled in some recipient sites. Two translocations included some captive-bred animals but most were translocated from wild populations. The definition of successful translocation was not stated for most species but, for others, it included measures of population increase and persistence.

A study in 1995–2002 in a mixed oak forest reserve in the south of France (29) found that following translocation in groups (alongside other associated actions), approximately half of female roe deer *Capreolus capreolus* survived over one year after release and that overall the deer population increased six years after the translocations began. Twenty-six out of 49 (53%) translocated female roe deer survived over one year post-release. Of the animals that died in the first year, 35% of mortality occurred within the first month after release. After six years the deer population had increased to 0.47 deer/km^2 compared to 0.06 deer/km^2 in the first year after translocation began. In February 1995–1997, fifty-two male and 52 female roe deer were translocated from Northern France into a 3,300-ha forest reserve in Southern France in seven release sessions. Animals were released in groups of approximately 15 individuals. They were initially placed into enclosures for 2–10 days and provided food during this time (pellets and fresh vegetables) prior to release. Forty-nine females (21 <1 year old and 28 >1 year old) were radio-tagged and were located from a vehicle once or twice each week, over one year post-release. In addition, surveys were carried out on foot (6 transects, each 5–7 km long) eight times a year in February-March

1996–2002 to estimate population growth. Deer were present in low numbers prior to translocation.

A study in 1999–2003 in a temperate forest site in northern Italy (30) found that most translocated brown bears *Ursus arctos* survived 2–3 years after release. Two to three years after release of 10 bears, at least eight were alive. In 1999–2002, ten bears (3 males, 7 females; all 3–6 years old) were captured in two sites in Slovenia and fitted with radio-collars and ear-tag transmitters. Animals were released in Adamello-Brenta Natural Park, Italy. Bears were located from the ground twice each day using radio antennae, from May 1999 to October 2003.

A study in 1988–1991 on an offshore island dominated by temperate forest in Georgia, USA (31) found that translocated bobcats *Lynx rufus* increased in numbers and reproduced in the wild. One year after the first releases, population density was 1 bobcat/10 km^2. One year after the second releases, population density was 3 bobcats/10 km^2. Over the two years after the first releases, 12 offspring were born. In September–December of 1988–1989, thirty-two bobcats fitted with radio-collars were released on Cumberland Island. Bobcats had previously become extinct on the island, in 1907. Radio signals were monitored throughout the year from the ground or from an aircraft. If females showed reduced movement, their location was visited to identify if they had given birth.

A replicated, controlled study in 2002–2004 on two islands in Florida, USA (32) found that translocated Lower Keys marsh rabbits *Sylvilagus palustris hefneri* had post-release survival rates similar to those of animals in established populations. Of rabbits whose fate was known, nine of eleven (81%) translocated to one island survived ≥5 months (two were predated) and all six (100%) translocated to another island survived ≥5 months. Eleven out of 14 (79%) caught and released at capture sites survived ≥5 months, with two predated and one dying from unknown causes. Transmitter failure curtailed monitoring of two further rabbits from these groups. Twelve rabbits, caught in 2002, were released within two hours of capture onto a nearby rabbit-free island. Seven rabbits, caught in 2004, were released onto a different rabbit-free island. In 2002, nine rabbits were also released at respective capture sites. Rabbit survival was determined by radio-tracking.

A study in 2002–2005 in two wetland areas in the Netherlands (33) found that following translocation, and release of some captive-bred

animals, most Eurasian otters *Lutra lutra* settled in their release areas, where successful breeding then occurred. After three weeks, 14 of 23 otters settled within their release areas, while two died and seven moved away from release areas. Three years after the first translocations, five female otters had successfully reproduced, producing nine young. At this time, the total population was 12 otters. In 2002, fifteen wild-caught otters were released at one site. At a second site, in 2004–2005, eight animals, comprising a mix of wild-caught and captive-bred individuals, were released. Before release, animals were fitted with radio-transmitters and DNA samples were taken. Following release, otters were monitored by radio-tracking and by collection of faeces, which was analysed to identify animals individually.

A study in 2001–2003 in woodland across Peninsula Michigan, USA (34) found that translocated American martens *Martes americana* established a population. Ninety-four trapped martens had a sex ratio of 1.5 males for each female (1.9:1 considering just adults). This was not significantly different from the ratio of 2:1 which authors stated that for trapped animals, indicated that the harvest was sustainable. The age ratio was 3.3 juveniles (≤1.5 years old) for each adult (≥2.5 years old) female. This also was not significantly different from the ratio of 3:1, stated as indicating a sustainable harvest. Translocations into five areas in Peninsula Michigan, where martens had been extirpated, occurred in 1955–1957, 1968–1970 and 1979. These involved 276 martens. In 1989–1992, sixty-six martens were translocated internally within Peninsula Michigan. Marten trapping was permitted in limited areas from 2000. Sex and age data were determined for 94 martens obtained from commercial trappers in 2001–2003.

A controlled study in 1999–2002 in a shrubland site in Huelva, Spain (35) found that translocation of European rabbits *Oryctolagus cuniculus* increased rabbit abundance. Average rabbit abundance over the study was higher in translocation plots (5.0 pellets/m^2) than in non-translocation plots (1.9 pellets/m^2). The study was conducted in two 4-ha plots (≥1 km apart) in Doñana National Park. Annually, over three years, two batches of 32–34 rabbits were translocated into one plot and no translocations occurred in the other plot. The first two batches were translocated in November 1999 and February 2000. Plots were then switched such that the second and third pairs of translocations

(December 2000 and February 2001, and January and March 2002) were released into what was the non-translocation plot for the first batch. Between September 1999 and November 2002, rabbit abundance was estimated every two months by counting the number of pellets in 33 fixed-position 0.5-m diameter sampling points/plot. Wild rabbits were present in all plots prior to translocations beginning.

A review of studies conducted in 1985–2005 at 11 grassland and dry savanna sites in Eastern Cape, South Africa (36) found that reintroductions (mainly through translocations) of large carnivores led to increasing population sizes for four of six species. Twenty years after the first releases, there were 56 lions *Panthera leo* at seven sites (from 31 released), 41 cheetahs *Acinonyx jubatus* (seven sites, 40 released), 24 African wild dogs *Lycaon pictus* (two sites, 11 released) and 13 spotted hyena *Crocuta crocuta* (three sites, 11 released). There were reductions or unknown trends in two species with seven known surviving leopards *Panthera pardus* (five sites, 15 released) and an unknown number of servals *Leptailurus serval* (though known to be present — two sites, 16 released). Releases were made in 1985–2005, into 11 protected areas. Most schemes involved translocations of wild-caught animals, but at least one of seven lion reintroductions involved captive-bred animals. Monitoring methods are not specified.

A replicated, controlled study (year not provided) in six protected areas across five states in western USA (37) found that translocated elk *Cervus canadensis* populations had similar levels of genetic diversity compared to non-translocated populations. The genetic diversity (expressed as 'expected heterozygosity', He) of translocated elk populations (0.51–0.60 He) did not differ significantly from that of the source population (0.60 He). Between 1912 and 1985, five populations of elk were founded using animals translocated from source herds in Yellowstone National Park. Translocated populations had different founding histories but starting populations ranged from 12 to >150 individuals. The size of the translocated populations at the time of the research was 500–10,000 elk. In each population, 17–43 samples of skin or muscle tissue were collected from hunter-harvested elks. Tissue samples were frozen or stored in ethanol before DNA extraction. The dates of sample collection and laboratory work are not provided.

A study in 1990–2005 in a forest site in Montana and northern Idaho, USA (38) found that most translocated female brown bears *Ursus arctos* survived for at least one year after release and at least one of four reproduced in the release area. Three of the four translocated bears (75%) survived for at least one year. The fourth bear died of unknown causes. After 12 years, at least one translocated bear was alive and had produced two litters with different males. In 1990–1994, four young wild female bears were caught in southeastern British Columbia and released in the Cabinet Mountains (no more than one released each summer). Radio-satellite monitoring was carried out over 1–2 years after release. Hair samples were collected from 2000–2005 and genetic analysis was used to determine presence of translocated bears and their offspring.

A study in 2001–2003 in agricultural fields and mixed woodland in a mountain range in Fundão, Portugal (39) found that most translocated roe deer *Capreolus capreolus* survived more than two years after release. At least five out of seven translocated roe deer (71%) survived more than two years after release. One was found dead and the radio-transmitted of another stopped working. In winter 2001, fourteen adult roe deer were released into a 50-km^2 area. Roe deer had been absent for the area for more than a century. Seven of the 14 deer were radio-tagged. Tagged animals were located daily during summer 2002 (May–September) and winter 2002–2003 (November–March).

A review in 2008 of 49 studies in 1990–2006 of carnivore reintroductions in Africa, Europe, and North America (40) found that wild-born translocated animals had higher survival rates than did released captive-bred animals. Survival of wild-born translocated carnivores (53%) was higher than survival of captive-born animals following release (32%). The review analysed 20 reintroductions of 983 captive-bred carnivores and 29 reintroductions of 1,169 wild-caught carnivores. Post-release monitoring ranged in duration from 6 to 18 months.

A before-and-after, site comparison study in 2002–2006 in two alpine grassland sites in British Columbia, Canada (41) found that translocating American badgers *Taxidea taxus* increased the population growth rate at the recipient site, but survival was lower than in a nearby resident population. The badger population growth rate was higher at the recipient site after translocation than before and was similar to that found in a nearby non-translocated population (data reported as

geometric growth rate). Ten young were born to translocated badgers. The adult annual survival rate was lower in the release site (77%) than in a nearby resident population (90%). In 2002, sixteen badgers were translocated from north-western Montana to supplement a declining population at a site in British Columbia. Translocated badgers were monitored in 2002–2006, by radio-tracking, from an aeroplane. Comparisons were made with a nearby site containing a resident badger population.

A randomized, controlled study in 2005–2006 in a plantation in Georgia, USA (42) found that most translocated nine-banded armadillos *Dasypus novemcinctus* dispersed from their release site within the first few days after release. Eleven out of 12 translocated armadillos (92%) dispersed from their release sites within the first few days (duration not specified) after release. Only six of the translocated animals were successfully relocated, of which two returned to their original capture sites, and three made long-distance movements away from their release sites. However, all 29 armadillos released at their original capture site remained near their release sites over the same period and maintained stable home ranges (3–30 ha). Between May 2005 and March 2006, forty-one armadillos were captured using long-handled dip nets and unbaited wire cage traps. Twelve armadillos were randomly selected to be translocated and the remainder were released at their capture sites. Translocated animals were released 0.7–8.1 km from their capture site. All individuals were tagged with transmitters and monitored 3–4 times/week for up to 358 days.

A study in 2001–2006 on grassland in a national park in Botswana (43) found that most translocated white rhinoceros *Ceratotherium simum* released in groups survived at least three years after release, but some dispersed away from the park when released into areas already occupied by released animals. Of 32 rhinoceroses released into the park in four batches during just over two years, five died soon after release and 21 remained in the park through to three years after the final release. Six (all females) left the park. All were from the final release. The authors suggest that this may be because suitable habitat close to the release site was already occupied by previously released animals. Rhinoceroses, sourced from protected sanctuaries, were all released from the same boma, in four batches, from November 2001 to November 2003. They

were monitored by radio-tracking from a vehicle or aircraft, through to 2006.

A replicated study in 1949–2001 in South Africa (44) found that following translocations inside and outside of their historical ranges, population sizes of most of 22 species of grazing mammals increased. Following translocation, 82 out of 125 populations (66%) of 22 grazing mammals (white rhinoceros *Ceratotherium simum*, mountain zebra *Equus zebra*, plains zebra *Equus quagga*, giraffe *Giraffa camelopardalis,* African buffalo *Syncerus caffer* and seventeen species of antelope) exhibited positive growth rates (data presented as results of population growth models). Population models were based on long-term monitoring data from 178 populations relocated to 24 reserves in 1949–1978 (see original paper for details). Only translocations with five or more consecutive years of monitoring results were included (125 translocations, monitoring data duration: 5–47 years). Translocation details are not provided but authors state that most translocated populations began with fewer than 15 individuals and that most reserves contained water impoundments and lacked top predators, such as lions *Panthera leo* or spotted hyenas *Crocuta crocuta*. Seventeen of the 22 species were introduced outside of their historical range.

A replicated study in 1951–2007 in 10 desert sites in Arizona and New Mexico, USA, and the Gulf of California, Mexico (45) found that translocating desert bighorn sheep *Ovis canadensis* did not increase the population size at the release site. No bighorn sheep populations which were supplemented with translocated individuals significantly increased in size (data not presented). Between 1951 and 1990, a total of 654 bighorn sheep were released, but details of individual releases are not provided. Data were obtained from historical records for ten sites with long-term survey and hunting information. Data included counts of bighorn sheep from both surveys and hunter harvests, and bighorn sheep translocations.

A study in 1999–2008 in an area of mixed agricultural land, forest, and grassland in the Alps of northern Italy (46) found that following translocation, brown bears *Ursus arctos* bred successfully in the release area and the population increased, but genetic diversity declined. Three years after the first translocations, there were 10 bears in the area. By nine years after the first translocations, this increased to 27–31 bears.

Over this time, 35 cubs had been born. However, genetic diversity declined over time (data reported as allelic richness). In 1999–2002, nine bears were caught in Slovenia and translocated into Trentino, Italy, where the resident population had fallen to around three individuals. In 2002–2008, hair and faecal samples were collected opportunistically and along transects. Samples were also collected from bear carcasses found in the area. DNA from these samples was analysed to identify individuals and to measure genetic diversity.

A study in 2002–2008 in an area of peatland, fen, woodland, ditches and lakes in the Netherlands (47) found that after release of 30 translocated and captive-bred Eurasian otters *Lutra lutra*, at least six were still alive six years later and some had reproduced. Most dead otters recovered were killed in collisions with road vehicles. Fifty-four offspring from released otters or their descendants were detected. Between July 2002 and November 2007, thirty otters were released. Seventeen were translocated, wild-caught animals and 13 were captive-bred. A publicity campaign encouraged people to report dead otters that they found. These were then examined to establish cause of death.

A controlled study in 1999–2001 on three grassland sites in an area in South Dakota, USA (48) found that wild-born translocated black-footed ferret *Mustela nigripes* kits had higher survival rates after release than did captive-born kits released from holding pens. Thirty-day post-release survival of captive-born kits (66%) was lower than that of wild-born translocated kits at the same site (94%). Annual survival was also for lower for captive-born kits (females: 44%; males: 22%) than for wild-born kits (females: 67%; males: 43%). Annual survival at the donor site remained high (females: 80%; males: 51%) whilst survival of translocated and released kits was comparable with that at an unmanipulated colony (females: 59%; males: 28%). Eighteen wild-born ferrets were released along with 18 captive-bred ferrets at a site from which the species was then absent. Captive-born ferrets were transferred to outdoor conditioning pens, sited on prairie dog colonies, when about 90 days old and then released on 29 September and 13 October 1999. Wild-born ferrets were released the day after capture. All were born in 1999. Ferrets at the release site, the donor site for wild-born kits and an unmanipulated site were monitored by radio-tracking and by reading transponder chips.

A review of studies in 1991–2008 at 11 grassland sites in the USA and Mexico (49) found that most captive-bred (with some translocated) black-footed ferret *Mustela nigripes* releases were unsuccessful at maintaining a population, but success was higher where prey was abundant over larger areas. Of 11 reintroduction sites, populations of more than 30 adult black-footed ferrets were maintained at four sites over two years without further reintroductions. Two sites no longer contained ferrets by December 2008, and the other five sites only had small populations or were supplemented by further releases. Sites where populations were maintained tended to have more prairie dogs *Cynomys* spp., the main prey species of black-footed ferrets, covering a larger area (at least 4,300 ha) and with a higher density of animals (data presented as index of prairie dog abundance). From 1991–2008, around 2,964 captive-bred and 157 translocated wild ferrets were released at 18 sites in multiple releases. The study reports success of the 11 sites where initial releases occurred before 2003. Sites received on average over 200 ferrets over 10 years. Ferrets were monitored by annual spotlight surveys to locate, capture and uniquely mark individuals.

A study in 1987–2009 in grassland and shrubland in the Western Cape, South Africa (50) found that numbers of translocated Cape mountain zebra *Equus zebra zebra* increased four-fold over 19 years. Nineteen years after release, there were four times more Cape mountain zebras (48) than at the time of release (12). In the first 14 years after translocations, 13 foals were born. In 1987–1990, twelve Cape mountain zebras were translocated into a 3,435-ha national park dominated by renosterveld and fynbos vegetation. No translocation or monitoring details are provided. Grass availability was promoted by artificial fires at four-year intervals.

A replicated study in 2000–2007 in two mountain sites in northern Utah, USA (51) found that following translocation of bighorn sheep *Ovis canadensis*, 48–98% of young descended from these animals survived into their first winter. The average survival of bighorn sheep lambs to their first winter was 48% at one site and 55–98% at the second site. In January and February 2000–2002 and 2007, one hundred and fourteen wild-born bighorn sheep (including 92 adult females) were translocated to Mount Timpanogos (67 females, 11 males, 4 young) and Rock Canyon (25 females, 4 males, 3 young). Thirty-one individuals

on Mount Timpanogos and 10 in Rock Canyon were fitted with radio-collars. Collared and uncollared females were relocated every 4–5 days from April–July 2001–2007 to count the number of young born. The number of young that survived to their first winter was determined by comparing the highest number of young observed during winter (October to March) with the number observed in the previous spring (April to July).

A study in 2003–2009 in a temperate grassland site in South Dakota, USA (52) found that translocating swift foxes *Vulpes velox* led to the establishment of a population in which genetic diversity of wild-born descendants was at least as high as that of the translocated animals. For two key measures of genetic diversity, values for descendants of translocated foxes (heterozygosity: 0.75; allelic richness: 11.2) were at least as high as those of the translocated animals (heterozygosity: 0.75–0.78; allelic richness: 7.5–8.6). In 2003–2006, one hundred and eight wild-caught swift foxes from Colorado and Wyoming were released into a national park in South Dakota from which the species had been extirpated. Four hundred DNA samples (108 from translocated foxes and 292 collected in 2004–2009 from their wild-born descendants) were analyzed for measures of genetic diversity.

A study in 1978–2004 and a controlled study in 2006–2009 in an alpine site comprising forest, rock and scree in Italy (53) found that following translocations of Alpine ibex *Capra ibex*, the population increased and translocated ibex used similar habitats to resident ibex. Twenty-three years after translocation, the estimated number of Alpine ibex (456 individuals) was higher than the number released (10 individuals). However, two years later the population declined by 75% due to a sarcoptic mange epidemic. Following further translocations, released ibex selected the same habitat resources as used by resident ibex (data presented as an ordination analysis), but translocated ibex initially occupied larger ranges and were separated from resident animals. By one year after release the home range size of translocated and resident ibex was similar, and by three years translocated animals were integrated into the resident social group. In 1978–1979, ten Alpine ibex were translocated from the Gran Paradiso National Park to the Marmolada massif in the Alps. In 2006–2007, fourteen additional male ibex were translocated to reinforce the Marmolada massif population.

All ibex translocated in 2006–2007 were radio-collared. From 2006–2009, sixty-seven resident male ibex from the established population were caught and ear-tagged and 52 were radio-collared. Translocated and established ibex were followed for 3–4 years.

A study in 1986–2011 in two reserves in western Nepal (54) found that translocated populations of the greater one-horned rhinoceros *Rhinoceros unicornis* persisted for at least 11–25 years post-release. On one reserve, there were 67 rhinoceroses in 2000, fourteen years after the first translocations, but this fell to a count of 24 rhinoceroses 11 years later. Poaching was thought to be the main cause of deaths. The second reserve had seven rhinoceroses 11 years after the translocations. Between 1986 and 2003, eighty-three rhinoceroses (38 males, 45 females) were translocated to Bardia National Park and, in 2000, four rhinoceros (three females and one male) were translocated to Suklaphanta Wildlife Reserve, which already held a single male. From 1986–2003, rhinoceros in Bardia National Park were protected by anti-poaching patrols formed of 10–15 soldiers and in 2007 a nationwide anti-poaching programme was launched. Monitoring details are not provided.

A replicated, randomized, controlled study in 2008–2009 in 10 pine plantation sites in Ñuble Province, Chile (55) found that translocated long-haired field mice *Abrothrix longipilis* travelled two-to four-times further and had lower survival than non-translocated mice. The average maximum distance travelled from the release site was longer in translocated mice (125–199 m) than in non-translocated mice (50 m). Mice released 0–100 m from their capture location had higher survival rates (20/20 survived) than mice translocated 500–1,300 m (14/18 survived). Additionally, eight of 10 mice that were translocated short distances (100 m) and nine of 10 mice which were released at their capture site returned to or stayed in their capture location, whereas mice which were translocated further (500 m = 1 of 10; 1,300 m = 0 of 10) did not return to their capture locations. From January–March 2008 and 2009, four male long-haired field mice were trapped at each of 10 sites in Quirihue and Cobquecura, using 80 baited live traps (3 × 3.5 × 9 inches) per site. Mice from each capture site were randomly allocated to one of four groups, which were released at sunset either at the capture site or 100, 500, and 1,300 m from their capture point. Each individual was radio-tagged and relocated once/day for three days after release.

A study in 2009–2012 on mixed grassland, shrub and woodland vegetation in a mountainous region in Wyoming, USA (56) found that following translocation of bighorn sheep *Ovis canadensis*, most animals survived at least 60 days after release. Sixty days after release, at least 62 of the 64 translocated sheep were alive. One sheep died, probably due to capture-induced stress, and the GPS collar on another malfunctioned after release, so it could not be tracked. In 2009–2012, seventy-seven bighorn sheep were released. Of these, 65 were GPS-collared and signals were received from 64 of the collars after release (including the one that subsequently failed). Location data were collected for 18 months after release though survival data only for the first 60 days are presented.

A review of translocations carried out in 1969–2006 in Australia (57) found that translocating wild-born and releasing captive-bred macropod species (kangaroos and allies) led to the successful establishment of populations in 44 of 72 cases. Of the established populations, 29 persisted for more than five years. Of the 28 releases considered to be failures, 17 were thought to have failed due to predation by non-native carnivores, such as red foxes *Vulpes vulpes*. Releases considered in the review included both wild-caught, translocated animals and captive-bred animals. The number of animals released ranged from one to 70 and included 20 different macropod species. Only translocations where animals were released into areas larger than 100 ha were considered for the review.

A replicated study in 2011–2014 of two grasslands in Slovakia (58) found that translocated European ground squirrels *Spermophilus citellus* bred in small numbers after four years of releases. Nine juveniles in four litters during the fourth year of releases were the first breeding evidence at one site (with 174 animals released up to then). At a second site, also during the fourth year of releases, a female with five young was the first breeding evidence (with 284 animals released up to then). Ground squirrels were translocated in 2011–2014. Some were lost to predators (e.g. red fox *Vulpes vulpes* and feral cat *Felis catus*). Heavy rain in spring 2013 and 2014 may have reduced the population at one site. Grass cutting was required to maintain suitable habitat at one site. Ground squirrels were translocated from nearby donor sites, especially airfields. Monitoring focussed on burrows as well as counting individuals, aided by individual fur clipping patterns.

A study in 1972–2011 in a grassland and rock area above the treeline in central Appenines, Italy (59) found that a population of translocated red deer *Cervus elaphus* released in groups persisted at least 24 years after release, but over the same period, the density of Apennine chamois *Rupicapra pyrenaica ornata* in the area almost halved. Red deer pellets were detected in 31–35 out of 38 (82–92%) sampling plots 23–24 years after translocation. However, authors reported that over a similar period, chamois density almost halved in the core area of their range (1984–1985: c. 38/100 ha; 2012: c. 20 individuals/100 ha). Authors found a large space (> 75%) and diet (> 90%) overlap between deer and chamois, an increase in unpalatable plant species and a reduced bite rate of adult female chamois in patches also used by deer (see paper for details). Forty-five red deer were translocated into Abruzzo, Lazio and Molise National Park in 1972 (0.5 individuals/100 ha). A further 36 deer were released in groups of 7–10 individuals (in 4 operations) in 1972–1987. In June–October 2010 and 2011, the presence/absence of groups of >5 red deer pellets was recorded in circular, 5-m radius, sampling plots, randomly placed in 38 grassland sites. Sites were located in a 65-ha mountainous area above the treeline.

A study in 2003–2007 in a mixed shrub, grassland and forest area near Madrid, Spain (60) found that following translocation, Iberian ibex *Capra pyrenaica* numbers increased and ibex expanded their range. In the first eight to 10 years after translocation began, ibex numbers increased by 23%/year on average (at release: 67 individuals; after 8–10 years: 359 individuals), by 36%/year for the next three years (after 11–13 years: 773 individuals), and by 19%/year in the following four years (after 15–17 years: 1,523 individuals). The birth rate was 0.76 calves/adult female and the area that ibex occupied increased from 2,102 ha in 2000 to 3,279 ha in 2007. In 1990–1992, sixty-seven wild-born Iberian ibex (41 females and 26 males) were translocated to a 4,890-ha national park. The translocated population was monitored between May and June in 2000, 2005, and 2007. Ibex were counted along 22 transects (average length 3.6 km) using binoculars. Transects were walked 2–3 hours after sunrise or 2–3 hours before sunset. The study area included high altitude (1,100–2,200 m) shrubland, grassland and forest areas.

A study in 1999–2012 of woodland in and around a national park in Italy (61) found that, following the start of translocations, a re-established

brown bear *Ursus arctos* population increased steadily in numbers over 12 years. From 10 bears translocated to the area in 1999–2001, the population grew by 20% annually in 2002–2006, with the rate gradually falling to 16% annual growth by 2012. Breeding was first recorded in 2002, with ≥74 cubs born in ≥34 reproductive events up to 2012. At that point, there were 47 bears in the population (16 adults, 14 juveniles and 17 cubs). Ten bears (seven female, three male) were translocated from Slovenia in 1999–2001. Up to 2012, twenty-one young males had dispersed from the province (though six subsequently returned). Other documented population losses included those attributed to illegal hunting, road casualties and removal of problem bears.

A controlled study in 2008–2010 in a mountain site in the Central Apennines, Italy (62) found that wild-caught translocated Apennine chamois *Rupicapra pyrenaica ornata* survived and reproduced in similar numbers to released captive-bred chamois, but captive-born chamois remained closer to the release site. Seven of eight captive-born (88%) and seven of eight (88%) wild-caught translocated Apennine chamois survived over five months after release. Four of five captive-born (80%) and three of five wild-caught translocated (60%) female chamois reproduced in the first year after release. During the first week after release, captive-born chamois remained closer to the release site (within 1.1 km on average) than wild-caught chamois (average 1.8 km). Eight captive-born chamois (2.5–11.5 years old, five females and three males) and eight wild-caught translocated chamois (2.5–10.5 years old, five females and three males) were released into Sibillini Mountains National Park. Chamois were released in groups of one-three individuals; each group was all wild or all captive-born. Captive-born chamois were bred in large enclosures within four national parks. Translocated chamois were taken from a national park approximately 200 km away. All of the 16 released chamois were fitted with radio-collars and monitored for five months after release in 2008–2010.

A replicated study in 1971–2014 in 13 forested mountainous areas in Catalonia, Spain (63) found that translocating roe deer *Capreolus capreolus* resulted in a six-fold increase in distribution after multiple translocation events. Forty-two years after the first translocation roe deer were present in 85% of Catalonia (2013: 288 10 × 10 km squares), a six-fold increase on the area occupied compared to 23 years after the

first translocation (1994: 52 10 × 10 km squares). Between 1971 and 2008, five hundred and fourty-two translocated roe deer were released in 13 areas across Catalonia. Deer were captured from the wild in France and Spain and released after 24 hours directly into protected areas. In 1971–1992, animals (46 individuals) were translocated into areas already occupied by roe deer and in 1993–2008 into areas where roe deer were currently absent (496 individuals). Distribution data were obtained from terrestrial mammal distributions atlases supplemented by traffic police reports, hunting data and sightings by volunteers.

A study in 1963–2010 in two areas of mixed broadleaf and montane forest with alpine meadows in the northern Carpathian mountains of Ukraine, Slovakia and Poland (64) found that three European bison *Bison bonasus* herds persisted >6 years after the last release of translocated individuals. Between 6–47 years after releases, around 320 free-ranging European bison survived in the three herds. Two herds (totalling about 300 individuals) resulted from 30–47-year-old translocations. The third herd (about 20 individuals) resulted from a translocation some six years earlier. The study was conducted in the Polish Bieszczady Mountains and in the Slovak Poloniny National. Bison were translocated to the Polish Bieszczady Mountains between 1963 and 1980 and to the Slovak Poloniny National in 2004. No details are provided on the number of animals translocated nor on their origin. GPS locations of bison were collected in 2001–2010 (29,382 records). No monitoring details are provided, but bison presence data included direct observations, tracks, faeces and signs of feeding. Six bison were radio-tracked in 2002–2006 (two locations recorded at least twice a week).

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14.11. Translocate mammals to reduce overpopulation

https://www.conservationevidence.com/actions/2430

- **Three studies** evaluated the effects of translocating mammals to reduce overpopulation. Two studies were in the USA[1,2] and one was in Australia[3].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (3 STUDIES)

- **Abundance (1 study):** A before-and-after study in the USA[2] found that adult elk numbers approximately halved after the translocation of wolves to the reserve.
- **Reproductive success (1 study):** A before-and-after study in the USA[2] found that elk calf:cow ratios approximately halved after the translocation of wolves to the reserve.
- **Survival (2 studies):** A study in Australia[3] found that koalas translocated to reduce overpopulation had lower survival than individuals in the source population. A study in the USA[1] found that following translocation to reduce over-abundance, white-tailed deer had lower survival rates compared to non-translocated deer at the recipient site.
- **Occupancy/range (1 study):** A study in the USA[1] found that following translocation to reduce over-abundance at the source site, white-tailed deer had similar home range sizes compared to non-translocated deer at the recipient site.

BEHAVIOUR (0 STUDIES)

Background

Overpopulation can reduce the long-term persistence of a population, as competition for resources increases. Translocating individuals of the target species away from the area or predators into the area for example, to reduce population numbers may help reduce competition for resources and thus improve the fitness of the remaining population.

A study in 1993–1995 in a forest reserve in New York, USA (1) found that following translocation to reduce over-abundance at the source site, white-tailed deer *Odocoileus virginianus* had lower survival rates but similar home range sizes compared to non-translocated deer at the recipient site. One year after release, the annual survival rate for translocated deer (53%) was lower than that of non-translocated deer at the recipient site (75–88%). During the year after release, average home range sizes did not differ significantly between translocated deer (0.23 km^2) and non-translocated deer at the recipient site (0.22 km^2). In May–June 1994, seventeen female white-tailed deer were translocated from an over-populated site to a site 60 km away. In April–July of 1993–1995, twenty deer resident at the recipient site (16 females, 4 males) were captured. All deer were radio-collared. Before release, deer were held for 1–12 days in a 50-m^2 pen. Deer were monitored using radio-telemetry, 5–15 times/week, in April–August of 1993–1995, and less frequently at other times of the year.

A before-and-after study in 1986–2004 in a grassland and forest reserve in Wyoming, USA (2) found that adult elk *Cervus canadensis* numbers and elk calf:cow ratios approximately halved after the translocation of wolves *Canis lupus* to the reserve. Results were not subject to statistical analysis. Nine years after wolves were translocated, there were fewer adult elk (8,335) and a lower calf:cow ratio (12 calves/100 female elk) than the average before wolf translocation (adult elk: 16,664; 25 calves/100 female elk). A similar number of elk that had migrated out of the park were killed by hunters before (1,148 elk/year) and after (1,297 elk/year) wolves were translocated. Wolves were translocated into Yellowstone National Park in 1995. Between 1996 and 2004 wolf numbers increased from 21 to 106. Elk adults and calves were counted from aeroplanes annually during December–January 1986–2004. No counts were conducted during the winters of 1996 and 1997.

A study in 2007–2008 of forest sites on an island and the mainland of southeastern Australia (3) found that koalas *Phascolarctos cinereus* translocated to reduce overpopulation had higher mortality than individuals in the source population. Six of 16 koalas (38%) that were sterilized and translocated died within 12 months of release, whereas none of 13 koalas in the source population died within the same time period. In April–May 2007, sixteen koalas (eight females; eight males)

were surgically sterilized and translocated from an overpopulated island to the mainland. Release sites were 10-ha forest blocks dominated by rough-barked manna gum Eucalyptus viminalis. Released koalas were radio-collared and tracked daily for one week followed by weekly for seven weeks and monthly until June 2008. Thirteen unsterilized koalas (eight females; five males) belonging to the source population were radio-collared and tracked over the same period in 2007–2008.

(1) Jones M.L., Mathews N.E. & Porter W.F. (1997) Influence of social organization on dispersal and survival of translocated female white-tailed deer. *Wildlife Society Bulletin*, 25, 272–278.

(2) White P.J. & Garrott R.A. (2005) Northern Yellowstone elk after wolf restoration. *Wildlife Society Bulletin*, 33, 942–955, https://doi.org/10.2193/0091-7648(2005)33[942:nyeawr]2.0.co;2

(3) Whisson D.A., Holland G.J. & Carlyon K. (2012) Translocation of overabundant species: Implications for translocated individuals. *The Journal of Wildlife Management*, 76, 1661–1669, https://doi.org/10.1002/jwmg.401

14.12. Translocate predators for ecosystem restoration

https://www.conservationevidence.com/actions/2431

- **Two studies** evaluated the effects of translocating predators for ecosystem restoration. These studies were in the USA[1,2].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (2 STUDIES)

- **Abundance (2 studies):** A before-and-after study in the USA[2] found that following reintroduction of wolves, populations of beavers and bison increased. A before-and-after study in the USA[1] found that after the translocation of wolves to the reserve, adult elk numbers approximately halved.
- **Reproductive success (1 study):** A before-and-after study in the USA[1] found that after the translocation of wolves to the reserve, elk calf:cow ratios approximately halved.

BEHAVIOUR (0 STUDIES)

Background

In areas where predators have historically been made locally extinct or populations severely reduced, often due to hunting, they may be translocated from other areas and released in an attempt to restore the ecosystem. Predators may help to reduce medium to large herbivore populations for example, and thus allow some recovery of the habitat and other species groups.

A before-and-after study in 1986–2004 in a grassland and forest reserve in Wyoming, USA (1) found that after the translocation of wolves *Canis lupus* to the reserve, adult elk *Cervus canadensis* numbers and elk calf:cow ratios approximately halved. Results were not subjected to statistical analysis. Nine years after wolves were translocated, there were fewer adult elk (8,335) and a lower calf:cow ratio (12 calves/100 female elk) than the average before wolf translocation (adult elk: 16,664; 25 calves/100 female elk). A similar number of elk that had migrated out of the park were killed by hunters before (1,148 elk/year) and after (1,297 elk/year) wolves were translocated. Wolves were translocated into Yellowstone National Park in 1995. Between 1996 and 2004 wolf numbers increased from 21 to 106. Elk adults and calves were counted from aeroplanes annually during December–January 1986–2004. No counts were conducted during the winters of 1996 and 1997.

A before-and-after study in 1990–2010 of riparian and adjacent upland habitat in a national park in Wyoming, USA (2) found that following reintroduction of wolves *Canis lupus*, populations of beavers *Castor canadensis* and bison *Bison bison* increased. There were more beaver colonies in a monitored area 13 years after wolf reintroduction began (12 colonies) than at the start of reintroduction (one colony). Average summer bison counts were higher in the decade after wolf reintroduction began (1,385 bison) than in the preceding decade (708 bison). Following the start of reintroduction in 1995–1996, wolf numbers in the study area increased to 98 in 2003, followed by a decline and substantial fluctuations. Their establishment was associated with a fall in elk *Cervus canadensis* numbers from >15,000 in the early 1990s to approximately 6,100 in 2010. Elk browsing on woody vegetation

reduced, increasing resources available to beaver and bison. Beaver and bison numbers were derived from annual surveys.

(1) White P.J. & Garrott R.A. (2005) Northern Yellowstone elk after wolf restoration. *Wildlife Society Bulletin*, 33, 942–955, https://doi.org/10.2193/0091-7648(2005)33[942:nyeawr]2.0.co;2

(2) Ripple W.J. & Beschta R.L. (2012) Trophic cascades in Yellowstone: The first 15 years after wolf reintroduction. *Biological Conservation*, 145, 205–213, https://doi.org/10.1016/j.biocon.2011.11.005

14.13. Use holding pens at release site prior to release of translocated mammals

https://www.conservationevidence.com/actions/2434

- **Thirty-five studies** evaluated the effects of using holding pens at the release site prior to release of translocated mammals. Ten studies were in the USA[2,3,4,5,8,11,17,31,33,34], seven were in South Africa[9,15,16,22,24,25,27], four were in the UK[6,10,20,35], three studies were in France[12,18,21], two studies were in each of Canada[7,23], Australia[14,30] and Spain[28,32] and one was in each of Kenya[1], Zimbabwe[13], Italy[19], Ireland[26] and India[29].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (31 STUDIES)

- **Abundance (4 studies):** Three of four studies (two replicated, one before-and-after study) in South Africa[22], Canada[23], France[18] and Spain[32] found that following release from holding pens at release sites (in some cases with other associated actions), populations of roe deer[18], European rabbits[32] and lions[22] increased in size. The other study found that elk[23] numbers increased at two of four sites.
- **Reproductive success (10 studies):** A replicated study in the USA[8] found that translocated gray wolves[8] had similar breeding success in the first two years after release when adult family groups were released together from holding pens or when young adults were released directly into the wild. Seven of nine studies (including two replicated and

one controlled study) in Kenya[1], South Africa[16,25], the USA[2,11], Italy[19], Ireland[26], Australia[30] and the UK[35] found that following release from holding pens at release sites (in some cases with other associated actions), translocated populations of roan[1], California ground squirrels[2], black-tailed prairie dogs[11], lions[25], four of four mammal populations[30], most female red squirrels[26] and some pine martens[35] reproduced successfully. Two studies found that one of two groups of Cape buffalo[16] and one pair out of 18 Eurasian badgers[19] reproduced.

- **Survival (26 studies):** Two of seven studies (five controlled, three replicated studies) in Canada[7], the USA[3,8,31], France[12,21], the UK[20] found that releasing animals from holding pens at release sites (in some cases with associated actions) resulted in higher survival for water voles[20] and female European rabbits[12] compared to those released directly into the wild. Four studies found that translocated swift foxes[7], gray wolves[8], Eurasian lynx[21] and Gunnison's prairie dogs[31] released from holding pens had similar survival rates to those released directly into the wild. One study found that translocated American martens[3] released from holding pens had lower survival than those released directly into the wild. Two of four studies (three controlled) in South Africa[24], Spain[28], and the USA[33,34] found that translocated African wild dogs[24] and European rabbits[28] that spent longer in holding pens at release sites had a higher survival rate after release. One study found mixed effects for swift foxes[33] and one found no effect of time in holding pens for San Joaquin kit foxes[34]. Eleven studies (one replicated) in Kenya[1], South Africa[9,22], the USA[5,11], France[18], Italy[19], Ireland[26], India[29], Australia[30] and the UK[35] found that after release from holding pens at release sites (in some cases with other associated actions), translocated populations or individuals survived between one month and six years, and four of four mammal populations[30] survived. Two studies in the UK[10] and South Africa[27] found that no released red squirrels[10] or rock hyraxes[27] survived over five months or 18 days respectively. One of two controlled studies (one replicated, one before-and-after) in South Africa[25] and the USA[34] found that following release from holding pens, survival of translocated lions[25] was

higher than that of resident animals, whilst that of translocated San Joaquin kit foxes[34] was lower than that of resident animals. A study in Australia[14] found that translocated bridled nailtail wallabies[14] kept in holding pens prior to release into areas where predators had been controlled had similar annual survival to that of captive-bred animals.

- **Condition (1 study):** A controlled study in the UK[6] found that translocated common dormice held in pens before release gained weight after release whereas those released directly lost weight.

BEHAVIOUR (5 STUDIES)

- **Behaviour change (5 studies):** Three studies (one replicated) in the USA[4,17] and Canada[23] found that following release from holding pens, fewer translocated sea otters[4] and gray wolves[17] returned to the capture site compared to those released immediately after translocation, and elk[23] remained at all release sites. Two studies in Zimbabwe[13] and South Africa[15] found that following release from holding pens, translocated lions formed new prides.

Background

Holding pens at release sites (sometimes termed 'soft release') may be used to enable mammals to become accustomed to new surroundings before release. They are often enclosures containing natural habitat and enabling views of surrounding land. Additionally, some wild translocated mammals may display a homing instinct after release and pens may therefore be used to reduce the chance of animals returning.

The use of holding pens may be employed both for translocations of wild mammals to new sites and releases of captive-bred mammals, here we focus on the first group. See also: *Use holding pens at release site prior to release of captive-bred mammals.*

For studies that held translocated mammals in captivity away from the release site before release, see: *Hold translocated mammals in captivity before release.*

A study in 1970–1978 in a grassland and forest reserve in southeast Kenya (1) found that after being kept in a holding pen prior to release, a population of roan *Hippotragus equinus* translocated into an area outside their native range persisted and bred for more than six years. Only eight out of the original 38 translocated roan could be located 18 months after the last release. However, six years after the last translocations, roan numbers had increased to 22. From 1973–1976, at least 15 calves were born, of which one-third survived to nine months of age. Between 1970 and 1972, 38 roan were released in Shimba Hills National Reserve, where there is no evidence for their existence since at least 1885. Animals were captured in the Ithanga Hills, by funnelling them into a 2.5 acre corral using horses, trucks and a helicopter. Prior to release roan were kept in a 30-acre holding pen. Roan were monitored between June 1973 and January 1978, but no further monitoring details are provided.

A study in 1976–1978 in a pasture in California, USA (2) found that following release from holding pens at the release site, translocated California ground squirrels *Spermophilus beecheyi* established a reproductive colony. Reproduction occurred within one of the holding cages, but the number of young was not determined. At least three of the eight ground squirrels released from cages were still alive 8–13 months after release. Four wire-mesh cages (1.2 × 2.4 × 0.6 m high) were part-filled with soil, to 41 cm depth, in a 7.5-ha pasture. Cages each had four pipes (20 cm long, 10 cm diameter) leading down into the soil, as refuges. Cages were positioned in two adjacent pairs. Pairs were 46 m apart. In November 1976, one pair of wild-caught California ground squirrels was released into each cage. Squirrels were allowed to exit from two of the cages in March 1977 and from the other two in June 1977. In February–April 1978, tagged and non-tagged squirrels were observed and/or live-trapped near the cages.

A randomized, controlled study in 1975–1976 in a temperate forest in Wisconsin, USA (3) found that when using holding pens prior to releasing translocated animals, American marten *Martes americana* survival was lower than when animals were released immediately after translocation. Eight of 10 American martens released after being held in pens died within 154 days. Only one of 11 animals released immediately after translocation had died within 161 days. None of the martens reproduced in this time. Thirty days after release, martens that had been held in pens stayed closer to the release site than did those

released immediately (data not reported). In January 1975–April 1976, 124 martens, captured in Ontario, Canada, were released at a forest site in Wisconsin, USA. Twenty-six animals were held in pens at the release site for seven days before release and 97 animals were released within 48 hours of being transported to the site. Individuals were randomly assigned a release method. Twenty-one of the martens were radio-collared. Their movements were monitored until June 1976.

A study in 1988–1989 in coastal waters of California, USA (4) found that after being held in pens at the release site, fewer translocated sea otters *Enhydra lutris* returned to the capture site compared to those released immediately after translocation. No statistical analyses were performed. None of 10 sea otters held in release pens returned to the capture site and all remained within 27 km for the duration of monitoring. Five of nine released immediately on arrival returned to the capture site. Nineteen sea otters (18 male, one female) were caught between May 1988 and May 1989 and were released 291 km further north. Nine were released immediately on arrival and 10 were held for 48 hours in floating pens before release. Sea otters were radio-tracked from the ground or air for 16–87 days after release.

A study in 1988–1989 in forest and swamp habitats in Florida and Georgia, USA (5) found that after being held in holding pens at the release site, more than half of translocated mountain lions *Puma concolor* survived over three months. Four out of seven translocated mountain lions survived at least 124–303 days after release. Individuals that had been in the wild >35 days established 96–930-km^2 home ranges. However, during the hunting season, these home ranges were abandoned. At least three mountain lions died during the study, including one that was shot. In 1988, seven mountain lions were captured in Texas and flown to Florida. They were released as a trial for evaluating the feasibility of translocating Florida panthers *Puma concolor coryi*. Animals were sterilized, radio-collared and kept in holding pens for one week before release. They were monitored six days/week for 306 days from an airplane. Before translocation, the study area (>12,000 km^2) had no mountain lions but had a high abundance of deer and wild hog and a low density of humans.

A controlled study in 1992 in woodland edge in Somerset, UK (6) found that translocated common dormice *Muscardinus avellanarius* held

in pens before release gained weight after release, whereas dormice released directly into the wild lost weight. The body mass of dormice released from pre-release pens increased after release by 0.12 g/day, whereas dormice released directly into the wild lost 0.14 g/day. The study was conducted along a 9-ha strip of trees and shrubs in August–September 1992. Six wild-caught dormice were placed in pre-release pens and 10 wild-caught dormice were released directly into the wild on their day of capture. Pre-release pens (0.45 m width, 0.5 m depth and 0.9 m height) were constructed from 1-cm^2 weldmesh. Nest boxes, food and water were provided. Dormice stayed in pens for eight nights before release. Dormice were monitored by radio-tracking and were recaptured and weighed 10–14 days after release.

A replicated, controlled study in 1983–1993 in three grassland sites in Alberta, Canada (7) found that translocated and captive-bred swift foxes *Vulpes velox* released after time in holding pens had similar survival rates to those released without use of holding pens. No statistical analyses were performed. At least six out of 45 (13%) swift foxes held in pens before release survived over two years post-release, compared with at least five out of 43 (12%) released without use of holding pens. In 1983–1987, forty-five translocated swift foxes were held in pens before release. Pens (3.7 × 7.3 m) were fenced for protection from cattle. Animals were placed in pens in October–November and released between the following spring and autumn. They were provided with supplementary food for 1–8 months after release. In 1987–1991, four hundred and thirty-three foxes were released without use of holding pens. Released foxes included both wild-born and captive-bred animals. All foxes released from pens and 155 of those released directly were radio-tracked, from the ground or air, for up to two years.

A replicated study in 1995–1996 in two forest sites in Idaho and Wyoming, USA, (8) found that translocated gray wolves *Canis lupus* had similar survival rates and breeding success in the first two years after release when adult family groups were released together from holding pens or when young adults were released directly into the wild. No statistical analyses were conducted. Thirty out of 35 young adult wolves released directly into the wild were still alive seven months after the last releases, and had produced up to 40 pups from 3–8 pairs. Thirty-one adult wolves released from holding pens in family groups had produced

23 pups four months after the last releases. From these 54 animals, nine had died. Six of the seven adult pairs released together from holding pens remained together, and five of these pairs established territories in the vicinity of the pens. Wolves were wild-caught from Canada in January 1995 and 1996. In Idaho, young adults were directly released in January 1995 and 1996. In Wyoming, family groups of 2–6 wolves spent 8–9 weeks in 0.4-ha chain-link holding pens before release in March 1995 and April 1996. Wolves were radio-tracked every 1–3 weeks until August 1996.

A study in 1994–1998 in a savannah reserve in North West province, South Africa (9) found that after release from holding pens in groups, approximately half of translocated cheetahs *Acinonyx jubatus* survived at least 18 months, of which half died within three years. Nine of 19 cheetahs survived 19–24 months, of which six were cubs that matured to independence, but only four cheetahs were known to still be alive at the end of the study period. Six cheetahs survived in the reserve less than one year, of which one died after a few weeks and two were removed to a captive breeding facility. The fate of four released cheetahs was unknown. In total 19 cheetahs were released into a game reserve between October 1994 and January 1998. Cheetahs were initially placed in 1 ha holding pens with electrified fencing for 4 weeks to several months. The feeding regime is not specified, but cheetahs were provided with at least one carcass on being placed in the pen and were lured from the pen with a carcass. Cheetahs were mostly rescued wild-caught animals, except for one that was habituated to humans (and had to be removed after two weeks). Cheetahs were either held in family groups (mothers with cubs) or as coalitions (of adult males). One animal/group was radio collared for monitoring.

A study in 1993–1994 on a forested peninsula in Dorset, UK (10) found that none of the translocated red squirrels *Sciurus vulgaris* released into holding pens (with supplementary food, water and nestboxes) survived over five months after release. Out of 14 translocated red squirrels, 11 (79%) survived over one week. Only three (21%) survived >3 months and none survived >4.5 months. At least half of the 14 squirrels were killed by mammalian predators. When intact carcasses were examined they showed signs of weight loss and stress (see original paper for details). Between October and November 1993, fourteen

wild-born red squirrels were released into an 80-ha forest dominated by Scots pine *Pinus sylvestris*. The forest had no red squirrels but had introduced grey squirrels *Sciurus carolinensis*. Capture and release sites were similar habitats. Squirrels were kept in 1.5 × 1.5 × 1.5 m weldmesh pens surrounded by electric fencing for 3–6 days before release. Squirrels were kept individually except for two males who shared a pen. After release, squirrels continued to have access to food, water and nest boxes inside the pens and outside (20–100 m away). All squirrels were radio-tagged and located 1–3 times/day, for 10–20 days after release and thereafter every 1–2 days.

A replicated study in 1995–1997 in four grassland sites in New Mexico, USA (11) found that after release from holding pens and provision of supplementary food, translocated populations of black-tailed prairie dogs *Cynomys ludovicianusi* persisted at least two years and reproduced in the wild. The number of black-tailed prairie dogs approximately doubled during the first spring after release from holding pens in one site on one ranch where supplementary food was provided. Between the second spring and summer, after all supplementary feeding had ceased, the number of animals associated with both release sites on the same ranch doubled. Precise numbers are not reported. One hundred and one prairie dogs were translocated to two ranches (Armendaris Ranch received 71 individuals; Ladder Ranch: 30 individuals) between June 1995 and June 1997. At each ranch, prairie dogs were released into two 0.4-ha holding pens (number of individuals/holding pen is not provided). Holding pens were fenced and surrounded by electric wire. Animals at Armendaris ranch were provided with supplementary food in pens for up to year. Information on population persistence at Ladder Ranch is not provided. The time individuals were kept in the holding pens before subsequent release varied between a few days and weeks (see original paper for details).

A controlled study in 1997 in a mixed pasture and cultivated fields farmland site in northern France (12) found that keeping translocated European rabbits *Oryctolagus cuniculus* in holding pens for three days prior to release (and carrying out associated management such as supplementary feeding) increased survival rates of female, but not male rabbits immediately following release compared to rabbits released directly into the wild. During the first day after translocations,

the survival rate of female rabbits released from pre-release pens was higher (100%) than that of females released directly into the wild (83%) and male rabbits released from release pens (78%). The survival rate of male rabbits released from pre-release pens (78%) was not significantly different to that of male rabbits released directly into the wild (92%). One hundred and four rabbits were translocated from Parc-du-Sausset to a 150-ha area of cultivated fields and pasture in Héric, approximately 400 km away in January 1997. Of these, roughly half were acclimatised in eight 100-m² enclosures (fence height: 1 m), for three days prior to release. Rabbits were provided with supplementary food. Survival was estimated by night-time relocation of ear-tagged rabbits using a spotlight, daily in the first week after release and twice a week until late February 1997.

A study in 1997–1998 on a savanna estate in Zimbabwe (13) found that a translocated lion *Panthera leo* family kept in a holding pen prior to release joined with immigrant lions and formed a new pride. A lioness was translocated with three cubs (one male, two female). Within 45 days, seven male lions were close by and the female mated with one of these. The male cub moved away and the pride then entailed the female and daughters with two adult male lions. A wild lioness joined the pride 1.7 months after release, but was killed by a snare after six months. After 12–13 months, the original lioness had three new cubs and her daughters each also had litters. Resident lions on the estate were eliminated in 1995. In January 1997, a lioness and three cubs were translocated from communal land to a holding pen and were released on the estate after 90 days. Lions were monitored through to May 1998 by radio-tracking and direct observation.

A study in 1996–1999 at a woodland reserve in Queensland, Australia (14) found that wild-born translocated bridled nailtail wallabies *Onychogalea fraenata* kept in holding pens prior to release into areas where predators had been controlled had similar average annual survival to that of captive-bred animals. Over four years, the average annual survival of wild-born translocated wallabies (77–80%) did not differ significantly from that of captive-bred bridled nailtail wallabies (57–92%). In 1996–1998, nine wild-born translocated and 124 captive-bred bridled nailtail wallabies were released into three sites across Idalia National Park. Ten captive-bred wallabies were held in a 10-ha

enclosure within the reserve for six months before release, and 85 were bred within the 10-ha enclosure. All of the 133 released wallabies were kept in a holding pen (30-m diameter) for one week at each site before release. Mammalian predators were culled at release sites. A total of 67 wallabies (58 captive-bred, nine wild-born) were radio-tagged and tracked every 2–7 days in 1996–1998. Wallabies were live-trapped at irregular intervals with 20–35 wire cage traps in 1997–1999.

A study in 1998–2002 in a shrubland wildlife reserve in Limpopo, South Africa (15) found that after being held together in a pen for three months before release, five translocated African lions *Panthera leo* eventually formed two separate prides. Two months after release, there was aggression between two males and a female, which had sustained injuries shortly after release. Aggression continued intermittently for 10 weeks until the injured lion mated. Subsequently, over the following 3.5–4 years, two prides established territories. One pride comprised of a male and female half-siblings with an additional related female. The second pride was a looser association between a male and female sibling. Thus, inbreeding was likely to occur between mated pairs. Two male and three female wild-caught lions (from two locations) were released on 16 January 1998 into a 33,000-ha fenced reserve, after being held for three months in a 50 × 50-m pen. Lions were monitored by radio-tracking through to February 2002.

A study in 2000–2003 in a mixed karoo grassland reserve in Northern Cape Province, South Africa (16) found that following release from a holding pen in groups into a fenced reserve, one out of two translocated Cape buffalo *Syncerus caffer* groups scattered and escaped the reserve while the other formed a single herd and stayed in the reserve and bred. One month after release, a group of four buffalo had split into two solitary animals and a pair formed by one male and one female. One of the solitary animals was not seen again, the second solitary male animal was located two years after release on a neighbouring farm and released into the second group of translocated animals in May 2003. The pair escaped the reserve three times in 13 months. After the third escape, the male was moved to a different reserve and a new male introduced to form a herd with the remaining female. A second group of 10 translocated animals formed a single herd (along with the two remaining animals from the previous introduction) and over 10 months no animals died

or escaped. A year after the introduction, five calves were born. Four subadult buffalo (2 male, 2 female) were placed in a holding pen in July 2000 and released in August into a fenced 12,000-ha reserve. A second group of seven adult and three subadult animals (4 male, 6 female) was placed into a holding pen in August 2002 and released into a 200 ha area in September before being completely released in October 2002. Both groups were monitored weekly with telemetry until October 2003.

A study in 1989–2002 in 25 temperate forest sites in Montana, Idaho, and Wyoming, USA (17) found that holding translocated wolves *Canis lupus* in pens at the release site before release (soft release) increased the chance of wolves not returning to their capture site relative to direct (hard) release. A lower proportion of soft-released wolves returned to their capture site (8%) than of hard-released wolves (30%). Soft-releases entailed confinement at release sites for ≥28 days after capture. Hard-releases were those occurring ≤7 days following capture. Eighty-eight wolves were translocated 74–515 km in 1989–2001 in response to livestock predation (75 wolves) or pre-emptively to avoid such conflict (13 wolves). Translocated wolves were radio-collared, and were monitored through to the end of 2002.

A study in 1995–2002 in a mixed oak forest reserve in the south of France (18) found that following translocation using holding pens prior to release and associated actions, approximately half of female roe deer *Capreolus capreolus* survived over one year after release and that overall the deer population increased six years after the translocations began. Twenty-six out of 49 (53%) translocated female roe deer survived over one year post-release. Of the animals that died in the first year, 35% of mortality occurred within the first month after release. After six years the deer population had increased to 0.47 deer/km^2 compared to 0.06 deer/km^2 in the first year after translocation began. In February 1995–1997, fifty-two male and 52 female roe deer were translocated from Northern France into a 3,300-ha forest reserve in Southern France in seven release sessions. Animals were placed into enclosures in groups of approximately 15 individuals for 2–10 days and provided with food (pellets and fresh vegetables) during this time prior to release. Forty-nine females (21 <1 year old and 28 >1 year old) were radio-tagged and were located from a vehicle once or twice each week, over one year post-release. In addition, surveys were carried out on foot (6 transects,

each 5–7 km long) eight times a year in February-March 1996–2002 to estimate population growth. Deer were present in low numbers prior to translocation.

A study in 2001–2005 in a mixed forest and farmland site in northern Italy (19) found that just over half of translocated Eurasian badgers *Meles meles* released from holding pens (with supplementary food) in groups survived at least one month after release and one pair reproduced. Seven out of 12 badgers survived for 1–9 months, after which monitoring equipment stopped operating. One badger died almost immediately after release due to unknown causes. Two badgers escaped (one after the first month, the other after an unknown period). The fate of three other badgers was unknown. One pair of translocated animals reproduced in the wild 4 years after release. From March 2001 to May 2004, twelve badgers were captured at four sites in northern Italy. Badgers were fitted with radio-collars and transported 20–40 km to the release site where they were kept in a 350 m^2 enclosure in a wooded area in their release groups (2001: 2 individuals, 2002: 4 individuals, 2003: 2 individuals; 2004: 4 individuals) and provided supplementary food for 3–10 weeks before release. Seven of the 12 badgers were located once/week, for up to nine months after release.

A review of a study in 2001–2002 at a restored wetland in London, UK (20) found that using holding pens prior to release of translocated and captive-bred water voles *Arvicola terrestris* resulted in greater post-release survival than did releasing them directly into the wild. Voles released from pens were three times more likely to be recorded during the initial follow-up survey than were those released without use of pens (result presented as odds ratio). A total of 38 wild-caught and 109 captive-bred water voles were released in groups of 6–15 animals in May–July 2001. Prior to release, no water voles were present at the site. An unspecified number of animals were placed in an enclosure with food and shelter and allowed to burrow out at will. The remainder were released directly into the wild. Animals were monitored by live-trapping over three periods of five days, between autumn 2001 and early-summer 2002.

A controlled study in 1983–2002 in a temperate forest in Vosges massif, France (21) found that survival of translocated Eurasian lynx *Lynx lynx* that were held in captivity before release was similar between

animals kept in holding pens at the release site and animals which were released directly. Four of eight animals which were kept in enclosures at the release site prior to release survived for 10–11 years, compared to six of 13 animals that survived 2–7 years after being released without holding pens. The distribution of lynx increased from 1,870 km^2 (six years after the first releases) to 3,160 km^2 (12 years later). At least two females, both of which were released without holding pens, produced litters. In 1983–1993, twenty-one adult lynx were brought to France from European zoos. The program sought wild-caught lynx for releases, however the exact origin of each animal, and the length of time that each spent in captivity, are unclear. Lynx were released at four sites in the Vosges mountains. The first eight animals were held in cages at the release site for 4–45 days prior to release, but the remainder were released immediately upon arrival. Animals were radio-tracked for 1–847 days. The presence of lynx was also established through sightings, lynx footprints, detection of faeces or hair and reports of attacks on domestic animals.

A study in 1992–2004 in a grassland reserve in KwaZuluNatal Province, South Africa (22) found that most translocated lions *Panthera leo* held in pens before release survived for more than one year and established stable home ranges and that the population grew. Of 15 lions released, all except three, which were removed after killing a tourist, survived ≥398 days post-release. Average post-release survival was ≥1,212 days. At least 95 cubs from 25 litters were documented among translocated lions and descendants over the 13-year study. Excluding cubs translocated to other sites or those still <18 months old at the end of the study, 51 of 65 cubs (78%) survived past 18 months old. Nine lions were released in May 1992, six in February 1993 and two in January 2003. Releases were into a fenced reserve (initially 176 km^2, then extended to 210 km^2). Before release, lions were held in groups, each in an 80-m^2 acclimation pen, for 6–8 weeks, during which time socialization occurred and stable prides were formed. Eleven of the founder lions were monitored by radio-tracking and other animals were monitored by direct observations.

A replicated study in 1998–2004 within four largely forested areas in Ontario, Canada (23) found that following translocation elk *Cervus canadensis*, most of which had been kept in holding pens in groups,

remained present at all release sites and numbers had increased at two of four sites. By 3–6 years after translocations, elk populations had grown at two sites and fallen at two. From 443 elk translocated, the population at the end of the study was estimated at 375–440 animals. Between 1998 and 2004, forty-one percent of translocated elk died. Causes of death included 10% lost to wolf predation, 5% to emaciation and 5% to being shot. Elk were translocated from a site in Alberta, Canada in 1998–2001 in nine releases. Transportation took 24–58 hours. Elk were held in pens at recipient sites for up to 16 weeks before release (some were released immediately) but the effect of holding pens was not tested. Of 443 elk released, 416 were monitored by radio-tracking. The overall population was estimated in March 2004.

A study in 1995–2005 in 12 dry savanna and temperate grassland sites in South Africa (24) found that translocated and captive-bred African wild dogs *Lycaon pictus* that spent more time in holding pens in groups had a higher survival rate after release. Wild dog families that had more time to socialise in holding pens prior to release into fenced areas had a higher survival rate than groups which spent less time in holding pens (data presented as model results). Overall, 85% of released animals and their wild-born offspring survived the first six months after release/birth. Released animals that survived their first year had a high survival rate 12–18 months (91%) and 18–24 months (92%) after release. Between 1995 and 2005, one hundred and twenty-seven wild dogs (79 wild-caught, 16 captive-bred, 16 wild-caught but captive-raised, 16 'mixed' pups) were translocated over 18 release events into 12 sites in five provinces of South Africa. Individuals were kept in pre-release pens for an average of 212 days, but groups were given between 15 and 634 days to socialise in pens prior to release. Animals were monitored for 24 months after release, and the 129 pups which they produced after release were monitored up to 12 months of age. Forty characteristics of the individual animals, release sites and methods of release were recorded, and their impact on post-release survival was tested.

A replicated, controlled study in 1999–2004 in three mixed savanna and woodland sites in KwaZulu-Natal, South Africa (25) found that after translocation to a fenced reserve with holding pens, survival of released lions *Panthera leo* was higher than that of resident lions, and that translocated animals reproduced successfully. No statistical tests

were performed. After five years, a higher proportion of introduced animals survived (eight of 16 animals, 50%) than of resident animals (20 of 84 animals, 24%). Seven translocated females reproduced successfully. Between August 1999 and January 2001, sixteen lions were translocated to an enclosed reserve to improve genetic diversity. They were held at release sites in 0.5–1.0-ha pens for 4–6 weeks before release. Nine translocated lions were fitted with radio-collars. From August 1999 to December 2004, translocated animals were located at least every 10 days. Resident lions were also tracked at least every 10 days.

A study in 2005–2007 in a mixed conifer forest in Galway, Ireland (26) found that following release from holding pens (with nest boxes and supplementary food), over half of translocated red squirrels *Sciurus vulgaris* survived over eight months after release and most females reproduced during that period. At least 10 out of 19 (53%) translocated squirrels survived over eight months post-release and five out of nine translocated females (56%) were lactating five-seven months after release. In August 2006, seven juvenile squirrels were caught. At least one squirrel was still alive in the release location in two years after the original release. Two squirrels died while in the release pen or shortly afterwards. Another four squirrels died 1–2 months after release. Nineteen squirrels were translocated to a nature reserve (19 ha) in the middle of a 789-ha commercial pine plantation, 112 km from the capture site. Individuals were marked and radio-tagged. Squirrels were kept on average for 46 days in one of two pre-release enclosures (3.6 × 3.6 × 3.9 m high). Enclosures contained branches, platforms, nest boxes, and supplementary feeders (containing nuts, maize, seeds and fruit). Supplementary food (50/50 peanut/maize mix) was provided in six feeders in the nature reserve until July 2006. Twenty nest boxes were also provided Squirrels were radio-tracked in September and November 2005 and February and May 2006, and were trapped in February, May and August 2006 and observed once in October 2007.

A study in 2007 at rocky outcrops on a reserve in KwaZulu-Natal Province, South Africa (27) found that all translocated rock hyraxes *Procavia capensis* kept in a holding pen and released as a group died (or were presumed to have died) within 18 days of release. Eight of nine wild translocated hyraxes died within 18 days of release and the other was presumed to have died. The group split up and were not seen

together after release. In October 2007, nine hyraxes (one juvenile, three sub-adults and five adults) were caught in baited mammal traps (900 × 310 × 320 mm) in an area where they were abundant, and moved 150 km to a 656-ha reserve where the species was nearly extinct. Hyraxes were kept together in a holding cage (1850 × 1,850 × 1850 mm) for 14 days before release. They were monitored daily for one week, and then every few days by direct observation and radio-tracking.

A replicated, randomized, controlled study published in 2010 of a grassland site in Andalucía, Spain (28) found that holding translocated wild European rabbits *Oryctolagus cuniculus* for longer in acclimation pens before release improved subsequent survival rates. A lower proportion of rabbits enclosed for six nights before release was killed by mammalian predators over the following 10 days (9%) than of rabbits enclosed for three nights before release (38%). Rabbits were translocated to a 4-ha grass field with artificial warrens. Food and water were provided. Of 181 rabbits released (average 10/warren), 38 randomly selected rabbits (2–5 in each of 15 warrens) were radio-collared. Twenty-three of these were released on the seventh day, following six nights of confinement and 14 were released on the fourth day, following three nights of confinement. The date of the study is not stated. Rabbits were monitored daily during confinement and for 10 days following release.

A study in 2008–2009 in a subtropical forest in Rajasthan, India (29) found that three translocated tigers *Panthera tigris tigris* that were kept in holding pens prior to release survived for at least 3–11 months after release and established home ranges. The annual home range of a released male was 169 km^2 and that of a female was 181 km^2. The summer home range of a later released female was 223 km^2. Home ranges overlapped by 54–99 km^2. Mating was observed between the male and each female. Of 115 recorded kills by tigers, 12 were of domestic animals. Thirty-two villages were located within the 881-km^2 reserve. Tigers had been absent since 2004. One male and one female wild-caught tiger were released on 6 and 8 July 2008, respectively. A further female was released on 27 February 2009. Tigers were held in 1-ha enclosures at release sites for 2–8 days before release. They were satellite-and radio-tracked from release until June 2009.

A study in 1998–2010 in a desert site in South Australia (30) found that after being kept in a holding pen, all four mammal populations

released into an invasive-species-free fenced enclosure survived and bred. After being kept in a holding pen prior to release into a fenced enclosure, where red foxes *Vulpes vulpes*, cats *Felis catus* and rabbits *Oryctolagus cuniculus* had been eradicated, greater stick-nest rats *Leporillus conditor*, burrowing bettongs *Bettongia lesueur*, western barred bandicoots *Perameles bougainville* and greater bilbies *Macrotis lagotis* were detected for eight years, increased their distribution range within five years and produced a second generation within two years. In 1998–2005, eight wild-born greater stick-nest rats, 10 wild-born burrowing bettongs, 12 wild-born western barred bandicoots and nine captive-bred greater bilbies were translocated into a 14-km^2 invasive-species-free fenced area. Rabbits, cats and foxes were eradicated within the fenced area in 1999. Animals were kept in a 10-ha holding pen before full release after a few months. Between 2000 and 2010, tracks were surveyed annually along eight 1 km × 1 m transects.

A replicated, controlled study in 2008–2009 of grassland at two sites in Arizona, USA (31) found that following translocation of Gunnison's prairie dogs *Cynomys gunnisoni* into burrows that were topped with acclimation cages for one week, survival was not greater than that of prairie dogs released into uncaged burrows. Among prairie dogs whose identity could be established in the second year, 10% of both those released into borrows topped with acclimation cages and those released into uncaged burrows survived for at least one year. Additionally, pups were seen at both sites a year after release (39 and 37 pups at the two sites). No definite immigrants to the recipient colonies were recorded. Prairie dogs were trapped from 7 July to 5 August 2008 at one urban and one suburban site (74 and 75 prairie dogs, respectively) and moved approximately 50 km to two abandoned colonies (6 km apart) in a rural area. Approximately half at each colony was released directly into open burrows and half into borrows topped, for one week, with acclimation cages. Survival monitoring, from 10 June to 25 August 2009, entailed live-trapping, PIT-tag reading and direct observations.

A replicated, before-and-after study in 2008–2012 in 32 shrubland sites in Andalusia, Spain (32) found that following release from holding pens with artificial warrens to boost a local population, translocated European rabbit *Oryctolagus cuniculus* abundance was higher after three years. Rabbit abundance was around nine-fold higher three years after

translocations (9.3 latrines/km) than before translocation (1.0 latrines/km). In autumn and winter of 2008–2009, between 75 and 90 rabbits/ha were released into artificial warrens located in 32 electric-fenced 0.5–7.7 ha plots (fencing was 0.5 m below ground and 1.7 m above ground). At the end of the 2009–2011 breeding season, small gates on the fences were opened and the rabbits were allowed to disperse into adjacent areas. Rabbit abundance was estimated by latrine counts along four 500-m transects (128 total transects) around each plot, in the summers of 2008–2009 before gates were opened and in 2012 after gates were opened. Wooden branches and artificial warrens were added within a 500-m radius of some plots and, in some, scrub was cleared to create pasture.

A controlled study in 2002–2007 on a large area of prairie in South Dakota, USA (33) found that using holding pens at release sites affected survival rates of translocated swift foxes *Vulpes velox*. A higher proportion of foxes released after 14–21 days in holding pens survived for ≥60 days post-release (76%) than of foxes held in pens for >250 days (66%) or released after 14–21 days in kennels at a field station (61%). A total of 179 foxes (85 males and 94 females; 91 adults and 88 sub-adults) were translocated in 2002–2007. Holding pens provided acclimatisation at release sites, with food provided at pens following release. Foxes released from short stays in holding pens, and those released having been held in kennels, were released in August–October. Long-stay foxes were released in mid-July. Survival was monitored by radio-tracking and visual observations at dens.

A controlled, before-and-after study in 1989–1992 on a hilly grassland and scrubland site in California, USA (34) found that the survival of translocated San Joaquin kit foxes *Vulpes macrotis mutica* kept in holding pens in pairs prior to release was lower than that of resident animals, but did not change with the length of time in holding pens. The survival of 40 translocated foxes in the first year after release (six alive, 32 dead, two unknown) was lower than that of 26 resident foxes (13 alive, 13 dead), but did not change with the length of time spent in holding pens. Eleven pups born in the holding pens and released with their parents all died within 17 days of release. Only four foxes were known to breed after release, all with resident foxes. At the end of the study (in 1992) one fox was known to be alive and 36 (out of 40) were

known to have died. Causes of death were predation (20 foxes), road accidents (two foxes) and death during trapping operations (one fox). The cause of death was unknown for 13 foxes. In August and December 1988 and January 1989, and from June–October 1989, foxes were caught and translocated up to 50 km to a 19,120-ha reserve. Foxes were kept in male–female pairs in holding pens (6.1 × 3.1–6.1 × 1.8 m) for 32–354 days before release in spring and summer 1990 (12 adults, 1 pup) and 1991 (28 adults, 10 pups). Foxes were monitored by radio-tracking 4–5 days/week after release.

A study in 2015–2016 in a wooded mountain region in central Wales, UK (35) found that some translocated pine martens *Martes martes* held in pre-release pens and then provided with supplementary food and nest boxes survived and bred in the first year after release. At least four out of 10 females that had been kept in pre-release pens survived and bred the year after release. Around 10–12 months after release, 14 out of 20 martens were alive and in good condition. Twelve were within 10 km of their release site. Six martens died in the first year, two had a fungal infection two weeks after release. Authors suggest this may have been due to damp conditions in November. From September–November 2015, twenty breeding age (>3-years-old) pine martens were caught in Scotland, health checked, microchipped and fitted with a radio-collar, and in some cases a GPS logger. Martens were transported overnight to Wales, and held in individual pre-release pens (3.6 × 2.3 × 2 m) for up to seven nights. Males' pens were within 500 m of a female, but >2 km from the nearest male. Releases took place in autumn, and supplementary food was provided for 2–6 weeks after release (for as long as it continued to be taken). Den boxes were provided within 50 m of each release pen. Martens were radio-tracked until home-ranges were established, then located daily–weekly. Intensive tracking of females was carried out in March to locate breeding sites. Hair tubes and camera traps were used to monitor breeding success. A further 19 martens were released using the same procedure in September–October 2016.

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14.14. Hold translocated mammals in captivity before release

https://www.conservationevidence.com/actions/2458

- **Fifteen studies** evaluated the effects of holding translocated mammals in captivity before release. Four studies were in the USA[3,11,12,13], two were in Australia[14,15] and one was in each of India[1], Canada[2], Switzerland[4], Croatia and Slovenia[5], the USA and Canada[6], the UK[7], France[8], Spain[9] and South Africa[10].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (13 STUDIES)

- **Abundance (2 studies):** Two studies (one replicated, before-and-after study) in Croatia and Slovenia[5] and the USA[13] found that following translocation, with time in captivity prior to release, Eurasian lynx[5] established an increasing population and Allegheny woodrat[13] numbers in four of six sites increased over the first two years.
- **Reproductive success (4 studies):** Four studies in Croatia and Slovenia[5], Spain[9], the USA and Canada[6] and Australia[14] found that following translocation, with time in captivity prior to release, Eurasian lynx[5] established a breeding population, and swift foxes[6], European otters[9] and red-tailed phascogales[14] reproduced.
- **Survival (10 studies):** Two studies (one controlled) in the UK[7] and USA[12] found that being held for longer in captivity before release increased survival rates of translocated European hedgehogs[7] and, along with release in spring increased the survival rate of translocated Canada lynx[12] in the first year. Four of six studies in India[1], the USA and Canada[6], the USA[11], France[8], South Africa[10] and Australia[14] found that following translocation, with time in captivity prior to release, most swift foxes[6] and greater Indian rhinoceroses[1] survived for at least 12–20 months, 48% of Eurasian lynx[8] survived for 2–11 years and red-tailed phascogales[14] survived for at least six years. The other two studies found that most kangaroo rats[11] and all

rock hyraxes[10] died within 5–87 days. A replicated, controlled study in Canada[2] found that translocated swift foxes that had been held in captivity prior to release had higher post-release survival rates than did released captive-bred animals.

- **Condition (3 studies):** A randomised, controlled study in Australia[15] found that holding translocated eastern bettongs in captivity before release did not increase their body mass after release compared to animals released directly into the wild. A controlled study the UK[7] found that being held for longer in captivity before release, reduced weight loss after release in translocated European hedgehogs. A study in Spain[9] found that offspring of translocated European otters that were held in captivity before release, had similar genetic diversity to donor populations.
- **Occupancy/range (2 studies):** A study in the USA[3] found that most translocated and captive-bred mountain lions that had been held in captivity prior to release established home ranges in the release area. A study in Croatia and Slovenia[5] and review in Switzerland[4] found that following translocation, with time in captivity prior to release, the range of Eurasian lynx increased over time.

BEHAVIOUR (0 STUDIES)

Background

This intervention refers to holding translocated mammals in captivity away from the release site, before release. This may be done for a number of reasons such as logistics, to allow health checks to take place, to give captured animals time to form social groups, or to use animals in a captive breeding program. Time in captivity may be a few days, months or even a couple of years, depending on the reason for holding individuals in captivity before release.

See also: *Use holding pens at release site prior to release of translocated animals*.

A study in 1984–1986 in a national park in Uttar Pradesh, India (1) found that most translocated greater Indian rhinoceros *Rhinoceros unicornis* that had been held in captivity before release into a fenced reserve, survived over 20 months after release. Seven of eight translocated rhinoceroses were still alive at least 20 months after release into a fenced reserve, and three of these animals survived for over 31 months. One elderly female died three months after release, due to a paralysed limb. In March 1984, six rhinoceroses were captured in Assam and housed in a pen for 9–19 days (during which one individual escaped). The remaining five were transported to Dudhwa National Park, where one elderly female died before release (following abortion of a dead foetus) and four were released in April–May 1984. Four other animals captured in late March 1985 in Sauraha (Nepal) were released to Dudhwa National Park one week after capture. Survival data were collated up to December 1986.

A replicated, controlled study in 1990–1992 at two grassland sites in Alberta, Canada (2) found that translocated swift foxes *Vulpes velox* that had been held in captivity prior to release had higher post-release survival rates than did released captive-bred animals. No statistical analyses were performed. Nine months after release into the wild, 12 out of 28 (43%) wild-born translocated swift foxes were known to be alive, compared with at least two out of 27 (7%) captive-bred swift foxes. In May 1990 and 1991, a total of 28 wild-born and 27 captive-bred swift foxes were released simultaneously. Wild-born animals had been captured in Wyoming, USA, 4–7 months before release and were quarantined for 30 days. Animals were released without prior conditioning in holding pens. Foxes were radio-collared and monitored from the ground and air, for at least nine months.

A study in 1993–1995 in northern Florida, USA (3) found that most translocated and captive-bred mountain lions *Puma concolor stanleyana* that had been held in captivity prior to release established home ranges in the release area. Of 19 released mountain lions, 15 established one or more home ranges. Post-release survival periods for these 15 animals are not stated but two were killed (one illegally shot and one killed by a vehicle) and two were recaptured due to landowner concerns or concerns for their survival, 37–140 days after release. Nineteen mountain lions were released in northern Florida in 1993–1994. Ten were wild-caught

and released within three months, three were caught and released after 3–8 years, and six released animals were captive-bred. Mountain lions were radio-tracked daily in February 1993–April 1993 and then for three days/week until June 1995.

A review in 1998 of translocations in 1971–1989 of Eurasian lynx *Lynx lynx* into nine temperate forest sites in Switzerland (4) found that after being held in captivity before release, the range of lynx in the release area increased over time. Ten years after the first releases, lynx occupied approximately 4,000 km^2. Seventeen years later, this had increased to >10,000 km^2, although the rate of range expansion had slowed. One-hundred and three lynx were confirmed dead following translocations, mostly from road accidents (27%) and illegal shootings (26%). In 1971–1989, at least 25 lynx were released at nine sites in the Alps and Jura mountains in Switzerland. Most were captured in the Slovakian Carpathian Mountains, kept in captivity for at least one month and then released. From 1971 to 1998, questionnaires were distributed among the public to gather reports of lynx sightings. To confirm deaths, lynx carcasses were collected over an unspecified time period. From 1983 to 1998, thirty-seven lynx were captured and fitted with radio-collars to assess range occupancy.

A study in 1973–1995 in forests across Croatia and Slovenia (5) found that following translocation, Eurasian lynx *Lynx lynx* that had been held in captivity prior to release established a breeding population and expanded in number and range. Over the six years after release of six lynx, 19 litters totalling 30 kittens were recorded. Dispersing animals reached Bosnia-Herzegovina 11 years after releases and, two years later, one reached the Julian Alps, near Italy. The population, 22 years after releases, was estimated at 140 lynx in Slovenia and Croatia. These occupied approximately 3,700 km^2 in Slovenia and 3,000 km^2 in Croatia. Hunting was permitted from five years after releases and was the greatest cause of mortality, accounting for 229 of 277 known deaths. Lynx became extinct in Croatia and Slovenia at the beginning of the twentieth century. In 1973, six wild-caught lynx (three female, three male) were caught in Slovakia, quarantined for 46 days and released in Kocevje, Slovenia. Monitoring was based on reviews of hunting data and communications with hunters, foresters and naturalists.

A study in 1994–1998 at seven temperate grassland sites along the USA–Canada border (6) found that most translocated swift foxes *Vulpes velox* that had been held in captivity prior to release and were released in social groups survived for at least one year, and some reproduced near release sites. Eleven of 18 (61%) translocated swift foxes survived at least one year after release. Of these, 60% of animals translocated as juveniles went on to reproduce, as did 33% of translocated adults. In 1994–1996 foxes were captured in Wyoming, fitted with radio-collars and held in captivity for 22–57 days. In autumn 1994–1996, animals were released in mixed-gender groups of up to three individuals that had been trapped in close proximity. Release sites were located in areas with pre-existing, but small, fox populations and with low numbers of predators and high prey availability. Foxes were monitored by visual surveys and ground-based and aerial radio-tracking.

A controlled study in 2004 in 20 suburban gardens in Bristol, UK (7) found that after being held for a period in captivity before release, translocated European hedgehogs *Erinaceus europaeus* had higher survival rates and lower body weight loss than did individuals translocated with minimum time in captivity. A higher proportion of hedgehogs translocated after over a month in captivity survived (82%) and they lost less body weight (9%) over the eight weeks following release compared to individuals translocated after less than six days in captivity (survival: 41%; reduction in body weight: 33%). Over the same period, 64–95% of non-translocated hedgehogs survived and these lost 5–10% of body weight. Between May and June 2004, forty-three hedgehogs were translocated from the Outer Hebrides, Scotland, to 10 suburban gardens in Bristol. Twenty-three had spent >1 month in captivity and 20 had spent <6 days in captivity. Food was provided during the first week after release. Translocated hedgehogs were radio-tracked over eight weeks. Over the same period, 20 free-living hedgehogs captured and released <50 m from the same set of 20 gardens together with 26 free-living hedgehogs caught and released at gardens >3 km away were monitored. Hedgehogs were weighed every 10 days.

A study in 1983–2002 in a temperate forest in Vosges massif, France (8) found that following translocation of Eurasian lynx *Lynx lynx* that had been held in captivity before release, around half survived for 2–11 years. Ten of 21 animals survived for 2–11 years after release. The

distribution of lynx increased from 1,870 km^2 (six years after the first releases) to 3,160 km^2 (12 years later). At least two females produced litters. In 1983–1993, twenty-one adult lynx were brought to France from European zoos. The program sought wild-caught lynx for releases, however the exact origin of each animal, and the length of time that each spent in captivity, are unclear. Lynx were released at four sites in the Vosges Mountains. The first eight animals were held in cages at the release site for 4–45 days prior to release, but the remainder were released immediately upon arrival. Animals were radio-tracked for 1–847 days. The presence of lynx was also established through sightings, footprints, detection of faeces or hair and reports of attacks on domestic animals.

A study in 1995–2004 in three riparian and wetland sites in north-eastern Spain (9) found that following translocations of European otters *Lutra lutra* that were held in captivity before release, animals reproduced and offspring had similar genetic diversity to that of donor populations. By nine years after the first releases, at least 19 offspring had been born to translocated otters. Genetic diversity in these offspring was similar to that of the donor populations (data reported as genetic heterozygosity). In 1995–2002, forty-two otters were released into three wetland and river areas. All otters were caught in western Iberia and were quarantined before release. Blood samples were collected from 23 translocated otters. In February–March 2004, the study area was divided into eight zones, each of which was surveyed over five consecutive days. In total, 104 otter faeces and anal secretion samples were collected from release areas. Samples were genetically analysed and compared to samples from translocated otters.

A study in 2005–2006 at rocky outcrops on a reserve in KwaZulu-Natal Province, South Africa (10) found that translocated rock hyraxes *Procavia capensis* that were held in captivity before release in a social group, and provided with an artificial refuge and supplementary food after release, all died (or were presumed to have died) within 87 days of release. Eighty-seven days after the release of 17 hyraxes, none could be relocated. In July 2005, ten adult hyraxes were caught in baited mammal traps (900 × 310 × 320 mm), and held in captivity for 16 months, during which time three died. The remaining seven were released in November 2006, along with the eight juveniles and two pups born to them in captivity, to a 656-ha reserve where the species was nearly extinct. For

four months prior to release, the group was housed together in an outdoor cage (5.9 × 2.5 × 3.2 m). Hyraxes were released into a hay-filled hutch which was left in place for several months, and were provided with cabbage for one week after release. Hyraxes were monitored by direct observations and by walking regular transects, daily for the first week decreasing to monthly by the end of the study.

A study in 2001 in a grassland and shrubland site in California, USA (11) found that most translocated Tipton kangaroo rats *Dipodomys nitratoides nitratoides* and Heermann's kangaroo rats *Dipodomys heermanni* ssp. that were held in captivity prior to release died within five days of release. All four Tipton kangaroo rats were predated within five days of translocation, and only one of seven Heermann's kangaroo rats survived over 45 days. Three Heermann's kangaroo rats were predated, two died as a result of aggression from other Heermann's kangaroo rats, and the fate of one was unknown. In September 2001, four juvenile Tipton kangaroo rats and three Heermann's kangaroo rats were captured and held in captivity for two months before release at a protected site in November. In December 2001, a further four Heermann's kangaroo rats were caught and translocated to the same site. All 11 animals were fitted with a radio-transmitter and ear tags, and monitored for seven days in captivity prior to release. The release site was already occupied by Heermann's kangaroo rats. Animals were released into individual artificial burrows (two 90-cm-long cardboard tubes with a chamber about 30 cm below the surface), dug 10–15 m apart and provided with seeds. Burrows were plugged with paper towels until dusk. Animals were radio-tracked every 1–8 days for 18–45 days after release.

A study in 1999–2007 in montane forest in Colorado, USA (12) found that more time in captivity and release in spring increased the survival rate of translocated Canada lynx *Lynx canadensis* in the first year. Lynx released in spring after >45 days in captivity had lower monthly mortality rates (0.4–2.8% in 2000–2006) than lynx released in spring after 21 days in captivity (1.4% in 2000) or released after 7 days but not in spring (20.5% in 1999). Overall, 117 of 218 released lynxes (53%) survived to at least 1–8 years after release. From 1999 to 2006, two hundred and eighteen lynx were translocated to a 20,684-km^2 mixed forest area in the San Juan Mountains, Colorado, from Canada and the USA. Lynx were held in captivity near their source location (for 3–68

days) prior to transfer to a holding facility (40 pens, 2.4 x 1.2 m with ceilings) in Colorado (100 km from release site). Time in the Colorado holding facility varied (5–137 days): release within 7 days following veterinary inspection (4 individuals in 1999); release after 3 weeks (9 individuals in 2000); release after >3 weeks in the spring (1 April-31 May; 28 individuals in 2000); release in spring after >3 weeks in captivity but excluding any juveniles or pregnant females (177 individuals in 2000–2006). Lynx were fed a diet of rabbit and commercial carnivore food while in captivity. Lynx were radio-collared and monitored weekly for the first year following release (5,324 locations recorded).

A replicated, before-and-after study in 2005–2009 in six riparian areas in Indiana, USA (13) found that following translocation of Allegheny woodrats *Neotoma magister* that were held in captivity prior to release, numbers in four out of six sites increased over the first two years. Two years after 54 woodrats were translocated to six sites, numbers had increased in four sites, but only one woodrat was recorded at each of the other two sites. At this time, there were more woodrats overall (total 67 animals) than before animals were translocated (16 animals). In 2007–2008, sixty-seven woodrats were captured in Kentucky and Tennessee. After five days, they were fitted with radio-transmitters and transported to release sites. In 2005–2006 (before translocations) and in 2007–2009 (after translocations), woodrat abundance was estimated using 35–100 live traps/site between June and August. Trapping was carried out over two consecutive nights at each site and traps were checked at dawn. All woodrats caught were fitted with ear tags.

A study in 2009–2015 in a forest and shrubland reserve in Western Australia, Australia (14) found that a translocated population of red-tailed phascogales *Phascogale calura*, some of which were held in captivity prior to release into a fenced area containing artificial nest boxes, survived and reproduced for at least six years, and spread outside the release area. At least nine of 12 translocated female red-tailed phascogales survived 8–9 months post-release and all nine reproduced in the wild. At least one female survived two years after release. From 1–6 years post-release, nest box occupancy within and outside the fenced area remained over 60%. In April 2009, twenty red-tailed phascogales were translocated to a 430-ha fenced area, within a 560-ha reserve surrounded by farmland, and released at dusk on the day of capture. Seven phascogales were

released in June 2010, six weeks after capture. Animals were released into or adjacent to 22 nest boxes, alone or in pairs. From November 2010–January 2013, thirteen additional boxes were installed inside (four) and outside (nine) the fenced area. Invasive foxes *Vulpes vulpes* and cats *Felis catus* were absent from the fenced area, but the fence did not present a barrier to phascogales. Phascogales were monitored between April 2009 and March 2011 using baited Elliott live-traps (nine sessions, 5,341 trap nights) and through periodic monitoring between July 2009 and January 2015 of the nest boxes.

A randomised, controlled study in 2011–2014 in a woodland reserve in Australian Capital Territory, Australia (15) found that holding translocated eastern bettongs *Bettongia gaimardi* in captivity before release did not affect their body mass after release relative to animals released directly into the wild. Bettongs released after time in captivity were heavier at release (1.9 kg) than were those released immediately (1.7 kg) though subsequently there were no significant differences in body weight (see paper for details). In 2011–2012, thirty-two adult wild-born bettongs were captured in Tasmania and translocated to mainland Australia. Sixteen randomly selected individuals were immediately released into a fenced reserve, where invasive predators had been controlled. The remaining 16 were housed for 30 days in small enclosures (0.5–1.0 ha) before transfer to larger enclosures (2.6–9.4 ha). In total, they were held for 95–345 days before release. Bettongs were radio-tagged and were trapped and weighed periodically up to 18 months after release.

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(11) Germano D.J. (2010) Survivorship of translocated kangaroo rats in the San Joaquin Valley, California. *California Fish and Game*, 96, 82–89.

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14.15. Use tranquilizers to reduce stress during translocation

https://www.conservationevidence.com/actions/2465

- **One study** evaluated the effects on mammals of using tranquilizers to reduce stress during translocation. This study was in France[1].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (1 STUDY)

- **Survival (1 study):** A controlled study in France[1] found that using tranquilizers to reduce stress during translocation did not increase post-release survival of European rabbits.

BEHAVIOUR (0 STUDIES)

Background

Translocation of mammals can cause elevated stress levels. This may affect post-release survival (e.g. Beringer *et al*. 2002). Tranquilizers may be administered during the translocation process in order to reduce stress to captured mammals.

Beringer J., Hansen L.P., Demand J.A., Sartwell J., Wallendorf M. & Mange R. (2002) Efficacy of translocation to control urban deer in Missouri: costs, efficiency, and outcome. *Wildlife Society Bulletin*, 30, 767–774.

A controlled study in 1997 on a farmland site in northern France (1) found that using tranquilizers to reduce stress during translocation did not increase post-release survival of European rabbits *Oryctolagus cuniculus.* The re-sighting rate of rabbits that had been tranquilized over seven weeks after release did not differ significantly from that of non-tranquilized rabbits over the same period (data reported as statistical model results). In January 1997, a total of 104 rabbits were translocated from Parc-du-Sausset to an area of cultivated fields and pasture in Héric, 400 km away. Of these, approximately half were tranquillized just after capture using two intra-muscular injections of carazolol (0.1 mg/kg). Roughly half the tranquilized and half the non-tranquilized

rabbits were acclimatised in 100-m² enclosures for three days prior to release. Survival was estimated from nocturnal spotlight re-sighting sessions conducted every evening during the first week following release. Thereafter, monitoring was reduced to twice/week for a further six weeks, until late-February.

(1) Letty J., Marchandeau S., Clobert J. & Aubineau J. (2000) Improving translocation success: an experimental study of anti-stress treatment and release method for wild rabbits. *Animal Conservation*, 3, 211–219, https://doi.org/10.1111/j.1469-1795.2000.tb00105.x

14.16. Airborne translocation of mammals using parachutes

https://www.conservationevidence.com/actions/2466

- **One study** evaluated the effects of airborne translocation of mammals using parachutes. This study was in the USA[1].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (1 STUDY)

- **Survival (1 study):** A study in the USA[1] found that at least some North American beavers translocated using parachutes established territories and survived over one year after release.

BEHAVIOUR (0 STUDIES)

Background

Translocating animals into remote terrain can be logistically challenging. Holding animals for several days while moving across ground can cause them stress and, potentially, illness or mortality. Dropping animals from an airplane means that they can be held captive for shorter periods, though it may be harder to choose the precise release location. Parachutes, combined with a container that opens upon landing, can be used in aerial drops.

A study in 1948–1949 in a forest in Idaho, USA (1) found that at least some North American beavers *Castor canadensis* translocated using parachutes established territories and survived over one year after release. Seventy-six beavers were dropped from an airplane over the translocation area using parachutes. All but one survived the drop. After one year, an unspecified number of beavers had built dams and constructed houses. In the autumn of 1948, seventy-six beavers were parachuted into a remote forest area. Animals were dropped in pairs, inside wooden boxes (76 × 40 × 30 cm), using 7.3-m rayon parachutes of war surplus stock. Boxes consisted of two sections fitted together as a suitcase, with 2.5-cm ventilation holes. A system of ropes snapped the box open with the collapse of the parachute. The system had been tested on an old male beaver named 'Geronimo'. Observations were made of the surviving beavers in late 1949 (details not reported).

(1) Heter E.W. (1950) Transplanting beavers by airplane and parachute. *The Journal of Wildlife Management*, 14, 143–147.

14.17. Release translocated mammals into fenced areas

https://www.conservationevidence.com/actions/2467

- **Twenty-four studies** evaluated the effects of releasing translocated mammals into fenced areas. Nine studies were in Australia[5,11,15,19–24], six studies were in South Africa[6,7,8,10,12,16], two studies were in the USA[1,3] and one study was in each of India[2], China[4], Spain[9,18], Hungary[13], Namibia and South Africa[14] and France[17].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (22 STUDIES)

- **Abundance (5 studies):** Five studies (one replicated) in the USA[1,3], Australia[5,20] and South Africa[7] found that following translocation into fenced areas, 18 African elephant populations[7], tule elk[3], brushtail possum[20] and elk and bison[1] increased in number and following eradication of invasive species a population of translocated and released captive-bred burrowing bettongs[5] increased. A replicated, controlled study

in Spain[9] found that the abundance of translocated European rabbits was higher in areas fenced to exclude predators than unfenced areas.

- **Reproductive success (7 studies):** Two replicated, controlled studies in France[17] and Spain[18] found that after translocation, reproductive success of common hamsters[17] and European rabbits[18] was higher inside than outside fenced areas or warrens. Four studies (one replicated, controlled) in China[4] and South Africa[6,8,10] found that following translocation into a fenced area, Père David's deer[4], lions[10], translocated and captive-bred African wild dogs[8] and one of two groups of Cape buffalo[6] reproduced. A study in Australia[15] found that four of five mammal populations[15] released into a predator-free enclosure and one population released into a predator-reduced enclosure reproduced, whereas two populations released into an unfenced area with ongoing predator management did not survive to breed.
- **Survival (13 studies):** Two replicated, controlled studies in Spain[9] and France[17] found that after translocation, survival rates of common hamsters[17] and European rabbits[9] were higher inside than outside fenced areas or warrens. A study in Australia[15] found that four of five mammal populations[15] released into a predator-free enclosure and one population released into a predator-reduced enclosure survived, whereas two populations released into an unfenced area with ongoing predator management did not persist. Five studies in India[2], China[4], South Africa[12], Namibia and South Africa[14] and Australia[19] found that following translocation into fenced areas, most black rhinoceroses[14] and greater Indian rhinoceroses[2], Père David's deer[4], most oribi[12] and offspring of translocated golden bandicoots[19] survived for between one and 10 years. Two studies in Australia[11,24] found that only two of five translocated numbats[11] survived over seven months and western barred bandicoots[24] did not persist. A study in South Africa[8] found that translocated and captive-bred African wild dogs[8] released into fenced reserves in family groups had high survival rates. A study in Australia[21] found that following

release into fenced areas, a translocated population of red-tailed phascogales[21] survived longer than a released captive-bred population. A replicated, controlled study in South Africa[10] found that after translocation to a fenced reserve with holding pens, survival of released lions[10] was higher than that of resident lions.

- **Condition (3 studies):** A replicated, before-and-after study in Australia[23] found that eastern bettongs translocated into fenced predator proof enclosures increased in body weight post-release, with and without supplementary food. A replicated study in South Africa[16] found that following translocation into fenced reserves, stress hormone levels of African elephants declined over time. A study in Australia[19] found that golden bandicoots descended from a population translocated into a fenced area free from non-native predators, maintained genetic diversity relative to the founder and source populations.

BEHAVIOUR (2 STUDIES)

- **Use (2 studies):** A site comparison study in Australia[22] found that following translocation into a predator-free fenced area, woylies developed home ranges similar in size to those of an established population outside the enclosure. A study in Hungary[13] found that one fifth of translocated European ground squirrels released into a fenced area with artificial burrows remained in the area after release.

Background

Mammals that are being translocated to a new location may be released into fenced areas. This may be done to keep them within a certain area (e.g. a game reserve), or to keep predators or other problem species out of an area to increase their chances of survival. Here fenced areas refer to those that are large enough to cover the home ranges of the target species. Studies that use smaller holding or pre-release pens before releasing translocated mammals into the wild are covered in *Use holding pens at release site prior to release of translocated mammals.*

See also: *Release captive-bred mammals into fenced areas.*

A study in 1970–1973 in two grassland and forest sites in South Dakota, USA (1) found that following translocation into fenced areas, elk *Cervus canadensis* and bison *Bison bison* increased in numbers. Three years after the onset of translocations, there were more elk (214) and bison (109) than were released over that time (elk: 165; bison: 95). Additionally, over the same period, 55 elk and 22 bison were harvested by hunters. The study was conducted in two 4,000-ha game ranges. Both game ranges were enclosed by woven wire fences, approximately 2 m high. In 1970–1973, one hundred and sixty-five elk and 95 bison (origin not stated) were released across both sites (the number of individuals stocked into each game range is not provided). Mule deer *Odocoileus hemionus*, whitetail deer *Odocoileus virginianus* and pronghorn *Antilocapra americana* occurred naturally within the game ranges and were managed for game hunting.

A study in 1984–1986 in a national park in Uttar Pradesh, India (2) found that following translocation into a fenced reserve, most greater Indian rhinoceros *Rhinoceros unicornis* survived over 20 months after release. Seven of eight translocated rhinoceroses were still alive at least 20 months after release into a fenced reserve, and three of these animals had survived for over 31 months. One elderly female died three months after release, due to a paralysed limb. In March 1984, six rhinoceroses were captured in Assam. They were housed in a holding pen for 9–19 days (during which one individual escaped). The remaining five were transported to Dudhwa National Park, where one elderly female died before release (following abortion of a dead foetus) and four were released in April–May 1984. Four other animals captured in late March 1985 in Sauraha (Nepal) were released to Dudhwa National Park one week after capture. Survival data were collated up to December 1986.

A study in 1978–1998 in a grassland reserve in California, USA (3) found that numbers of tule elk *Cervus canadensis nannodes* translocated to a fenced reserve increased more than 50-fold over 20 years. In 1998, a translocated population of Tule elk grew to more than 500 individuals from the 10 individuals originally translocated 20 years earlier. In 1978, ten tule elk were translocated to a fenced reserve of approximately 1,000 ha. No monitoring details are provided.

A study in 1993–1997 in a grassland reserve in Hubei province, China (4) found that translocated Père David's deer *Elaphurus davidianus*

released into a fenced area survived at least two years and bred. Père David's deer survived at least two years after being translocated and reproduced in the second year following relocation (numbers not provided). Deer were released in 1993 (30 individuals), 1994 (34 individuals) and 1995 (74 individuals) into a 16 km^2 paddock. The origin of some of the deer is unclear, but most were wild-born offspring from captive-bred animals that had been released into another reserve in China.

A study in 1993–1999 on an arid peninsula in Western Australia, Australia (5) found that following release into a fenced area where invasive species had been eradicated, a population of burrowing bettongs *Bettongia lesueur* increased. In 1999, six years after initial releases, the population was estimated at 263–301 bettongs, with 340 individuals born between 1995 and 1999. The population died out due to fox incursion in 1994, but was re-established with further releases. In 1990, a 1.6-m tall wire mesh fence (with an external overhang, an apron to prevent burrowing and two electrified wires) was erected to enclose a 12-km^2 peninsular, within which foxes *Vulpes vulpes* and cats *Felis catus* were eliminated by poisoning in 1991 and 1995, respectively. Outside the fence foxes were controlled by biannual aerial baiting with meat containing 1080 toxin, distributed at 10 baits/km^2 over 200 km^2. From October 1993, an additional 200 baits/month were distributed along the fence and roads across the study area. Cats were controlled by trapping and poisoning in a 100 km^2 buffer zone. In May 1992 and September 1993, twenty-two wild-caught bettongs were transferred to an 8-ha *in-situ* captive-breeding pen. In September 1993 and October 1995, twenty wild-caught bettongs were translocated to range freely in the reserve. From 1993–1998, one hundred and fourteen captive-bred bettongs were released. Artificial warrens and supplementary food and water were provided in 1993, but not for later releases. Eighty released bettongs were radio-tagged. From 1991–1995, European rabbits *Oryctolagus cuniculus* were controlled within the fenced area using 1080 'one shot' oats. Bettongs were monitored every three months using cage traps set over two consecutive nights, at both 100-m intervals along approximately 40 km of track, and at warrens used by radio-collared individuals.

A study in 2000–2003 in a mixed karoo grassland reserve in Northern Cape Province, South Africa (6) found that after translocated Cape

buffalo *Syncerus caffer* were released into a fenced reserve in groups (after being held in a holding pen) one group scattered and escaped the reserve while the other formed a single herd and stayed in the reserve and bred. One month after release, a group of four buffalo had split into two solitary animals and a pair formed by one male and one female. One of the solitary animals was not seen again, the second solitary male animal was located two years after release on a neighbouring farm and released into the second group of translocated animals in May 2003. The pair escaped the reserve three times in 13 months. After the third escape, the male was moved to a different reserve and a new male introduced to form a herd with the remaining female. A second group of 10 translocated animals formed a single herd (along with the two remaining animals from the previous introduction) and over 10 months no animals died or escaped. A year after the introduction five calves were born. Four subadult buffalo (2 male, 2 female) were placed in a holding pen in July 2000 and released in August into a fenced 12,000-ha reserve. A second group of seven adult and three subadult animals (4 male, 6 female) was placed into a holding pen in August 2002 and released into a 200 ha area in September before being completely released in October 2002. Both groups were monitored weekly with telemetry until October 2003.

A replicated study in 1990–2001 in 18 savannah sites in South Africa (7) found that at least five years following translocation into fenced reserves, the population size of African elephants *Loxodonta africana* increased over time. The population size of translocated elephants increased at an average annual rate of 8.3%. Annual growth across recipient sites ranged from 1.7% to 16.5%. In 1990–1999, elephants were translocated into 18 fenced reserves. The number of animals translocated into each reserve ranged between 18 and 227. Translocation details and the data on numbers of animals present in 2001 were obtained through surveys of reserve owners or managers. All translocated elephants were wild-born, free-ranging animals.

A study in 1995–2005 in 12 dry savanna and temperate grassland sites in South Africa (8) found that translocated and captive-bred African wild dogs *Lycaon pictus* released into fenced reserves in family groups had high survival rates and bred successfully. Eighty-five percent of released animals and their wild-born offspring survived the first six months after release/birth, Released animals which survived

their first year had a high survival rate 12–18 months (91%) and 18–24 months (92%) after release. Additionally, groups which had more time to socialise in holding pens prior to release had higher survival rates (data presented as statistical models). Between 1995 and 2005, one hundred and twenty-seven wild dogs (79 wild-caught, 16 captive-bred, 16 wild-caught but captive-raised, 16 'mixed' pups) were translocated over 18 release events into 12 sites in five provinces of South Africa. Animals were monitored for 24 months after release, and the 129 pups which they produced after release were monitored up to 12 months of age. Forty characteristics of the individual animals, release sites and methods of release were recorded, and their impact on post-release survival was tested.

A replicated, controlled study in 2002–2003 in three grassland and shrubland sites in south-west Spain (9) found that the survival of translocated rabbits *Oryctolagus cuniculus* was similar between fenced and unfenced areas but that abundance was higher in areas fenced to exclude predators. Three months after translocation, rabbit survival did not differ significantly between fenced and unfenced plots (0.57 vs 0.4). However, four months after translocation the relative abundance of rabbits was higher in fenced than in unfenced plots (data presented as log abundance). Two fenced (1 m below and 2.5 m above ground with an electric wire on top) and two unfenced translocation areas (4 ha, 18 artificial warrens each) were established in Los Melonares, Sierra Norte of Seville Natural Park. A total of 724 wild rabbits were released in similar numbers into each area. Rabbit survival was based on 45 radio-collared rabbits (19 in fenced and 26 in unfenced areas). Abundance was estimated four months after translocation through pellet counts in 10 circular plots (18 cm diameter).

A replicated, controlled study in 1999–2004 in three mixed savanna and woodland sites in KwaZulu-Natal, South Africa (10) found that after translocation to a fenced reserve with holding pens, survival of released lions *Panthera leo* was higher than that of resident lions, and translocated animals reproduced successfully. No statistical tests were performed. After five years, a higher proportion of translocated animals survived (eight of 16 animals, 50%) than of resident animals (20 of 84 animals, 24%). Seven translocated females reproduced successfully. Between August 1999 and January 2001, sixteen lions were translocated

to an enclosed reserve to improve genetic diversity. They were held at release sites in 0.5–1-ha pens for 4–6 weeks before release. Nine translocated lions were fitted with radio-collars. From August 1999 to December 2004, translocated animals were located at least every 10 days. Resident lions were also tracked at least every 10 days.

A study in 2005–2006 of a savanna reserve in South Australia, Australia (11) found that following translocation and release into a fenced area, only two of five translocated numbats *Myrmecobius fasciatus* remained alive after seven months. One male was predated by a raptor 47 days after release. Two females were each carrying young four months after release, but both died three months later, probably due to raptor predation. Two males remained alive for at least 18 months after release. Five translocated numbats (three males and two females) were released in November 2005 into a 14-km^2 fenced area from which red foxes *Vulpes vulpes* and feral cats *Felis catus* were excluded. All animals were released on the day of capture or the following day. Animals were radio-tracked daily for three months and weekly for six further months. Methods for monitoring after that time are not detailed.

A study in 2004–2006 in a grassland reserve in KwaZulu-Natal, South Africa (12) found that following translocation into a fenced reserve, most oribi *Ourebia ourebi* survived at least one year after release. Fourteen of 15 (93%) oribi translocated into a fenced reserve survived for at least one year post-release. The other oribi (a male) died eight months after release but was old (based on horn length and wear). Four translocated females were pregnant and were observed with calves within three months of release (number not reported). Fifteen wild oribi from three populations (11 females, four males) were translocated into a 2,000-ha private game reserve in November 2004. The reserve was surrounded by a 2.1-m-high electric fence and was patrolled daily by armed guards. The grassland was managed for oribi by mowing and burning. All of the 15 oribi were ear-tagged and radio-collared. In 2005–2006, individuals were radio-tracked weekly for two months and monthly thereafter for one year.

A study in 2000 in a grassland site in central Hungary (13) found that one fifth of translocated European ground squirrels *Spermophilus citellus* released into a fenced area with artificial burrows remained in the area after release. From four to 10 days after release, 25 out of 117

ground squirrels were recaptured. The highest recapture rate came from the group released into plugged burrows in the morning (15 out of 30). The fence was designed to exclude predators from the site. From 22–24 April 2000, 117 wild-caught European ground squirrels were translocated to a fenced 40-ha protected grassland. Four 40 × 40-m grid cells were established, each containing vertical, artificial burrows (50 cm long, 4.5 cm diameter) spaced 4.5 m apart. Sixty animals were released into burrows plugged with wood caps (from which they could only exit by digging out) across two grid cells and 57 into unplugged artificial burrows in the other two grid cells. One individual was released/burrow. Approximately half the squirrels were released in the afternoon on the day of capture. Animals to be released in the morning were kept in individual wire cages (10 × 10 × 40 cm) for one night and provided with fresh apple slices prior to release. From 28 April–2 May, squirrels were recaptured with snares to record retention.

A study in 1981–2005 in reserves across Namibia and South Africa (14) found that 89% of translocated black rhinoceros *Diceros bicornis* released into fenced reserves survived over one year and 36% at least 10 years post-release. Seventy-four of 682 translocated black rhinoceroses died during the first year post-release. First-year post-release mortality was higher when animals were released into reserves occupied by other rhinoceroses (restocking, 13.4% mortality of 268 animals) than releases into new reserves (reintroduction, 7.9% mortality of 414 animals). At least 243 rhinoceroses survived at least 10 years after release. For restocking events, first-year post-release mortality was higher in rhinoceroses less than two years old (59%) than in all other age classes (9–20%), but there was no difference for reintroductions. Data on 89 reintroduction and 102 restocking events of black rhinoceroses into 81 reserves from 1981–2005 were compiled from the Namibia and South Africa Rhino Management Group reports. Animals were released in groups from 1 to 30 individuals, and reserves received up to five releases. Translocations were considered as different if the releases of individuals to the same reserve were more than 1 month apart. Deaths were detected by reserve staff. The location of reserves included in the study is not provided.

A study in 1998–2010 in a desert site in South Australia (15) found that four of five mammal populations released into a predator-free enclosure and one population released into a predator-reduced

enclosure survived, increased their distribution and produced a second generation, whereas two populations released into an unfenced area with ongoing predator management did not persist. After release into a fenced enclosure where red foxes *Vulpes vulpes*, cats *Felis catus* and rabbits *Oryctolagus cuniculus* had been eradicated, greater stick-nest rats *Leporillus conditor*, burrowing bettongs *Bettongia lesueur*, western barred bandicoots *Perameles bougainville* and greater bilbies *Macrotis lagotis* were detected for eight years, increased their distribution within five years and produced a second generation within two years. Numbats *Myrmecobius fasciatus* were only detected for three years and did not produce a second generation. Burrowing bettongs released into a fenced enclosure with cats and rabbits but no foxes survived and increased their distribution over at least three years and produced a second generation within two years. Greater bilbies and burrowing bettongs released into an unfenced area with some predator management did not survive to produce a second generation or increase their distribution. In 1998–2005, five numbats, 106 greater stick-nest rats (6 captive-bred individuals), 30 burrowing bettongs, 12 western barred bandicoots and nine greater bilbies (all captive-bred) were released into a 14-km^2 invasive-species-free fenced area. Rabbits, cats and foxes were eradicated within the fenced area in 1999. All western barred bandicoots and greater bilbies, and some greater stick-nest rats (8 individuals) and burrowing bettongs (10 individuals) were put into a 10-ha holding pen before full release after a few months. All other animals were released directly into the larger fenced area. In 2004–2008, thirty-two greater bilbies and 15 burrowing bettongs were translocated to an unfenced area (200 km^2) where invasive predators (cats and foxes) were managed with lethal controls and dingoes *Canis lupus dingo* were excluded by a fence on one side. In 2008, sixty-six burrowing bettongs were translocated to a 26 km^2 fenced area which contained small cat and rabbit populations as a result of previous eradication attempts. Between 2000 and 2010, animals were monitored using track counts, burrow monitoring and radio-tracking.

A replicated study in 2000–2006 in five savannah reserves in South Africa (16) found that following translocation into fenced reserves, stress hormone levels of African elephants *Loxodonta africana* declined with time since release. Average levels of stress hormones were respectively

10% and 40% lower in reserves where elephants had been released 10 and 24 years before sampling than in a reserve where elephants had been released one year before sampling. The concentrations of stress hormones levels (fecal glucocorticoid metabolites) were quantified from 1,567 fecal samples collected in 2000–2006 from elephants reintroduced to five fenced reserves. Translocated elephants had been released in 1981 in two of the reserves, in 1992 in two other reserves and in 2000 in one reserve. Samples were collected from all family groups on nearly consecutive days and efforts were made not to collect multiple samples from the same individual.

A replicated, controlled study in 2010–2011 in 10 agricultural plots in Alsace, France (17) found that survival rates and reproductive success of translocated common hamsters *Cricetus cricetus* were higher inside than outside fenced areas. Average reproductive success and weekly survival rates of translocated hamsters were higher inside (reproductive success: 0.44 litters/female; weekly survival: 89%) than outside fenced areas (reproductive success: 0.00 litters/female; weekly survival: 27%). Additionally, inside fenced areas, monthly survival was higher in wheat plots (harvested and unharvested wheat plots combined) than in alfalfa plots (61% vs 35%). The study was conducted in a 300-ha agricultural landscape, comprising small fields (ca. 0.75 ha) of multiple crops. In May 2010, a total of 14 hamsters were released in two batches into fenced plots and an equal number was released in two unfenced plots. Additionally, in May 2011, hamsters were released into two fenced plots each of harvested wheat (total 14 hamsters), unharvested wheat (total 14 hamsters) and mown alfalfa (total 14 hamsters). Animals were radio-tagged and released into artificial burrows. Fenced plots were surrounded by electrified wires located 10–100 cm above ground. Animals were located every 2–4 days in May–September by radio-tracking.

A replicated, controlled study in 2004–2006 in 16 grassland sites in Andalusia, Spain (18) found that European rabbits *Oryctolagus cuniculus* bred in artificial warrens and that reproductive success was higher in fenced than in unfenced warrens. One hundred and twenty-one rabbit kittens were detected during 222 artificial warren observations (0.54/observation). More kittens were detected in fenced than in unfenced artificial warrens (data presented as model results). The study was

conducted in sixteen 5-ha sites across two areas of Doñana National Park. Five artificial warrens in each site each consisted of a two-floor wooden structure (15 × 3 × 1 m) with 30 entrances, covered with a metallic net, ground cloth and sand. In eight sites, artificial warrens were fenced to deter terrestrial predators, with a 2-m tall metallic net that extended 0.5 m underground. In eight sites, warrens were not fenced. In each site, 5–19 rabbits/ha were released in October or November of 2004 or 2005. Rabbit reproductive success was surveyed the following year, between February and August, through observations of kittens in focal artificial warrens, using a spotting-scope.

A study in 2010–2013 at a grassland and woodland site in Western Australia, Australia (19) found that wild-born golden bandicoots *Isoodon auratus*, descended from a translocated population which had been released into a fenced area free from non-native predators, maintained genetic diversity relative to the founder and source populations and persisted for three years. For four measures of genetic diversity (allelic richness, the number of effective alleles per locus, observed heterozygosity and expected heterozygosity) there were no significant differences between descendants from translocated animals, founder animals that were translocated or source populations (see paper for details). The population size was estimated at 249 bandicoots in 2013. One hundred and sixty bandicoots were trapped on Barrow Island, which had a large population, in February 2010. They were released into a 1,100-ha enclosure free from introduced predators within 24 h of capture. Genetic material was sampled by ear punch biopsy from 57 founders in 2010 and from 67 wild-born progeny trapped in 2010–2012.

A study in 2010–2013 in a forest and shrubland reserve in Western Australia, Australia (20) found that following translocation into a predator-resistant fenced area, brushtail possums *Trichosurus vulpecula* numbers increased over the three years following release. Of five animals released in a formal translocation program, only one, a female, survived >8 months. This animal was still alive after three years. However, including survivors and progeny from four possums informally released two year earlier, there were 19 possums known to be alive three years after formal translocations. Twenty further possums were recorded over this time, of which most are presumed to have

subsequently died or left the sanctuary area. Four possums caught on nearby farms were informally released within a 427-ha predator-fenced sanctuary in 2008. Five possums were translocated and released at the same site in winter 2010. Possums were monitored by radio-tracking and by 3–4 live-trapping surveys/year in 2010–2013.

A study in 2006–2015 in two forest and shrubland sites in Western Australia and Northern Territory, Australia (21) found that following release into fenced areas, a translocated population of red-tailed phascogales *Phascogale calura* survived for more than five years, but a captive-bred population survived for less than a year. A population of phascogales established from wild-caught animals survived longer (>5 years) than a population established from captive-bred animals (that had been kept in pre-release pens and given supplementary food; < 1 year). Authors suggest that the unsuccessful site may also have had a shortage of tree hollows for nesting. In July 2006 and January–February 2007, thirty-two captive-bred phascogales were released into a 26-ha fenced reserve (outside which feral cats *Felis catus* were abundant) after spending either 10 days or over four months in a pre-release pen (3×6×2 or 4.5×3×2.2 m). Eleven nest boxes were provided within 150m of the release pen, and supplementary food was provided for one week after release. In April 2009 and June 2010, twenty-seven wild-caught phascogales were released into a 430-ha fenced reserve with 22 nest boxes, but with no pre-release pen or supplementary food. From November 2010–January 2013, thirteen additional boxes were installed inside (four) and outside (nine) the fenced area at this site. Phascogales were monitored after each release using radio-collaring or Elliott live traps, and through periodic monitoring of the nest boxes.

A site comparison study in 2010–2011 of forest at two sites in Western Australia, Australia (22) found that following translocation into a predator-free, enclosed sanctuary, woylies *Bettongia penicillata* developed home ranges similar in size to those of an established population outside the enclosure. Home ranges did not differ significantly in size between woylies inside the enclosure (28–115 ha) and those in a population outside the enclosure (42–141 ha). The 423-ha sanctuary area was enclosed by a 2-m-high fence in September 2010. This was followed by an intensive cat *Felis catus* and fox *Vulpes vulpes* eradication programme. In December 2010, forty-one woylies sourced from nearby populations

were released inside the fence. Eight woylies inside the fence (four male, four female) and seven from an established population 17 km to the north (five male, two female), were monitored by radio-tracking at night in March–April 2011.

A replicated, before-and-after study in 2011–2013 in two forest and grassland sites in the Australian Capital Territory, Australia (23) found that eastern bettongs *Bettongia gaimardi* translocated into fenced predator proof enclosures increased in body weight post-release, with and without supplementary food. Between twelve and 24 months post-release, the average body weight of translocated eastern bettongs (1.8 kg) increased compared to before release (1.7 kg). There was no difference in weight between bettongs fed supplementary food and those without (data not provided). In 2011−2012, sixty adult eastern bettongs were translocated from Tasmania to two predator-free fenced reserves. In one reserve bettongs (5 males, 7 females) received supplementary food at least weekly and were placed in 2.6–9.4 ha enclosures, whereas in a second reserve bettongs (8 males, 10 females) received no supplementary food and were not managed in enclosures. Supplementary food included fresh locally available produce and commercial pellets. Body weight was assessed before release and 12–24 months after release (May–November 2013). Bettongs were also monitored by radio-telemetry or camera traps and live-trapping every 3 months.

A study in 1995–2010 in a shrubland-dominated peninsula in Western Australia, Australia (24) found that a translocated population of western barred bandicoots *Perameles bougainville* released inside a predator-resistant fence did not persist. Nine years after translocations into a fenced area commenced, bandicoot numbers increased to 467, from 82 founders. However, then declined to four individuals eight months later and just one animal was recorded over the following three years. Fourteen bandicoots were translocated in 1995–1996 from an offshore island to a 17-ha enclosure, within a 1,200-ha section of a mainland peninsula, fenced to exclude foxes and feral cats. In 1997–2004, eighty-two bandicoots were released from the enclosure to the fenced peninsula. Bandicoots were monitored with cage traps at 100-m intervals over two nights during 47 trapping sessions between August 1995 and September 2010. The fence was built in 1989 and was rebuilt and repaired several times. However, it was considered to be an ineffective barrier to red

foxes *Vulpes vulpes* and cats *Felis catus*, which were controlled inside the fenced area by poisoning, trapping and shooting.

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14.18. Provide supplementary food during/after release of translocated mammals

https://www.conservationevidence.com/actions/2470

- **Sixteen studies** evaluated the effects of providing supplementary food during/after release of translocated mammals. Four studies were in the UK[1,2,7,16], two were in each of the USA[3,11], France[4,5], Australia[13,14] and Argentina[12,15], and one was in each of Italy[6], Spain[8], Ireland[9] and South Africa[10].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (15 STUDIES)

- **Abundance (2 studies):** A controlled study in Spain[8] found that providing supplementary food during translocation did not increase European rabbit abundance. A study in France[5] found that following supplementary feeding in a holding pen prior to release, a translocated deer population increased over six years.
- **Reproductive success (4 studies):** Three studies (one replicated) in the USA[3], Italy[6] and Ireland[9] found that having been provided with supplementary food in holding pens prior to release, translocated black-tailed prairie dogs[3], a pair of Eurasian badgers[6] and most female red squirrels[9] reproduced in the wild. A study in the UK[16] found that some translocated pine martens released from holding pens and then provided with supplementary food and nest boxes bred in the first year after release.
- **Survival (10 studies):** Six of 10 studies (including one replicated and one controlled study) in the UK[2,16], France[5], Italy[6], Ireland[9],

South Africa[10], USA[3,11], Argentina[12] and Australia[13] found that at sites with supplementary food in holding pens before (and in two cases after) release, translocated populations of black-tailed prairie dogs[3], approximately half of female roe deer[5] and over half of red squirrels[9], Eurasian badgers[6], pine martens[16] and released rehabilitated or captive reared giant anteaters[12] survived for between one month and at least two years. Four studies found that at translocation release sites with provision of supplementary food, in most cases artificial refuges and in one case water, no red squirrels[2], rock hyraxes[10] or burrowing bettongs[13] survived over 2–5 months and most translocated Tipton and Heermann's kangaroo rat spp.[11] died within five days. A controlled study in France[4] found that translocated European rabbits provided with supplementary food in holding pens for three days prior to release had higher female (but not male) survival rates immediately following release compared to those released directly. A controlled study in the UK[7] found that survival of translocated and rehabilitated European hedgehogs that were provided with supplementary food after release varied with release method.

- **Condition (2 studies):** One of three studies (including one replicated, one controlled and two before-and-after studies) in the UK[1,7] and Australia[14] found that translocated common dormice gained weight after being provided with supplementary food. One found that translocated eastern bettongs[14] did not have increased body weights after provision of supplementary food in fenced enclosures prior to release. The other found that translocated and rehabilitated European hedgehogs provided with food after release all lost body mass, with effects varying with release method.

BEHAVIOUR (2 STUDIES)

- **Use (1 study):** A controlled study in Australia[13] found that supplementary feeding stations were visited by translocated burrowing bettongs.
- **Behaviour change (1 study):** A controlled study in Argentina[15] found that after being provided with supplementary food and

kept in holding pens, released captive-bred giant anteaters were less nocturnal than wild-born rehabilitated and released individuals.

Background

Mammals that are translocated are especially vulnerable immediately after release. At this time, they may struggle to find natural food in an unfamiliar area. Furthermore, if the time they spend looking for food is increased, this may make them more vulnerable to predation. Hence, providing supplementary food at and after the period of release may improve longer term survival prospects.

See also: *Provide supplementary food during/after release of captive-bred mammals.*

A before-and-after study in 1991 in a woodland reserve in Somerset, UK (1) found that translocated common dormice *Muscardinus avellanarius* gained weight after being provided with supplementary food after release. Translocated common dormice lost an average 0.30 g/day before supplementary food was provided but then gained 0.20 g/day after supplementary food provision commenced. The study was conducted along a 9-ha strip of woodland and scrub. Seven dormice were translocated between 30 May and 28 June 1991. Dormice were weighed every 2–3 days up until 10–14 days after release. Six of the seven dormice were provided with supplementary food (sliced apple, sunflower seeds, fruits of trees from the study site) for 5–8 days. Dormice were caught in the morning and placed at the release site in the nest box in which they had been captured, by early afternoon of the same day.

A study in 1993–1994 on a forested peninsula in Dorset, UK (2) found that none of the translocated red squirrels *Sciurus vulgaris* provided with supplementary food and water in holding pens (with nestboxes) and once released survived over five months after release. Out of 14 translocated red squirrels, 11 (79%) survived over one week. Only three (21%) survived >3 months and none survived >4.5 months. At least half of the 14 squirrels were killed by mammalian predators. Intact carcasses examined showed signs of weight loss and stress (see original

paper for details). Between October and November 1993, fourteen wild-born red squirrels were released into an 80-ha forest dominated by Scots pine *Pinus sylvestris*. The forest had no red squirrels but had introduced grey squirrels *Sciurus carolinensis*. Capture and release sites were similar habitats. Supplementary food comprised a mixture of seeds, nuts and fruit on trays and in feed hoppers. Squirrels were kept in 1.5 × 1.5 × 1.5 m weldmesh pens surrounded by electric fencing for 3–6 days before release. Squirrels were kept individually except for 2 males who shared a pen. After release, squirrels continued to have access to food, water and nest boxes inside the pens and outside (20–100 m away). All squirrels were radio-tagged and located 1–3 times/day, for 10–20 days after release and thereafter every 1–2 days.

A replicated study in 1995–1997 in four grassland sites in New Mexico, USA (3) found that translocated populations of black-tailed prairie dogs *Cynomys ludovicianusi* provided with supplementary food and kept in holding pens prior to release persisted at least two years after release and reproduced in the wild. The number of black-tailed prairie dogs approximately doubled during the first spring after release in one site on one ranch where supplementary food was provided. Between the second spring and summer, after supplementary feeding had ceased, the number of animals associated with both release sites on the same ranch doubled. Precise numbers are not reported. One hundred and one prairie dogs were translocated to two ranches (Armendaris Ranch received 71 individuals; Ladder Ranch: 30 individuals) between June 1995 and June 1997. At each ranch, prairie dogs were released into two 0.4-ha holding pens (number of individuals per holding pen is not provided). Holding pens were fenced and surrounded by electric wire. Animals at Armendaris ranch were provided with supplementary food in pens for several months up to a year. Information on population persistence at Ladder Ranch is not provided. The time individuals were kept in the holding pens before subsequent release varied between a few days, weeks and some weren't released from them at all (see original paper for details).

A controlled study in 1997 in a mixed pasture and cultivated fields farmland site in northern France (4) found that translocated European rabbits *Oryctolagus cuniculus* provided with supplementary food in holding pens for three days prior to release had higher female survival rates immediately following release compared to rabbits released

directly, but male survival rates did not differ. During the first day after translocations, the survival rate of female rabbits released from pre-release pens with supplementary food was higher (100%) than that of females released directly into the wild (83%) and male rabbits released from release pens (78%). The survival rate of male rabbits released from pre-release pens with supplementary food (78%) was not significantly different to male rabbits released directly into the wild (92%). One hundred and four rabbits were translocated from Parc-du-Sausset to a 150-ha area of cultivated fields and pasture in Héric, approximately 400 km away in January 1997. Of these, roughly half were acclimatised in eight 100-m^2 enclosures (fence height: 1 m), for three days prior to release. Rabbits were provided supplementary food while in pens. Survival was estimated by night-time relocation of ear-tagged rabbits using a spotlight, daily in the first week after release and twice a week until late February 1997.

A study in 1995–2002 in a mixed oak forest reserve in the south of France (5) found that following supplementary feeding in a holding pen prior to release, approximately half of translocated female roe deer *Capreolus capreolus* survived over one year after release and overall the deer population increased six years after the translocations began. Twenty-six out of 49 (53%) translocated female roe deer survived over one year post-release. Of the animals that died in the first year, 35% of mortality occurred within the first month after release. After six years the deer population had increased to 0.47 deer/km^2 compared to 0.06 deer/km^2 in the first year after translocation began. In February 1995–1997, fifty-two male and 52 female roe deer were translocated from Northern France into a 3,300-ha forest reserve in Southern France in seven release sessions. Animals were placed into enclosures in groups of approximately 15 individuals for 2–10 days and provided with food (pellets and fresh vegetables) prior to release. Forty-nine females (21 <1 year old and 28 >1 year old) were radio-tagged and were located from a vehicle once or twice each week, over one year post-release. In addition, surveys were carried out on foot (6 transects, each 5–7 km long) eight times a year in February-March 1996–2002 to estimate population growth. Deer were present in low numbers prior to translocation.

A study in 2001–2005 in a mixed forest and farmland site in northern Italy (6) found that just over half of translocated Eurasian badgers *Meles meles* provided with supplementary food in holding pens (in groups)

survived at least 1–9 months after release and one pair reproduced. Seven out of 12 badgers survived for 1–9 months, after which monitoring equipment stopped operating. One badger died almost immediately after release due to unknown causes. Two badgers escaped (one after the first month, the other after an unknown period). The fate of three other badgers was unknown. One pair of translocated animals reproduced in the wild four years after release. From March 2001 to May 2004, twelve badgers were captured at four sites in northern Italy. Badgers were fitted with radio-collars and transported 20–40 km to the release site where they were kept in a 350 m^2 enclosure in a wooded area in their release groups (2001: 2 individuals, 2002: 4 individuals, 2003: 2 individuals; 2004: 4 individuals) and provided supplementary food for 3–10 weeks before release. Seven of the 12 badgers were located once/week, for up to nine months after release.

A controlled study in 2004 in 20 suburban gardens in Bristol, UK (7) found that translocated and rehabilitated European hedgehogs *Erinaceus europaeus* that were provided with supplementary food after release all lost body mass and some did not survive, but the effects differed with release type. Directly translocated hedgehogs (<6 days in captivity) had a lower eight-week survival probability (41%) and a larger reduction in body mass over this time (33%) than did resident hedgehogs in release gardens (survival: 95%; body mass reduction: 5%) and hedgehogs kept in captivity prior to release (survival: 82%; body mass reduction: 9%). Over the same period, rehabilitated hedgehogs (survival: 73%; body mass reduction: 13%) and resident hedgehogs 3 km away (survival: 64%; body mass reduction: 10%) had statistically similar survival and body mass loss as directly translocated hedgehogs. Only one translocated hedgehog survived seven weeks after release. Between May and June 2004, hedgehogs were translocated to gardens in Bristol: after rehabilitation in a wildlife hospital (20 individuals, >1 month in captivity) in Scotland, directly from Scotland (20 individuals, <6 days in captivity); and from Scotland with >1 month in captivity (23 individuals). In addition, 23 free-living resident hedgehogs were captured and re-released <50 m from release gardens, and 26 free-living resident hedgehogs were captured and released >3 km from release gardens. Food was provided during the first week after release. Hedgehogs were radio-tracked over eight weeks. Hedgehogs were weighed every 10 days.

A controlled study in 1999–2002 in a shrubland site in Huelva, Spain (8) found that providing supplementary food during translocation of European rabbits *Oryctolagus cuniculus* did not increase their abundance relative to unfed translocated rabbits. Over three years, the average rabbit abundance in translocation plots where food was provided (8.9 pellets/m^2) was not significantly different than in plots where translocated rabbits were not fed (5.0 pellets/m^2). The study was conducted in four 4-ha plots (1–6 km apart). Each year, in autumn, herbaceous crops (barley *Hordeum vulgare* and oats *Avena sativa*) were sown in two plots to provide supplementary feeding. Batches of 64–67 rabbits were translocated into each of two plots (one with and one without supplementary food) each winter from 1999–2000 to 2001–2002. Translocation plots were switched after the first year, such that translocations in the second and third year were into plots where no translocations were made in the first year. Between September 1999 and November 2002, rabbit abundance was estimated every two months by counting the number of pellets in 33 fixed-position 0.5-m diameter sampling points/plot. Wild rabbits were present in all plots prior to translocations beginning.

A study in 2005–2007 in a mixed conifer forest in Galway, Ireland (9) found that over half of translocated red squirrels *Sciurus vulgaris* provided with supplementary food in holding pens (with nest boxes) and after release survived over eight months after release and most females reproduced during that period. At least 10 out of 19 (53%) translocated squirrels survived over eight months post-release and five out of nine translocated females (56%) were lactating 5–7 months after release. In August 2006, seven juvenile squirrels were caught. At least one squirrel was still alive in the release location two years after the original release. Two squirrels died while in the release pen or shortly afterwards. Another four squirrels died 1–2 months after release. Ten of 13 squirrels established home ranges which contained supplementary feeding stations. Nineteen squirrels were translocated to a nature reserve (19 ha) in the middle of a 789-ha commercial pine plantation, 112 km from the capture site. Individuals were marked, radio-tagged and kept on average for 46 days in one of two pre-release enclosures (3.6 × 3.6 × 3.9 m high). Enclosures contained branches, platforms, nest boxes, and supplementary feeders (containing nuts, maize, seeds and fruit). Supplementary food (50/50 peanut/maize mix) was provided in

six feeders in the nature reserve until July 2006. Twenty nest boxes were also provided Squirrels were radio-tracked in September and November 2005 and February and May 2006, and were trapped in February, May and August 2006 and observed once in October 2007.

A study in 2005–2006 at rocky outcrops on a reserve in KwaZulu-Natal Province, South Africa (10) found that translocated rock hyraxes *Procavia capensis* that were provided with food and an artificial refuge after release in a social group, having been held in captivity, all died (or were presumed to have died) within 87 days of release. Eighty-seven days after the release of 17 hyraxes, none could be relocated. In July 2005, ten adult hyraxes were caught in baited mammal traps (900 × 310 × 320 mm) in an area where they were abundant, and held in captivity for 16 months, during which time three died. The remaining seven were released in November 2006, along with the eight juveniles and two pups born to them in captivity, to a 656-ha reserve where the species was nearly extinct. For four months prior to release, the group was housed together in an outdoor cage (5.9 × 2.5 × 3.2 m). Hyraxes were released into a hay-filled hutch which was left in place for several months, and were provided with cabbage for one week after release. Hyraxes were monitored by direct observations and by walking regular transects, daily for the first week but decreasing to monthly by the end of the study.

A study in 2001 in a grassland and shrubland site in California, USA (11) found that most translocated Tipton kangaroo rats *Dipodomys nitratoides nitratoides* and Heermann's kangaroo rats *Dipodomys heermanni* ssp. provided with supplementary food within artificial burrows after release died within five days of release. All four Tipton kangaroo rats were predated within five days of translocation, and only one out of seven Heermann's kangaroo rats survived over 45 days. Three Heermann's kangaroo rats were predated, two died as a result of aggression from other Heermann's kangaroo rats, and the fate of one was unknown. In September 2001, four juvenile Tipton kangaroo rats and three Heermann's kangaroo rats were captured and held in captivity for two months before release at a protected site in November. In December 2001, a further four Heermann's kangaroo rats were caught and translocated to the same site. All 11 animals were fitted with a radio-transmitter and ear tags, and monitored for seven days in captivity

prior to release. The release site was already occupied by Heermann's kangaroo rats. Animals were released into individual artificial burrows (two 90-cm-long cardboard tubes with a chamber about 30 cm below the surface), dug 10–15 m apart and provided with seeds. Burrows were plugged with paper towels until dusk. Animals were radio-tracked every 1–8 days for 18–45 days after release.

A study in 2007–2014 in a grassland reserve in Corrientes Province, Argentina (12; same study site as 15) found that over half of released rehabilitated or captive reared giant anteaters *Myrmecophaga tridactyla*, some of which were provided supplementary food and initially kept in holding pens, survived for at least six months. At least 18 of 31 (58%) released giant anteaters survived for a minimum of six months. Long term survival and the fate of the other 13 anteaters is not reported. In 2007–2013, thirty-one giant anteaters (18 males, 13 females; 1–8 years old) were released into a 124-km^2 private reserve. Hunting within the reserve was prohibited and livestock were absent. Three anteaters were wild-born but rehabilitated in captivity from injuries, 22 were wild-born but captive-reared and six were from zoos (origin not stated). Of the 18 surviving anteaters, six had been released after a short period in a 0.5-ha pen at the release site and 12 after 7–30 days in a 7-ha pen. Supplementary food was provided for several weeks after release. In 2007–2014, thirteen anteaters were tracked for less than six months, and 18 were tracked for 6–46 months.

A controlled study in 2013 at a desert site in South Australia, Australia (13) found that supplementary feeding stations were visited by translocated burrowing bettongs *Bettongia lesueur*, but populations did not persist. At a large release area, bettongs were detected at 52–80% of track pads at feeders compared to 0–8% of track pads sited 200 m from feeders. No bettongs were detected >42 days after the final release. At three smaller release areas, bettongs persisted for 10 and 53 days at sites where supplementary food was provided and for two days at a site where it was not provided. Bettongs were translocated and released into rabbit warrens in July–December 2013. In one area 1,266 bettongs were released. Five smaller releases, of 29–56 bettongs, were made at three further sites, 4 km apart. Oats were provided at five stations in the large release area and three stations each at two smaller release areas. From May–December 2003 feral cats *Felis catus* and foxes *Vulpes vulpes* were

intensively controlled in a 500-km^2 area by 428 hours of shooting patrols. Bettong visitation at feeders was assessed using 10 track pads/feeder for three one-day periods, four days apart. Persistence was monitored using track counts, camera trapping, warren monitoring and live-trapping.

A replicated, before-and-after study in 2011–2013 in two forest and grassland sites in the Australian Capital Territory, Australia (14) found that translocated eastern bettongs *Bettongia gaimardi* provided with supplementary food in fenced predator proof enclosures did not have greater body weights than those without enclosures and supplementary food. Between twelve and 24 months post-release, the average body weight of translocated eastern bettongs (1.83 kg) did not differ significantly between populations with and without supplementary feeding (weight values for each individual population not provided). Overall, the average body weight of bettongs increased compared to before they were released (pre-release average weight: 1.69 kg). In 2011−2012, sixty adult eastern bettongs were translocated from Tasmania to two predator-free fenced reserves. In one reserve bettongs (5 males, 7 females) received supplementary food at least weekly and were placed in 2.6–9.4 ha enclosures, whereas in a second reserve bettongs (8 males, 10 females) received no supplementary food and were not managed in enclosures. Supplementary food included fresh locally available produce and commercial pellets. Body weight was assessed before reintroduction and 12–24 months after release (May–November 2013). Bettongs were also monitored by radio-telemetry or camera traps and live-trapping every 3 months.

A controlled study in 2007–2012 in a grassland reserve in Corrientes, Argentina (15; same study site as 12) found that after being provided with supplementary food and kept in holding pens, captive-bred giant anteaters *Myrmecophaga tridactyla* released into the wild were less nocturnal in their activity patterns than were wild-born rehabilitated and released individuals. Released captive-bred giant anteaters were proportionally less active at night than released wild-born animals (43% vs 70% of activity records were at night). During 2007–2012, three captive-bred and four wild-born adult giant anteaters were released into a 124-km^2 private reserve. Wild-born animals were rehabilitated after being injured by hunters or in road accidents. Six anteaters (all wild-born and two captive-bred anteaters) were released after spending a

short period of time in a 0.5 ha acclimatisation pen. The remaining 12 anteaters spent 7–30 days in a 7 ha holding pen at the release site prior to release. Supplementary food was provided in the holding pen, and for several weeks after anteaters were released. Each of the seven anteaters was fitted with a radio-transmitter and tracked for one or two 24 h periods/month in 2007 and 2011. The released anteaters were further monitored using 14 baited camera traps for an average of 336 days/trap in 2008–2012.

A study in 2015–2016 in a wooded mountain region in central Wales, UK (16) found that some translocated pine martens *Martes martes* held in pre-release pens and then provided with supplementary food and nest boxes survived and bred in the first year after release. At least four out of 10 females that had been kept in pre-release pens survived and bred the year after release. Around 10–12 months after release, 14 out of 20 martens were alive and in good condition. Twelve were within 10 km of their release site. Six martens died in the first year, two had a fungal infection two weeks after release. Authors suggest this may have been due to damp conditions in November. From September–November 2015, twenty breeding age (>3-years-old) pine martens were caught in Scotland, health checked, microchipped and fitted with a radio-collar, and in some cases a GPS logger. Martens were transported overnight to Wales, and held in individual pre-release pens (3.6 × 2.3 × 2 m) for up to seven nights. Males' pens were within 500 m of a female, but >2 km from the nearest male. Releases took place in autumn, and supplementary food was provided for 2–6 weeks after release (for as long as it continued to be taken). Den boxes were provided within 50 m of each release pen. Martens were radio-tracked until home-ranges were established, then located daily–weekly. Intensive tracking of females was carried out in March to locate breeding sites. Hair tubes and camera traps were used to monitor breeding success. A further 19 martens were released using the same procedure in September–October 2016.

(1) Bright P.W. & Morris P.A. (1994) Animal translocation for conservation: performance of dormice in relation to release methods, origin and season. *Journal of Applied Ecology*, 31, 699–708.

(2) Kenward R.E. & Hodder K.H. (1998) Red squirrels (*Sciurus vulgaris*) released in conifer woodland: the effects of source habitat, predation and interactions with grey squirrels (*Sciurus carolinensis*). *Journal of Zoology*, 244, 23–32.

(3) Truett J.C. & Savage T. (1998) Reintroducing prairie dogs into desert grasslands. *Restoration and Management Notes*, 16, 189–195.

(4) Letty J., Marchandeau S., Clobert J. & Aubineau J. (2000) Improving translocation success: an experimental study of anti-stress treatment and release method for wild rabbits. *Animal Conservation*, 3, 211–219, https://doi.org/10.1111/j.1469-1795.2000.tb00105.x

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(6) Balestrieri A., Remonti L. & Prigioni C. (2006) Reintroduction of the Eurasian badger (*Meles meles*) in a protected area of northern Italy. *Italian Journal of Zoology*, 73, 227–235, https://doi.org/10.1080/11250000600679603

(7) Molony S.E., Dowding C.V., Baker P.J., Cuthill I.C. & Harris S. (2006) The effect of translocation and temporary captivity on wildlife rehabilitation success: an experimental study using European hedgehogs (*Erinaceus europaeus*). *Biological Conservation*, 130, 530–537, https://doi.org/10.1016/j.biocon.2006.01.015

(8) Cabezas S. & Moreno S. (2007) An experimental study of translocation success and habitat improvement in wild rabbits. *Animal Conservation*, 10, 340–348, https://doi.org/10.1111/j.1469-1795.2007.00119.x

(9) Poole A. & Lawton C. (2009) The translocation and post release settlement of red squirrels *Sciurus vulgaris* to a previously uninhabited woodland. *Biodiversity and Conservation*, 18, 3205–3218, https://doi.org/10.1007/s10531-009-9637-z

(10) Wimberger K., Downs C.T., Perrin M.R. (2009) Two unsuccessful reintroduction attempts of rock hyraxes (*Procavia capensis*) into a reserve in the KwaZulu-Natal Province, South Africa. *South African Journal of Wildlife Research*, 39, 192–201, https://doi.org/10.3957/056.039.0213

(11) Germano D.J. (2010) Survivorship of translocated kangaroo rats in the San Joaquin Valley, California. *California Fish and Game*, 96, 82–89.

(12) Di Blanco Y.E., Jiménez Pérez I. & Di Bitetti M.S. (2015) Habitat selection in reintroduced giant anteaters: the critical role of conservation areas. *Journal of Mammalogy*, 96, 1024–1035, https://doi.org/10.1093/jmammal/gyv107

(13) Bannister H.L., Lynch C.E. & Moseby K.E. (2016) Predator swamping and supplementary feeding do not improve reintroduction success for a threatened Australian mammal, *Bettongia lesueur*. *Australian Mammalogy*, 38, 177–187, https://doi.org/10.1071/am15020

(14) Portas T.J., Cunningham R.B., Spratt D., Devlin J., Holz P., Batson W., Owens J. & Manning A.D. (2016) Beyond morbidity and mortality in reintroduction programmes: changing health parameters in reintroduced eastern

bettongs *Bettongia gaimardi*. *Oryx*, 50, 674–683, https://doi.org/10.1017/s0030605315001283

(15) Di Blanco Y.E., Spørring K.L. & Di Bitetti M.S. (2017) Daily activity pattern of reintroduced giant anteaters (*Myrmecophaga tridactyla*): effects of seasonality and experience. *Mammalia*, 81, 11–21, https://doi.org/10.1515/mammalia-2015-0088

(16) MacPherson J.L. (2017) *Pine marten translocations: the road to recovery and beyond.* Bulletin of the Chartered Institute of Ecology and Environmental Management: Rewilding and species reintroductions, 95, 32–36.

Captive-breeding

14.19. Breed mammals in captivity

https://www.conservationevidence.com/actions/2471

- **Three studies** evaluated the effects of breeding mammals in captivity. One study was across Europe[1], one was in the USA[2] and one was global[3].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (3 STUDIES)

- **Abundance (1 study):** A review of captive-breeding programmes across the world[3] found that the majority of 118 captive-bred mammal populations increased.
- **Reproductive success (2 studies):** A review of a captive breeding programme across Europe[1] found that the number of European otters born in captivity tended to increase over 15 years. A study in the USA[2] found that wild-caught Allegheny woodrats bred in captivity.
- **Survival (1 study):** A review of a captive breeding programme across Europe[1] found that the number of European otters born in captivity that survived tended to increase over 15 years.

BEHAVIOUR (0 STUDIES)

Background

Captive breeding involves taking wild animals into captivity and establishing and maintaining breeding populations. It tends to be undertaken when wild populations become very small or fragmented or when they are declining rapidly. Captive populations can be maintained while threats in the wild are reduced or removed and can provide an insurance policy against catastrophe in the wild. Captive breeding also potentially provides a method of increasing reproductive output beyond what would be possible in the wild. However, captive breeding can result in problems associated with inbreeding depression, removal of natural selection and adaptation to captive conditions.

The aim is usually to release captive-bred animals back to natural habitats, either to original sites once conditions are suitable, to reintroduce species to sites that were occupied in the past or to introduce species to new sites. Some captive populations may also be used for research to benefit wild populations.

Studies that investigate the effectiveness of releasing captive-bred mammals are discussed elsewhere. Those studies are not included in this section, unless specific details about captive breeding were included.

A review of a captive breeding programme in 1978–1992 across Europe (1) reported that the number of institutions successfully breeding European otters *Lutra lutra*, the number of otters born in captivity and that survived tended to increase over 15 years. These results were not tested for statistical significance. The number of institutions keeping otters remained fairly stable (23–32) from 1978 to 1989, whilst the number of captive animals born and surviving tended to increase from 1978–1983 (born: 0–20; survived: 0–18) to 1984–1989 (born: 18–46; survived: 12–38). Authors reported that until 1990, breeding was only successful in about 10 collections, but that in 1991–1992, when the number of institutions participating in the programme increased to 55, the number that successfully bred otters almost doubled. In 1992

the total captive population was 196 individuals, of which 67% was captive born, and 43 out of 50 cubs survived. In 1990, 36 otter keeping institutions (60% of those co-operating with the studbook) and in 1992 fifty five (91% included in the studbook) took part in the European breeding program for self-sustaining captive populations of otters. These institutions provided information about their captive breeding populations from 1978–1992.

A study in 2009–2011 in a captive facility in Indiana, USA (2) found that wild-caught Allegheny woodrats *Neotoma magister* bred in captivity. Over 26 months, 33 pairings resulted in copulation which produced 19 litters (58% pregnancy rate). Those litters comprised of 43 pups (26 male, 17 female), of which 40 (24 male, 16 female) survived to weaning at 45 days. Overall, eight of 12 wild-caught females produced offspring (1–5 litters) and four of six wild-caught males sired litters (1–8 litters). In 2009 a captive breeding program was established using eight wild-caught individuals collected from the seven populations in Indiana and four caught from populations in Pennsylvania. The breeding population was maintained at 12–13 animals with a female bias (8:4). Seven new wild animals replaced five in 2010–2011. Individuals were housed in wire mesh enclosures (91 x 61 x 46 cm or 76 x 46 x 91 cm) with access to the opposite sex and an external nest box (23 x 23 x 23 or 36 cm). Enclosures were at 20°C with 13 hours of light/24 hrs. Captive-reared juveniles were released into wild populations in April-July each year.

A review of captive-breeding programmes in 1970–2011 across the world (3) found that the majority of 118 captive-bred mammal populations increased in size. The average annual rate of population increase was 0.028, and only 17 populations (14%) declined (five 'endangered' or 'critically endangered' according to the IUCN Redlist). Authors reported that positive growth rates were maintained for a large majority of the populations in all IUCN categories except those of 'least concern'. However, average growth rates declined from 1970–1991 (0.054) to 1992–2011 (0.021). Authors reported that there was a slight decrease in average death rate of populations over time and either no change in average birth rate, or lower birth rates after 1989. Population growth rates did not vary with body mass, but were reported to decrease as the ratio of individuals in programs to populations increased (see original paper for details). Counts of births, deaths and end-of-year

totals of individuals in captive populations recorded in studbooks (excluding regional studbooks) were published in the International Zoo Yearbook. Those published from 1970 to 2011 were used to calculate rates of population growth for 118 captive-bred populations (81 species and 37 subspecies). Only populations for which the sum of end-of-year totals was at least 250 over the time period were included.

(1) Vogt, P. (1995) The European Breeding Program (EEP) for *Lutra lutra*: its chances and problems. *Hystrix — Italian Journal of Mammalogy*, 7, 247–253.

(2) Smyser, T.J. & Swihart, R.K. (2014) Allegheny woodrat (Neotoma magister) captive propagation to promote recovery of declining populations. *Zoo Biology*, 33, 29–35, https://doi.org/10.1002/zoo.21114

(3) Alroy, J. (2015) Limits to captive breeding of mammals in zoos. *Conservation Biology*, 29, 926–931, https://doi.org/10.1111/cobi.12471

14.20. Place captive young with captive foster parents

https://www.conservationevidence.com/actions/2472

- **Two studies** evaluated the effects of placing captive young mammals with captive foster parents. One study was in the USA[1] and one was in Sweden and Norway[2].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (2 STUDIES)

- **Survival (2 studies):** A replicated, controlled study in the USA[1] found that most captive coyote pups placed with foster parents were successfully reared. A replicated study in Sweden and Norway[2] found that captive grey wolf pups placed with foster parents had higher survival rates than pups that stayed with their biological mother.
- **Condition (1 study):** A replicated study in Sweden and Norway[2] found that captive grey wolf pups placed with foster parents weighed less than pups that stayed with their biological mother.

BEHAVIOUR (0 STUDIES)

Background

Success of captive breeding programmes for endangered mammal species may be reduced if the biological parents are unable to rear any or all of their young. This may occur when there are more young than parents can rear, or through disease, injury or death of the parents. One option may be to place the young with captive foster parents of the same species, where such animals are available. This may reduce the risk of the young becoming imprinted on humans (which could occur if they were hand reared) and so could increase their chance of survival after release into the wild.

Studies reported on here are examples of where this action is carried out in an experimental way, but where the results could help inform actions in future programmes.

See also *Hand-rear orphaned or abandoned young in captivity*, *Place orphaned or abandoned wild young with captive foster parents* and *Place orphaned or abandoned wild young with wild foster parents*.

A replicated, controlled study (year not stated) in a captive animal facility in Utah, USA (1) found that most coyote *Canis latrans* pups placed with foster parents in captivity were successfully reared. All eight pups fostered into four litters at <1 week old survived beyond six weeks of age. Of six 3–4-week-old pups fostered into three litters, four pups in two litters survived beyond six weeks old. The two pups in the third litter died. Two attempts each to foster two 6–7-week-old pups failed, with pups dying within 24 hours. All pups born into these litters survived. The survival rate of litters fostered in their entirety when <10 days old (17 out of 19 pups surviving from four litters) was similar to that in litters not fostered (18 out of 20 pups surviving from four litters). Causes of death were not established for pups that died. Litters of eight coyote pairs were augmented by adding two additional pups, four litters were replaced completely and four litters were reared by their parents without additions. Survival was monitored to six weeks of age.

A replicated study in 2011 in six zoos in Sweden and Norway (2) found that grey wolf *Canis lupus lupus* pups placed with foster parents

in captivity had higher survival rates but weighed less than pups that stayed with their biological mother. After 32 weeks, more fostered cubs survived (75%) than cubs that remained with their biological mother (65%). At 24–26 days age, fostered cubs weighed less (1,337 g) than cubs that remained with their biological mother (2,019 g). In 2011, eight pups born at zoos were removed from their biological mothers at 4–6 days of age. Pups were microchipped, to allow identification, given fluids to reduce dehydration, and transported by car or plane to new zoos. Foster pups were placed in litters containing 7–10 pups. On arrival, the tails of foster pups were rubbed in the urine of other pups so that they smelled similar. A total of 35 pups stayed with their biological mother. Cameras were placed at the den of each litter. Pups were weighed at irregular intervals and all deaths recorded.

(1) Kitchen A.M. & Knowlton F.F. (2006) Cross-fostering in coyotes: evaluation of a potential conservation and research tool for canids. *Biological Conservation*, 129, 221–255, https://doi.org/10.1016/j.biocon.2005.10.036

(2) Scharis I. & Amundin M. (2015) Cross-fostering in gray wolves (*Canis lupus lupus*). *Zoo Biology*, 34, 217–222, https://doi.org/10.1002/zoo.21208

14.21. Use artificial insemination

https://www.conservationevidence.com/actions/2473

- **Three studies** evaluated the effects on mammals of using artificial insemination. One study was in the USA[1], one was in Brazil[2] and one was in China[3].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (3 STUDIES)

- **Reproductive success (3 studies):** A study in the USA[1] found that following artificial insemination, fewer than half of female black-footed ferrets gave birth. A study in Brazil[2] found that following artificial insemination, a captive female Amazonian brown brocket deer gave birth. A replicated study in China[3] found that following artificial insemination, a lower proportion of captive female giant pandas became pregnant than after natural mating.

BEHAVIOUR (0 STUDIES)

Background

During programmes to rear endangered animals in captivity, in preparation for reintroductions into the wild, artificial insemination may be used to initiate pregnancies. The technique may be used instead of natural mating in situations such as animals being kept at different facilities or where natural mating has failed. It may also be carried out using preserved sperm for purposes of maintaining genetic diversity.

Studies included here are those identified by our searches of conservation journals. It is likely that other relevant studies exist in biological journals that specialise in reproduction.

A study in 2008–2011 in two ex-situ facilities in Wyoming and Virginia, USA (1) found that following artificial insemination, fewer than half of female black- footed ferrets *Mustela nigripes* gave birth. Five out of 18 (28%) artificially inseminated female black-footed ferrets gave birth. Eight kits were born. Six of those kits subsequently went on to breed by natural mating. Kinship (a measure of relatedness within a population) was lower among these kits and their descendants than among the population as a whole. The study was conducted at the National Black-Footed Ferret Conservation Center and at the Smithsonian Conservation Biology Institute. Ferrets were managed in individual cages (1.0–3.6 × 1.3–6.0 m). Semen was collected from adult ferrets (1–6 years old) by electroejaculation and cryopreserved for 10–20 years. Females were inseminated by transabdominal injections of sperm.

A study in 2012–2013 in an ex-situ facility in São Paulo, Brazil (2) found that following artificial inseminated, a captive female Amazonian brown brocket deer *Mazama nemorivaga* gave birth. Seven months after being artificially inseminated, a female Amazonian brown brocket deer gave birth without veterinary intervention to a healthy male fawn. A captive adult pair of Amazonian brown brocket deer was kept in isolated pens in a deer research facility. Animals were exposed to natural light conditions and given similar diets. Every morning for one month, a trained examiner manually observed the female for signs

of natural oestrus. Eight hours after oestrus was detected, the female was physically restrained, anesthetized and inseminated. Sperm was collected by electroejaculation. Tools and techniques used for artificial insemination were based on those from procedures carried out on sheep and other small ruminants.

A replicated study in 1996–2016 in Sichuan Province, China (3) found that following artificial insemination, a lower proportion of 78 captive female giant pandas *Ailuropoda melanoleucahela* became pregnant than after natural mating. Following artificial insemination, a lower percentage of female pandas became pregnant (19%) than following natural mating (61%). However, there was no significant difference in the litter size of females inseminated artificially or through natural mating (data reported as model results). Between 1996 and 2016, seventy-eight female pandas held in open-air enclosures at two facilities were subject to 65 attempts at artificial insemination and 150 attempts at natural mating. Natural mating was always attempted first but, in cases of excessive aggression between males and females, artificial insemination was used instead.

(1) Howard J.G., Lynch C., Santymire R.M., Marinari P.E. & Wildt D.E. (2016) Recovery of gene diversity using long-term cryopreserved spermatozoa and artificial insemination in the endangered black-footed ferret. *Animal Conservation*, 19, 102–111, https://doi.org/10.1111/acv.12229

(2) Oliveira M.E.F., dos Santos Zanetti E., Cursino M.S., Peroni E.F.C., Rola L.D., Feliciano M.A.R., Canola J.C. & Duarte J.M.B. (2016) First live offspring of Amazonian brown brocket deer (*Mazama nemorivaga*) born by artificial insemination. *European Journal of Wildlife Research*, 62, 767–770, https://doi.org/10.1007/s10344-016-1040-y

(3) Li D., Wintle N.J., Zhang G., Wang C., Luo B., Martin-Wintle M.S., Owen M. & Swaisgood R.R. (2017) Analyzing the past to understand the future: natural mating yields better reproductive rates than artificial insemination in the giant panda. *Biological Conservation*, 216, 10–17, https://doi.org/10.1016/j.biocon.2017.09.025

14.22. Clone rare species

https://www.conservationevidence.com/actions/2474

- **One study** evaluated the effects of cloning rare species. This study was in Iran[1].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (1 STUDY)

- **Reproductive success (1 study):** A controlled study in Iran[1] found that immature eggs of domestic sheep have potential to be used for cloning of Esfahan mouflon.

BEHAVIOUR (0 STUDIES)

Background

Cloning technology is advancing rapidly. For rare mammals, cloning provides the potential to increase reproductive output from a small number of individuals by using surrogate parents of closely related but non-threatened species.

Note that many relevant studies may be documented in journals that are not primarily conservation-related and which are, therefore, not included in our systematic searches for evidence.

A controlled study (date not stated) in Iran (1) found that immature eggs (oocytes) of domestic sheep have potential to be used for interspecies conservation cloning of Esfahan mouflon *Ovis orientalis isphahanica*. The success rate for transferring cell nuclei attached to Esfahan mouflon cells to domestic sheep oocytes (14.4%) did not significantly differ from that for transfer of nuclei attached to domestic sheep cells (22.1%). Subsequently, of 12 cloned mouflon blastocysts (early-stage cell mass which goes on to form an embryo) transferred to five domestic sheep recipients, two pregnancies resulted. In both cases live births of cloned Esfahan mouflon lambs resulted, but the lambs died soon after birth. Of 1,410 oocytes that had had their nucleus removed, 1,105 and 305 were attached to Esfahan mouflon and domestic sheep cells, respectively. Prior to transferring nuclei, donor cells were serum starved for 5 days. In vitro matured domestic sheep oocytes that had had their nucleus removed were then reconstituted with nuclei donor cells of mouflon and domestic sheep.

(1) Hajian M., Hosseini S.M., Forouzanfar M., Abedi P., Ostadhosseini S., Hosseini L., Moulavi F., Gourabi H., Shahverdi A.H., Vosough Taghi Dizaj A., Kalantari S.A., Fotouhi Z., Iranpour R., Mahyar H., Amiri-Yekta A. & Nasr-Esfahani M.H. (2011) 'Conservation cloning' of vulnerable Esfahan mouflon (*Ovis orientalis isphahanica*): in vitro and in vivo studies. *European Journal of Wildlife Research*, 57, 959–969, https://doi.org/10.1007/s10344-011-0510-5

14.23. Preserve genetic material for use in future captive breeding programs

https://www.conservationevidence.com/actions/2475

- **Two studies** evaluated the effects of preserving genetic material for use in future captive breeding programs. One study was in Mexico[1] and one was in the USA[2].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (2 STUDIES)

- **Survival (2 studies):** A study in Mexico[1] found that a series of non-traditional techniques, combined with natural mating, produced five aoudad embryos that could be cryogenically preserved. A study in USA[2], found that artificial insemination using preserved genetic material increased genetic diversity and lowered inbreeding in a captive black-footed ferret population.

BEHAVIOUR (0 STUDIES)

Background

Assisted reproductive technology is advancing rapidly. For rare mammals, preservation of genetic material provides potential to increase reproductive output from a small number of individuals and to retain embryos or other material for future development.

Note that many relevant studies may be documented in journals that are not primarily conservation-related and which are, therefore, not included in our systematic searches for evidence.

A study (date not stated) in a zoo in Mexico (1) found that using a series of non-traditional techniques, combined with natural mating, five embryos were produced from aoudad *Ammotragus lervia* that could be cryogenically preserved. The five embryos were obtained from just one of the three female aoudad, with the low embryo recovery rate being due to a low level of fertilization in vivo. The oestrus and superovulation of three female aoudad were synchronized. Procedures followed those used for domestic sheep combined with subcutaneous osmotic pumps for delivering the follicle-stimulating hormone. An aoudad ram was introduced for natural mating at the anticipated time of oestrous. Embryos were collected five and a half days later by incision through the abdominal wall. Embryos were cryopreserved, for use in conservation breeding programs (potentially by transferring to surrogates, such as domestic hybrids between aoudad and sheep or goats).

A controlled study in 1989–1998 and 2008–2011 in two captive facilities in Wyoming and Virginia, USA (2) found that artificial insemination using preserved genetic material increased genetic diversity and lowered measures of inbreeding in a captive population of black-footed ferrets *Mustela nigripes*. Genetic diversity of the captive population was greater when eight black-footed ferret kits (and their offspring) born as a result of artificial insemination with preserved semen were incorporated (86.5–86.8%) than when the population reproduced naturally (86.3–86.6%). Inbreeding also decreased by 6% (data reported as inbreeding coefficients). In 1989–1998, semen were collected from 16 male ferrets (1–6 years old) by electroejaculation and cryopreserved in liquid nitrogen for 10–20 years. In 2008–2011, a total of 18 female ferrets were inseminated with the thawed samples. Their eight offspring went on to produce 32 offspring and grand-offspring by natural mating. Selection of female recipients was based on the analysis of the pedigree of the captive population.

(1) López–Saucedo J., Ramón-Ugalde J.P., Barroso-Padilla J.J., Gutiérrez-Gutiérrez A.M., Fierro R. & Piña-Aguilar R.E. (2013) Superovulation, in vivo embryo recovery and cryopreservation for Aoudad (*Ammotragus lervia*) females using osmotic pumps and vitrification: a preliminary experience and its implications for conservation. *Tropical Conservation Science*, 6, 149–157, https://doi.org/10.1177/194008291300600105

(2) Howard J.G., Lynch C., Santymire R.M., Marinari P.E. & Wildt D.E. (2016) Recovery of gene diversity using long-term cryopreserved spermatozoa and artificial insemination in the endangered black-footed ferret. *Animal Conservation*, 19, 102–111, https://doi.org/10.1111/acv.12229

Release captive-bred mammals

14.24. Release captive-bred individuals to re-establish or boost populations in native range

https://www.conservationevidence.com/actions/2476

- **Thirty-one studies** evaluated the effects of releasing captive-bred mammals to establish or boost populations in their native range. Seven studies were in the USA[2,7,8,13,24,27,29], three were in Australia[11,23,28] and Italy[5,20,30], two studies were in each of Canada[1,17], Sweden[3,6], Saudi Arabia[4,25], the UK[9,10], the Netherlands[12,21] and South Africa[14,18] and one study was in each of France[15], Africa, Europe, and North America[16], Estonia[19], the USA and Mexico[22], Poland[26] and China[31].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (30 STUDIES)

- **Abundance (7 studies):** Five of five studies (one replicated) and two reviews in Saudi Arabia[4], Australia[11], the USA[13], South Africa[14], France[15], the Netherlands[21] and China[31] found that following release of captive-bred (or in one case captive-reared, or including translocated) animals, populations of mountain gazelles[4], Corsican red deer[15], Père David's deer[31], Eurasian otters[21] and swift foxes[13] increased. The two reviews found that following release of mainly translocated but some captive-bred large carnivores[14], populations of four of six species increased, and over half of mammal release programmes[11] were considered successful.
- **Reproductive success (5 studies):** Four studies (one replicated) in Saudi Arabia[4,25], the UK[9] and the Netherlands[12] found that released captive-bred (and in some cases some wild-born translocated) mountain gazelles[4], dormice[9] and

some Eurasian otters[12] reproduced successfully and female Arabian oryx[25] reproduced successfully regardless of prior breeding experience. A controlled study in Italy[30] found that released captive-born Apennine chamois[30] reproduced in similar numbers to wild-caught translocated chamois.

- **Survival (24 studies):** Four of three controlled studies (two replicated) and two reviews in Canada[1], Canada and the USA[8], Sweden[3], Italy[30] and across the world[16] found that released captive-bred swift foxes[1,8], European otters[3] and mammals from a review of 49 studies[16] had lower post-release survival rates than did wild-born translocated animals. The other study found that released captive-born Apennine chamois[30] survived in similar numbers to wild-caught translocated chamois. Three studies (one replicated) in the USA[27,29] and Canada[17] found that released captive-born Key Largo woodrats[27], Vancouver Island marmots[17] and swift fox pups[29] had lower survival rates than wild-born, wild-living animals. One of the studies also found that Vancouver Island marmots[17] released at two years old were more likely to survive than those released as yearlings. Eleven studies (three replicated) in Italy[5,20], Sweden[6], the UK[9,10], Estonia[19], Poland[26], Saudi Arabia[4,25], Australia[23] and the USA[24] found that following the release of captive-bred (and in some cases some wild-born translocated) animals, Arabian oryx[25], populations of European otters[6,10,20], European mink[19] and mountain gazelle[4] survived for 2–11 years, roe deer[5] and over a third of brush-tailed rock-wallabies[23], black-footed ferrets[24] and brown hares[26] survived for 0.5–24 months and dormice[9] populations survived three months to over seven years. A review in Australia[11] found that release programmes for macropod species resulted in successful establishment of populations in 61% of cases and that 40% survived over five years, and another review in Australia[28] found that over half of programmes were considered successful. Two studies and a review in the USA[7], USA and Mexico[22] and South Africa[18] found that over 40% of released captive-bred American black bears[7] were killed or had to be removed, only one of 10 oribi[18] survived over two years and that most black-footed ferret[22] releases were unsuccessful at maintaining a population.

BEHAVIOUR (3 STUDIES)

- **Use (3 studies):** Two studies in the USA[2] and Australia[23] found that following release, most captive-bred and translocated mountain lions[2] that had been held in captivity prior to release and most released captive-bred brush-tailed rock-wallabies[23] established stable home ranges. A controlled study in Italy[30] found that released captive-born Apennine chamois remained closer to the release site than released wild-caught translocated chamois.

Background

Captive breeding is normally used to provide individuals which can then be released into the wild (often called 'reintroduction') to either re-establish a population that has been lost, or to augment an existing population ('restocking').

Release techniques vary considerably, from 'hard releases' involving the simple release of individuals into the wild to 'soft releases' which involve a variety of adaptation and acclimatisation techniques before release or post-release feeding and care. This action includes studies describing the effects of release programmes for captive-bred or captive-reared mammals that do not provide details of specific release techniques. Studies that describe or compare specific release techniques, such as use of holding pens at release sites, or providing supplementary food, water or artificial refuges/breeding sites are described under each specific action.

This action includes studies where animals were released in groups but not studies where releases of different group sizes were compared, or where animals were released in family or social groups (including groups where social animals have been pre-conditioned together prior to release in holding pens). For those studies, *see Release translocated/captive-bred mammals in larger unrelated groups* and *Release translocated/captive-bred mammals in family/social groups.*

A replicated, controlled study in 1990–1992 at two grassland sites in Alberta, Canada (1) found that captive-born swift foxes *Vulpes velox* had lower post-release survival rates than did translocated, wild-born animals. No statistical analyses were performed. Nine months after release into the wild, at least two out of 27 (7%) captive-born swift foxes were known to be alive, compared with twelve out of 28 (43%) wild-born translocated swift foxes. In May 1990 and 1991, a total of 27 captive-born and 28 wild-born swift foxes were released simultaneously. Wild-born animals had been captured in Wyoming, USA, 4–7 months before release and were quarantined for ≥30 days. Animals were released without prior conditioning in holding pens. Foxes were radio-collared and monitored from the ground and air, for at least nine months.

A study in 1993–1995 in northern Florida, USA (2) found that following release, most captive-bred and translocated mountain lions *Puma concolor stanleyana* that had been held in captivity prior to release established home ranges in the release area. Of 19 released mountain lions, 15 established one or more home ranges. Post-release survival periods for these 15 animals are not stated but two were killed (one illegally shot and one killed by a vehicle) and two were recaptured due to landowner concerns or concerns for their survival, 37–140 days after release. Nineteen mountain lions were released in northern Florida in 1993–1994. Six animals were captive-bred, 10 were wild-caught and released within three months and three were caught and released after 3–8 years. mountain lions were radio-tracked daily in February 1993–April 1993 and then for three days/week until June 1995.

A replicated, controlled study in 1989–1993 in two rivers in southern Sweden (3; same experimental set-up as 6) found that captive-bred European otters *Lutra lutra* released into the wild had a lower survival rate than did wild-born translocated otters. One year after release, the survival rate of captive-bred otters (42%) was lower than that of wild-born translocated otters (79%). Additionally, captive-bred otters with a shorter (5–48 day) period between separation from their mother and release to the wild had a higher survival rate (80%) than individuals with a longer (49–98 day) period (13%). Between 1989 and 1992, twenty-five captive-bred and 11 wild-born otters were released into two rivers. Thirty-four otters were released in one river catchment and

two in the other. Captive-bred otters were descendants of two captive females. Wild-born otters were live-trapped along the Norwegian coast. All otters were around one year old when released. All except one were released between February and June. All were fitted with an implanted radio-transmitter and monitored for one year on 64% of days.

A study in 1991–1995 in a desert reserve in central Saudi Arabia (4) found that nearly half of captive-bred mountain gazelles *Gazella gazella* released into the wild survived more than two years, and the population bred successfully and more than doubled in size. Of a total of 71 released gazelles, 69–73% survived over one year and 58–59% survived over two years. Mortality was high in the first month after release (13% died), but the mean annual survival rate of gazelles which survived the first month was 78%. Gazelles that were over three years of age when released were more likely to die within 54 weeks of release than younger animals (54% vs 19% mortality) due to a higher rate of predation by wolves. Released females gave birth to at least 134 calves, of which at least 107 were conceived in the wild. By December 1994, the population had increased to 152–185 animals. Between January 1991 and June 1993, seventy-one captive-born mountain gazelles were released into three valleys inside a 2,000-km^2 reserve. The valleys were fenced to exclude domestic camels but allowed movement of gazelles. All released individuals were ear-tagged and 28 were fitted with a radio-collar. Gazelles were monitored using binoculars and a telescope on 396 days between January 1991 and June 1995. Gazelles were provided with water year-round.

A study in 1992–1993 in a mountain area dominated by deciduous forest in northern Italy (5) found that two captive-bred roe deer *Capreolus capreolus* that were released into the wild survived for at least 10 months. Both captive-bred roe deer survived over 10 months post-release (long term survival is not reported). Their average annual home range extended over 38.5 ha. In November 1992, the two captive-bred male roe deer (aged 17 months) were radio-tagged and released into the wild. The release site was within a 400-ha area with a roe deer population density of 0.2 deer/ha. The area was dominated by deciduous coppice (45%), mixed crops (21%), urbanized areas (14%) and meadows and pastures (13%). The two roe deer were radio-tracked for 10 months after release until September 1993.

A study in 1989–1992 at seven lakes in boreal forest in Sweden (6; same experimental set-up as 3) found that following release, at least 14 of 36 captive-bred or wild-born translocated European otters *Lutra lutra* survived for at least one to two years. Fourteen otters had established home ranges and were still alive when last recorded, 362–702 days after release. Eight further otters were monitored until their transmitters failed or they moved out of radio contact, 89–219 days after release. Fourteen were known to have died, 18–750 days after release. Otter origin (captive-bred or wild-caught) did not affect movement distance. In 1989–1992, thirty-six otters (25 captive-bred and 11 wild-born, translocated otters) were released in lakes and rivers in southern Sweden. Otters were fitted with radio-transmitters. Radio-tracking was carried out at least monthly, in 1989–1992.

A study in 1982–1997 in a mountain forest reserve in Tennessee, USA (7) found that at least 10 of 23 captive-bred American black bears *Ursus americanus* released into the wild were killed or had to be removed. Ten of 23 captive-bred black bears (43%) survived for an average of 172 days after release (range 4–468 days) before being killed (seven bears), euthanised after being hit by a vehicle (one bear), relocated (one bear) or returned to captivity (one bear). The fate of the 13 other released bears is not known (one tracked bear lost its radio-collar after 484 days, 12 bears were not radio-tracked or observed again after release). Twenty-three captive-bred, pen-reared black bears (11 male, 12 female; average 2.5 years old) were released in 1982–1995 at five sites in which bear hunting was prohibited in the Cherokee National Park. All bears were individually marked with ear-tags and/or tattoos. Seven were radio-collared and monitored an average of once every 18 days from an aircraft in 1983–1997.

A review of studies in 1989–1991 in prairie sites in Canada and the USA (8) found that following release, captive-bred swift foxes *Vulpes velox* had lower survival rates than did translocated, wild-caught swift foxes. Over an unspecified time period, 59% of wild-caught translocated swift foxes survived while three of 41 (7%) captive-bred swift foxes survived after release. In 1989–1991, thirty-three wild-caught, adult foxes and 41 captive-bred foxes, born the previous year, were released in the spring. Methods used for monitoring animals were unclear.

A replicated study in 1993–2002 in seven forest sites across England, UK (9) found that following releases of captive-bred (and some translocated wild-born) dormice *Muscardinus avellanarius*, populations persisted for between three months and over seven years and reproduced. In at least three of seven releases, dormouse populations were stable or increased from 19–57 released individuals to 40–55 individuals between two and seven years later. At one site, only one individual was detected 7–8 years after the release of 52 individuals in two batches. In three populations, the number of released animals is not provided, but populations persisted for at least three months and up to at least three years after release. Animals in all seven populations bred in the wild. Releases took place in 1993–2000 into woodlands in Cambridgeshire, Nottinghamshire, Cheshire, Warwickshire, Buckinghamshire, Yorkshire and Suffolk. Monitoring continued until 2000–2002. Precise numbers and origins of dormice released are not given for all sites. Most were captive-bred but some were wild-born translocated animals. Some dormice were kept in pre-release holding pens, sometimes for several weeks, before release. Nest boxes and supplementary food were provided at least at some sites. See paper for further details.

A replicated study in 1992–2000 on two rivers in Hertfordshire, UK (10) found that a population of released captive-bred European otters *Lutra lutra* persisted for over eight years after release. Eight years after release of six captive-bred otters into rivers with no otter populations, otters were still detected in the release area. Over this time, the range used by released otters expanded, but some of this may have been due to natural recolonization. At least one otter died during the study period. In October–December 1991, six captive-bred otters were released in two rivers with no known otter populations. Individuals were approximately two years old when released. The range and persistence of the populations were assessed by surveying droppings through to February 2000.

A review of 14 releases of six species of captive-bred mammals in Western Australia, Australia (11) found that where outcomes were available for release programmes, over half were regarded as successful. One out of two releases of rufous hare-wallabies *Lagorchestes hirsutus*, one out of two of dibblers *Parantechinus apicalis* and one out of four of western quolls *Dasyurus geoffroii* were classed as successful. However,

the only release of banded hare-wallabies *Lagostrophus fasciatus* and one out of two releases of rufous hare-wallabies *Lagorchestes hirsutus* were classed as unsuccessful. At the time of the review, the outcomes of two releases of bilbies *Perameles lagotis*, three of western quolls, one of dibblers and three of Shark Bay mouse *Pseudomys fieldi* remained uncertain. In 1993–2002, sixteen to 149 captive-bred mammals were released per location. One translocation of Shark Bay mouse was partially sourced from wild stock. Invasive mammals were controlled at some release sites. The definition of successful reintroduction was not stated for most species but, for others, it included measures of population increase and persistence.

A study in 2002–2005 in two wetland areas in the Netherlands (12) found that following release of captive-bred animals, together with the release of some translocated individuals, over half of Eurasian otters *Lutra lutra* settled in their release areas and some successfully reproduced. After three weeks, 14 of 23 otters settled within their release areas, while two died and seven moved away from release areas. Three years after the first translocations, five female otters had successfully reproduced, producing nine young. At this time, the total population was 12 otters. In 2002, fifteen wild-caught otters were released at one site. At a second site, in 2004–2005, eight animals, comprising a mix of wild-caught and captive-bred individuals, were released. Before release, animals were fitted with radio-transmitters and DNA samples were taken. Following release, otters were monitored by radio-tracking and by collection of faeces, which was analysed to identify individuals.

A study in 1998–2005 at a prairie grassland site in Montana, USA (13) found that following releases of captive-reared swift foxes *Vulpes velox*, a population became established and grew. One year after releases finished, there were 62 animals, increasing to 93 animals two years later. From 50 to 100% of mature female swift foxes reproduced each year, producing 4–5 offspring. Five to seven years after reintroductions, adult swift fox annual survival was 60–73%, and that of young swift foxes was 69–77%. Of the 33 animals that died during the study, 26 were killed by coyotes *Canis latrans* or birds of prey. In 1998–2002, one-hundred and twenty-three captive-reared swift foxes were released in the Blackfeet Indian Reservation. In 2003–2005, twenty-three adult and 35 juvenile

foxes were trapped and radio-collared. They were then tracked weekly, until 2005.

A review of studies conducted in 1985–2005 at 11 grassland and dry savanna sites in Eastern Cape, South Africa (14) found that reintroductions (mainly through translocations but including some captive-bred animals) of large carnivores led to increasing population sizes for four of six species. Twenty years after the first releases, there were 56 lions *Panthera leo* at seven sites (from 31 released), 41 cheetahs *Acinonyx jubatus* (seven sites, 40 released), 24 African wild dogs *Lycaon pictus* (two sites, 11 released) and 13 spotted hyena *Crocuta crocuta* (three sites, 11 released). There were reductions or unknown trends in two species with seven known surviving leopards *Panthera pardus* (five sites, 15 released) and an unknown number of servals *Leptailurus serval* (though known to be present — two sites, 16 released). Releases were made in 1985–2005, into 11 protected areas. Most schemes involved translocations of wild-caught animals but at least one of seven lion reintroductions involved captive-bred animals. Monitoring methods are not specified.

A replicated study in 1998–2004 of woodland at three sites in Corsica, France (15) found that captive-bred Corsican red deer *Cervus elaphus corsicanus*, released following extinction on the island, increased in number at all three sites. At one site, following two releases, four years apart, totalling 35 founders, there were 100 deer two years after the second release. At a second site, 24 founders grew to 60 animals over seven years. Twenty-seven founders released at a third site increased to 40 animals later that year. Corsican red deer became extinct on Corsica in 1970. Captive populations of deer, sourced from Sardinia, were established at three sites on Corsica from 1985 onwards, to provide animals for reintroductions. From 7, 14 and 17 founders, captive populations in enclosures grew and were artificially restricted to 35 each at two sites and 50 at the third site (each equating to 3.2 deer/ha). Releases from the captive populations took place in February and March of 1998–2004 and the wild population was then estimated at each site later in 2004.

A review in 2008 of 49 studies in 1990–2006 of carnivore reintroductions in Africa, Europe, and North America (16) found that captive-bred animals released into the wild had lower survival than did wild-born

translocated animals. Survival of captive-born carnivores following release (32%) was lower than survival of wild-born translocated animals (53%). The review analysed 20 reintroductions of 983 captive-bred carnivores and 29 reintroductions of 1,169 wild-caught carnivores. Post-release monitoring ranged in duration from 6 to 18 months.

A replicated study in 2003–2007 at two mountain sites on Vancouver Island, Canada (17) found that released captive-born Vancouver Island marmots *Marmota vancouverensis* had lower annual survival rates than wild-born marmots, and those released at two years old were more likely to survive than those released as yearlings. The average annual post-release survival rate of captive-bred marmots (61%) was lower than that of wild-born marmots (85%). Captive-bred marmots released at the age of two or more years had higher annual survival rates (77%) than those released as yearlings (60%). In 2003–2007, ninety-six captive-born Vancouver Island marmots were released at two sites. The released marmots were radio-tagged and monitored for a total of 154 marmot-years (one marmot-year represents one record/marmot/year). Wild-born marmots (number not reported) were also radio-tagged and monitored for 101 marmot-years in 2003–2007. All radio-tagged marmots were tracked from the ground or from a helicopter. Monitoring frequency is not stated.

A study in 2004–2006 at a grassland reserve in KwaZulu-Natal, South Africa (18) found that one of 10 captive-bred oribi *Ourebia ourebi* released into the wild survived more than two years. One captive-bred female oribi released into the wild survived for at least 27 months. Eight oribi died, six within one month of release and three within eight months. One oribi was taken back into captivity with a broken leg. Two of the eight animals that died were predated, two were poached, one died in cold weather and the cause of death in three cases was unknown. In April 2004, ten adult oribi (four males, six females) from a private breeding facility (9 x 1–3 ha enclosures) were fitted with radio-collars and released into two grassland sites (five animals at each) within three hours of capture. In 2004–2005, the released oribi were monitored weekly during the first month and monthly after the first three months post-release.

A study in 2000–2006 in an unspecified number of riparian sites on Hiiumaa Island, Estonia (19) found that captive-bred European mink

Mustela lutreola survived up to 39 months after release into the wild. Eighty days after release, 88 of 172 released mink had survived. After 39 months, at least one released mink was still alive. Seventy-five percent of deaths were caused by predators, including foxes, dogs *Canis lupus familiaris*, and raptors. In autumn 2000–2003, one-hundred and seventy-two captive-born mink were released at the site. Fifty-four mink were fitted with radio-collars before release and were monitored for up to five months. To monitor mink survival, animals were repeatedly trapped over 39 months.

A study in 2008 along a river in northern Italy (20) found that the release of a pair of captive-bred Eurasian otters *Lutra lutra* resulted in a population that persisted for at least 11 years. Eleven years after the introduction of a pair of Eurasian otters, signs of otter presence were detected along at least three of the 10 contiguous stretches of river that were surveyed. In 1997, a pair of captive-bred otters was released at a site in an area where the species had been extirpated in the late 1980s. In June–September 2008, otter presence was monitored along 5 km of the river, in 10 stretches, each 500 m long. Monitoring entailed searches for spraints and anal secretions. Each river stretch was surveyed 8–11 times.

A study in 2002–2008 in an area of peatland, fen, woodland, ditches and lakes in the Netherlands (21) found that following release of captive-bred and translocated wild-born Eurasian otters *Lutra lutra*, the population grew. By the end of the study (1–6 years after releases), six of the released otters were known to be still alive. Fifty-four offspring from released otters or their descendants were detected during the course of the study. Most dead otters found were killed in collisions with road vehicles. Between July 2002 and November 2007, thirty otters were released. Thirteen were captive-bred and 17 were translocated, wild-caught animals. Monitoring was mostly by genetic analysis of otter spraints. A publicity campaign encouraged people to report dead otters that they found. These were examined to establish cause of death.

A review of studies in 1991–2008 at 11 grassland sites in the USA and Mexico (22) found that most captive-bred (with some translocated) black-footed ferret *Mustela nigripes* releases were unsuccessful at maintaining a population, but success was higher where prey was abundant over larger areas. Of 11 reintroduction sites, populations of more than 30 adult black-footed ferrets were maintained at four sites

over two years without further reintroductions. Two sites no longer contained ferrets by December 2008, and the other five sites only had small populations or were supplemented by further releases. Sites where populations were maintained tended to have more prairie dogs *Cynomys* spp., the main prey species of black-footed ferrets, covering a larger area (at least 4,300 ha) and with a higher density of animals (data presented as index of prairie dog abundance). From 1991–2008, around 2,964 captive-bred and 157 translocated wild ferrets were released at 18 sites in multiple releases. The study reports success of the 11 sites where initial releases occurred before 2003. Sites received on average over 200 ferrets over 10 years. Ferrets were monitored by annual spotlight surveys to locate, capture and uniquely mark individuals.

A study in 2009–2010 of a woodland area and adjacent escarpment in Victoria, Australia (23) found that most captive-bred brush-tailed rock wallabies *Petrogale penicillata* survived for at least five months after release and established stable home ranges. Four animals from five released were alive at least five months after release. One animal died two months after release, from undetermined causes. Additionally, three animals from an earlier release that were alive 11 months after release all survived to at least 16 months after release. Rock-wallabies established stable home ranges of 16.2–41.5 ha in extent, with core areas of 1.2–4.5 ha. Five captive-bred brush-tailed rock-wallabies were released in October 2009. Three from a release in November 2008 that were still alive in October 2009 were also monitored. Wallabies were monitored by radio-tracking, through October 2009 and for two weeks in March 2010.

A replicated study in 1996–1997 in three grassland sites in South Dakota, USA (24) found that over half of released captive-bred black-footed ferrets *Mustela nigripes* survived more than two weeks. At each of the three sites, 48% (12 of 25), 50% (9 of 18) and 89% (32 of 36) of captive-bred ferrets released into the wild survived for at least two weeks (long term survival is not reported). Overall, 53 out of 79 captive-bred black-footed ferrets (67%) survived more than two weeks after release into the wild. Twenty-four ferrets were killed by native predators (mostly great-horned owls *Bubo virginianus* and coyotes *Canis latrans*) and the cause of death of two others could not be determined. A total of 79 captive-bred black-footed ferrets were released across three mixed-grass prairie sites

(18–36 ferrets/site) in September–October 1996 and October–November 1997. Between 18 and 35 individuals were released at each site. Each of the 79 ferrets was radio-tagged and tracked every 5–30 min/night for two weeks post-release in 1996–1997.

A study in 1990–2007 in a desert reserve in west-central Saudi Arabia (25) found that released captive-bred female Arabian oryx *Oryx leucoryx* survived more than 10 years and successfully reproduced, regardless of prior breeding experience. Released captive-bred female oryx lived 11–12 years in the wild. Average birth rates were similar for 'experienced' females that had given birth prior to release (0.69 calves/year) and 'inexperienced' females that had not (0.74 calves/year). Between 1990 and 1994, a total of 76 captive-bred oryx were released, of which 36 were females aged 0.5–8.9 years (numbers of experienced/inexperienced mothers not specified). Animals were identified by collars, ear-tags or ear notches. Individuals were located at least once every two weeks until 2007.

A study in 2005–2009 in a mostly agricultural area in Maciejowice, Poland (26) found that approximately one third of released captive-bred brown hares *Lepus europaeus* survived for at least one year. Twenty-two of 60 hares (37%) survived for at least one year after release. Of those that died during the first year after release, males survived for an average of 57 days and females for an average of 64 days. Deaths were due to predation (31%), poaching (13%) and road kills (7%), with the remainder (49%) disappearing or dying of unknown causes. Seventy-eight brown hares bred in a 20-ha open-field enclosure were released in a landscape comprising cultivated fields, floodbanks, forest, orchards and meadows. The hares (at least six months old) were released in groups of 18–30 individuals in November 2005, 2006 and 2007. Sixty radio-collared hares (15–29 hares/group) were tracked 3–7 times/week for 1–2 years after release in 2005–2009.

A study in 2002–2011 of forest on two islands in Florida, USA (27) found that released captive-bred Key Largo woodrats *Neotoma floridana smalli* had a lower survival rate than did wild-born, wild-living animals. From 40 captive-bred woodrats radio-tracked for an average of 49 days, 33 (67%) deaths were recorded. From 58 wild-born, wild-living woodrats radio-tracked for an average of 80 days, ten (6%) deaths were recorded. All but one death, from both groups combined, was thought to be due

to predation. Adult captive-bred woodrats were released on two islands between February 2010 and December 2011. They were located at least every second day by radio-tracking, for up to four months. Nineteen adult wild-born woodrats were radio-tracked at least three times/week from March to December 2002 and 39 were radio-tracked 2–5 times/week, from June 2005 to February 2006.

A review of translocations carried out in 1969–2006 in Australia (28) found that releasing captive-bred and wild-born translocated macropod species (kangaroos and allies) led to the successful establishment of populations in 44 of 72 cases, of which 29 survived for over five years. Of the established populations, 29 persisted for more than five years. Of the 28 releases considered to be failures, 17 were thought to have failed due to predation by non-native carnivores, such as red foxes *Vulpes vulpes*. Releases considered in the review included both wild-caught translocated animals and captive-bred animals. The number of animals released ranged from one to 70 and included 20 different macropod species. Only translocations where animals were released into areas larger than 100 ha were considered for the review.

A study in 2002–2007 on prairie in South Dakota, USA (29) found that post-release survival rates of captive-bred swift fox *Vulpes velox* pups were lower than survival rates of wild-born pups. The proportion of captive-bred pups that survived for 60 days after release (48%) was lower than the proportion of wild-born pups that survived for 60 days (100%). Forty-three pups (26 male, 17 female) born in pens to wild-caught foxes formed the captive-bred cohort. They were released in mid-July of 2003–2007. Survival was compared, using radio-telemetry and visual observations at dens, to that of 90 pups born in the wild in 2003–2007, to previously translocated and released foxes.

A controlled study in 2008–2010 in a mountain site in the Central Apennines, Italy (30) found that released captive-born Apennine chamois *Rupicapra pyrenaica ornata* survived and reproduced in similar numbers to wild-caught translocated chamois, but captive-born chamois remained closer to the release site. Seven of eight captive-born (88%) and seven of eight (88%) wild-caught translocated Apennine chamois survived over five months after release. Four of five captive-born (80%) and three of five wild-caught translocated (60%) female chamois reproduced in the first year after release. During the first week after

release, captive-born chamois remained closer to the release site (within 1.1 km on average) than wild-caught chamois (average 1.8 km). Eight captive-born chamois (2.5–11.5 years old, five females and three males) and eight wild-caught translocated chamois (2.5–10.5 years old, five females and three males) were released into Sibillini Mountains National Park. Chamois were released in groups of one-three individuals; each group was all wild or all captive-born. Captive-born chamois were bred in large enclosures within four national parks. Translocated chamois were taken from a national park approximately 200 km away. All of the 16 released chamois were fitted with radio-collars and monitored for five months after release in 2008–2010.

A study in 1997–2016 in a grassland area in Jiangsu province, China (31) found that a population of released captive-bred Père David's deer *Elaphurus davidianus*, established and increased in number over time. From a total of 82 founders, the population increased to 325 animals by 18 years after the first of these founders were released. In 1998, seven deer were released into a 1,000-ha area in which there were no other Père David's deer. Between 2002 and 2016, a further 75 animals were released. Observations were made with binoculars and using a drone, to estimate the deer population size. No other details of monitoring were provided in the study.

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14.25. Captive rear in large enclosures prior to release

https://www.conservationevidence.com/actions/2507

- **Four studies** evaluated the effects of captive rearing mammals in large enclosures prior to release. Two studies were in the USA[1,2], one was in Mexico[3] and one was in Australia[4].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (3 STUDIES)

- **Reproductive success (1 study):** A study in Mexico[3] found that peninsular pronghorn taken from the wild and kept in a large enclosure bred successfully and the population increased, providing stock suitable for reintroductions.
- **Survival (2 studies):** A replicated, controlled study in USA[1] found that black-footed ferrets reared in outdoor pens had higher post-release survival rates than did ferrets raised indoors. A controlled study in Australia[4] found that Tasmanian devils reared free-range in large enclosures did not have greater post-release survival rates than animals from intensively managed captive-rearing facilities.
- **Condition (1 study):** A controlled study in Australia[4] found that Tasmanian devils reared free-range in large enclosures did not gain more body weight post-release compared to animals from intensively managed captive-rearing facilities.

BEHAVIOUR (1 STUDY)

- **Behaviour change (1 study):** A controlled study in USA[2] found that captive-bred black-footed ferrets raised in large enclosures dispersed shorter distances post-release than did ferrets raised in small enclosures.

Background

Captive-bred mammals may take time to adapt to conditions in the wild post-release, making them especially vulnerable to predation, starvation and disease. If they are reared in large enclosures, with habitat that resembles natural conditions, they may develop more natural behaviour and be better able to find food and shelter in the wild, compared to those animals reared in smaller pens.

A replicated, controlled study in 1991–1996 at three grassland sites in South Dakota, Wyoming and Montana, USA (1) found that black-footed ferrets *Mustela nigripes* reared in outdoor pens had a higher survival rate after release than did ferrets raised indoors. Nine months after release, a higher proportion of black-footed ferrets that were reared in outdoor pens were still alive (20%) than of animals reared in indoor cages (2%). In 1991–1995, one hundred and ninety-one ferrets were reared in indoor cages and 58 were raised in outdoor pens. Pens were 18–280 m^2 and were stocked with white-tailed prairie dogs *Cynomys ludovicianus* (as food for ferrets and to dig burrows that were used by ferrets). Ferrets, implanted with Passive Integrated Transponder (PIT) tags, were released in August–November of 1991–1995 at three sites. In 1991–1996, each area was surveyed on at least three consecutive nights by 8–32 people, on foot or in vehicles. All ferrets located were individually identified using PIT tags.

A controlled study in 1992 in a grassland area in Wyoming, USA (2) found that captive-bred black-footed ferrets *Mustela nigripes* raised in large enclosures dispersed smaller distances and moved less after release than did ferrets raised in small enclosures. Black-footed ferrets raised in large enclosures had a lower average maximum dispersal distance during the first three days post-release (1.7 km) and lower

average cumulative movement over any three-day period post-release (8.2 km) than ferrets raised in small enclosures (maximum dispersal distance: 5.6 km; average cumulative movement: 21.1 km). Between September and October 1992, twenty-five 16.5–18-week-old captive-bred black-footed ferrets were radio-tagged and released into a 20,596-ha area. Eight ferrets were born in cages but raised in 80-m^2 outdoor pens with prairie dog burrows and 17 were born and raised in indoor-1.5 m^2 cages. All ferrets were fed live prairie dogs. Ferrets were followed in October–November 1992.

A study in 1998–2003 at a captive breeding facility in Baja California Sur, Mexico (3) found that peninsular pronghorn *Antilocapra americana peninsularis* taken from the wild and kept in a large enclosure increased in number and provided a suitable resource for future reintroductions. Nine adult pronghorns and 16 fawns were captured in the wild, in 1998–2003, to establish the captive breeding herd. Births in captivity occurred from 2000, with 85 occurring up to 2003. There were 20 deaths. In 2003, the captive population stood at 90 animals. The captive breeding facility measured 1,400 × 1,850 m, with moveable internal divisions to manage animal separations where necessary. The founder animals were wild-caught. Fawns caught wild were bottle-fed until weaned. A different male was used for mating each year.

A controlled study in 2012–2015 on a forested island in Tasmania, Australia (4) found that Tasmanian devils *Sarcophilus harrisii* reared free-range in large enclosures did not have greater post-release survival rates and body weight gains compared to animals from intensively managed captive-rearing facilities. Survival of animals reared in free-range enclosures (eight of nine animals survived ≥825 days after release) did not differ from that of those reared in intensive captive facilities (18 of 19 survived ≥825 days after release). Free-range enclosure animals did not gain more body weight than did intensive captive facility animals over 440 days post-release (average 14% gain across all animals). Twenty-eight adult (c.1 year old) Tasmanian devils (13 females, 15 males) were released. Nine had been reared in free-range enclosures (22-ha pens) and 19 in intensive captive rearing facilities (which included zoos and hand-rearing).

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14.26. Use holding pens at release site prior to release of captive-bred mammals

https://www.conservationevidence.com/actions/2510

- **Thirty-one studies** evaluated the effects of using holding pens at the release site prior to release of captive-bred mammals. Seven studies were in Australia[9,14,17,22,23,29,30], and in the USA[8,10,12,19,20,21,27], four were in the UK[1,2,3,15], three in Argentina[24,28,31], two in each of Israel[5,13], Saudi Arabia[7,25] and China[11,26] and one in each of Canada[4], Namibia[6], South Africa[16] and Germany[18].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (30 STUDIES)

- **Abundance (2 studies):** A study in Saudi Arabia[7] found that a population of captive-bred Arabian sand gazelles kept in holding pens prior to release nearly doubled in size over four years. A before-and-after study in China[26] found that following release of captive-bred animals from a pre-release enclosure into the semi-wild (free-roaming in summer, enclosed in winter and provided with food), Przewalski's horses increased in number.

- **Reproductive success (10 studies):** Eight studies (one replicated) and one review in the UK[1,2], Saudi Arabia[7,25], the USA[10,12], Israel[5,13] and Australia[17] found that following the use of holding pens prior to release (and in some cases provision of supplementary food), captive-bred Eurasian otters[1,2], Arabian sand gazelles[7], eastern-barred bandicoots[17], some swift foxes[10], some red wolves[12] and over 33% of Persian fallow deer[13] reproduced, Arabian gazelles[25] started breeding in the first year and the reproductive success of female Asiatic wild ass[5] increased over 10 years. A study in Australia[22] found that after being kept in a holding pen, all four mammal populations[22] released into an invasive-species-free fenced enclosure reproduced.
- **Survival (23 studies):** One of three studies (two controlled, one replicated) in the UK[15], Canada[4] and Australia[30] found that using holding pens prior to release of captive-bred (and some translocated) animals resulted in greater post-release survival for water voles[15] compared to animals released directly into the wild. The other two studies found similar survival rates for eastern barred bandicoots[30] and swift foxes[4] compared to animals released directly into the wild. A replicated study in the USA[27] found that captive-bred Allegheny woodrats kept in holding pens prior to release, had higher early survival rates than those not kept in holding pens, but overall survival rates tended to be lower than wild resident woodrats. Three studies in South Africa[16], USA[19] and Argentina[24] found that released captive-bred (and some translocated) African wild dogs[16], riparian brush rabbits[19] and guanacos[24] that spent longer in, and in one case in larger[24], holding pens had a higher survival rate. Three studies (one controlled) in Australia[9] and the USA[20,21] found that captive-bred animals kept in holding pens prior to release had similar (bridled nailtail wallabies)[9] or lower (black-footed ferret kits)[20] annual survival rate after release to that of wild-born translocated animals and lower (black-footed ferrets)[21] survival rates than resident animals. Ten studies (including one controlled, before-and-after study) and one review in

Saudi Arabia[7], the USA[10,12], Argentina[28], China[11], Israel[5,13], Australia[14,17,22] and Germany[18] found that following the use of holding pens prior to release of captive-bred animals (or in some cases captive-reared/rehabilitated, or with provision of supplementary food), four of four mammal populations[22], 19% of red wolves[12], Asiatic wild ass[5], Persian fallow deer[13], most Arabian sand gazelles[7], most swift foxes[10], eastern-barred bandicoots[17] and European mink[18] survived at least 1–10 years, over half of giant anteaters[28], hare-wallabies[14] and Père David's deer[11] survived for at least 1.5–6 months. Three studies in Namibia[6], the USA[8] and Australia[29] found that that following the use of holding pens prior to release of captive-bred or reared animals (some provided with nest boxes and/or supplementary food), red-tailed phascogales[29], most Mexican wolves[8] and African wild dogs[6] survived less than 6–12 months.

- **Condition (4 studies):** A randomized, controlled study in Australia[30] found that eastern barred bandicoots released after time in holding pens lost a similar proportion of body weight and recovered to a similar weight compared to bandicoots released directly. A controlled study in the UK[3] found that common dormice lost weight after being put into holding pens whereas wild translocated dormice gained weight. A controlled, before-and-after study in Australia[14] found that captive-bred rufous hare-wallabies placed in holding pens prior to release lost body condition in holding pens. A before-and-after study in Australia[23] found that captive-bred brush-tailed rock-wallabies placed in a holding pen prior to release maintained good health.

BEHAVIOUR (1 STUDY)

- **Behaviour change (1 study):** A controlled study in Argentina[31] found that after being kept in holding pens and provided with supplementary food, released captive-bred giant anteaters were less nocturnal in their activity patterns than released wild-born rehabilitated individuals.

Background

Holding pens at release sites (sometimes termed 'soft release') may be used to enable mammals to become accustomed to new surroundings before release. They are often enclosures containing natural habitat and enabling views of surrounding land. The technique may be employed both for releases of captive-bred mammals and for translocations of wild mammals to new sites, here we focus on the first group.

See also: *Use holding pens at release site prior to release of translocated mammals.*

This intervention does not include studies that solely document use of pens or enclosures used as part of captive-rearing processes if these are remote from release sites.

A replicated study in summer 1983–1984 at a riparian site in East Anglia, UK (1) found that captive-bred European otters *Lutra lutra* kept in a pre-release pen and provided supplementary food after release bred successfully. Footprints of at least one otter cub were found in the year after release. Otters settled near the release site, but ranged along 31.5 km of river over the first 100 days after release. In July 1983, three 18-month-old captive-bred otters (one male, two female) were released. Before release, they were held together in a pen at the release site, for an unspecified period of time. After release, supplementary food was provided in the pens for 12 days. The male otter was radio-tracked for 50 nights after release. Local bridges were monitored for 100 days after release for signs of otter faeces.

A study in 1983–1985 along river on the Norfolk-Suffolk border, UK (2) found that following the use of holding pens at release sites and short-term provision of supplementary food, released captive-bred Eurasian otters *Lutra lutra* stayed in their release area for at least two years and bred. Otters survived in the release area at least 28 months after release. Breeding was confirmed the summer after release and suspected again the following summer. Otters held in pens before release displayed similar activity periods, range sizes, and behaviours

to those seen in wild otter populations. One male and two female otters (captive-bred and unrelated) were kept in a large pen with a pool where they had limited contact with humans from 10 to 18 months of age. In June 1983, at 18 months, they were moved to a 9 × 15-m pre-release pen, 10 m from a river bank, on a river island. After 20 days, the pen door was fixed open. Food was placed in the pen daily for 12 days after release. The male was radio-tracked from 5 July to 24 August 1983. Otter signs (especially spraints) were then monitored until 1985.

A controlled study in 1992 in a woodland reserve in Somerset, UK (3) found that captive-bred common dormice *Muscardinus avellanarius* lost weight after release into holding pens whereas wild-caught translocated dormice gained weight. The body mass of captive-bred common dormice decreased after release into holding pens by 0.23 g/day, whereas that of translocated wild-caught dormice increased by 0.12 g/day. After release from the holding pens, both captive-bred and wild-caught translocated dormice lost a small amount of weight (see original paper for details). The study was conducted along a 9-ha strip of woodland and scrub between 24 August and 30 September 1992. Eight captive-bred and six wild-caught dormice were held in a pre-release pen for eight nights, and then released into the wild. The pre-release pen (0.45 m wide, 0.5 m deep and 0.9 m high) was constructed from 1-cm^2 weldmesh and had food and water. Dormice were released in the same groups as they were found in nestboxes or in which they had been living in captivity. All individuals were weighed 10–14 days after release.

A replicated, controlled study in 1983–1993 in three grassland sites in Alberta, Canada (4) found that captive-bred and translocated swift foxes *Vulpes velox* released after time in holding pens had similar survival rates to those released without use of holding pens two years after release. No statistical analyses were performed. At least six out of 45 (13%) swift foxes held in pens before release survived over two years post-release, compared with at least five out of 43 (12%) released without use of holding pens. In 1983–1987, forty-five translocated swift foxes were held in pens before release. Pens (3.7 × 7.3 m) were fenced for protection from cattle. Animals were placed in pens in October–November and released between the following spring and fall. They were provided with supplementary food for 1–8 months after release. In 1987–1991, four hundred and thirty-three foxes were released

without use of holding pens. Released foxes included both wild-born and captive-bred animals. All foxes released from pens and 155 of those released directly were radio-tracked, from the ground or air, for up to two years.

A study in 1982–1993 in a desert reserve in Israel (5) found that a released population of captive-reared Asiatic wild ass *Equus hemionus* spp. kept in holding pens prior to release persisted over 10 years, and the reproductive success of females increased over time. The number of adult females (≥3 years old) in the released herd was 14 in 1987 and 16 in 1993. The reproductive success of released females increased over time (first five years = 0.27; following 4–5 years = 0.74 foals/female/year). By 1993, sixty-six foals had been born in the wild, of which 24 were second or third generation. The reproductive success of wild-born females (0.81) was higher than released females (0.19) at the same age. From 1982–1987, fourteen adult females and 14 adult males aged two to six (except one 17-year-old animal) were released into a 200 km^2 nature reserve in the Negev Desert in four release events. Three females died immediately. Asses were sourced from zoos and maintained in a 2km^2 enclosure until the release program began. Before three releases, animals were kept in a holding pen for up to three months with food, water and shade. Animals were released directly into the wild in the final release. Wild asses were surveyed 2–3 times/week in the spring and summer by random visual searching from an off-road vehicle, tracking of spoor and monitoring of water sources. The population size of males is not reported.

A study in 1978–1990 on a savanna site in Namibia (6) found that released captive-bred or captive-reared African wild dogs *Lycaon pictus* held in a holding pen prior to release did not survive more than six months. None of 24 African wild dogs introduced at the site survived for more than six months. Causes of death included starvation, predation by lions *Panthera leo* and rabies. In 1978, 1989 and 1990, a total of 24 captive-bred wild dogs were released. In 1990, animals were held in an enclosure adjacent to the release site prior to release, and were vaccinated against rabies and canine distemper. While in the enclosure, wild dogs were fed daily and live springbok were released in the pen, so they could learn to hunt. Methods used for monitoring animals introduced in 1978 and 1989 were unclear. Animals introduced in 1990

were monitored for four months after release and, if dogs did not feed for 2–3 days, they were provided with a springbok carcass. The 1978 release was of captive-reared animals (details of whether or not they were born in captivity are not given). The 1989 and 1990 releases were of captive-bred animals.

A study in 1990–1994 in a desert reserve in southwest Saudi Arabia (7) found that most captive-bred Arabian sand gazelles *Gazella subgutturosa marica* kept in holding pens prior to release survived for at least four years, the population bred successfully and nearly doubled in size. Of the 164 sand gazelles released, 155 (95%) survived for at least four years. A total of 108 births were recorded in the wild and the number of sand gazelles increased to approximately 300 individuals over four years. In 1990–1993, a total of 135 sand gazelles were moved from captive-breeding facilities to a fenced 2,200-km^2 open desert steppe reserve. Before release, gazelles were kept in four 40 × 30-m quarantine enclosures for 2–3 months and then transferred to a 25-ha pre-release enclosure for 10–14 months. Twenty-five gazelle died within the enclosures before release. A total of 164 gazelle (98 translocated and 66 born in the enclosures) were released in five groups in 1991–1994. Radio-tagged individuals (number not reported) were monitored 1–2 times/week by ground telemetry and at least once each fortnight by air telemetry (dates not reported).

A study in 1998 in a grassland, shrubland and forest reserve in Arizona, USA (8) found that most captive-bred Mexican wolves *Canis lupus baileyi* kept in holding pens prior to release in groups and provided with supplementary food did not survive over eight months after release into the wild. Out of 11 captive-bred Mexican wolves released, six (55%) were illegally killed within eight months, three (27%) were returned to captivity and two (18%) survived in the wild for at least one year (long term survival is not reported). Three weeks after their release, three individuals from one family group killed an adult elk *Cervus canadensis*. Two females gave birth two months after release but only one pup survived. Eleven wolves in three family groups were released in March 1998. Before release, wolves were kept for two months in pre-release holding pens, where they were fed carcasses of native prey. Carcasses were provided as supplementary food for two months post-release when sufficient killing of prey was confirmed. The released wolves were fitted with radio-collars. No monitoring details are provided.

A study in 1996–1999 at a woodland reserve in Queensland, Australia (9) found that captive-bred bridled nailtail wallabies *Onychogalea fraenata* kept in holding pens where predators were controlled prior to release had similar average annual survival after release to that of wild-born translocated animals. Over four years, the average annual survival of captive-bred bridled nailtail wallabies (57–92%) did not differ significantly from that of wild-born translocated animals (77–80%). In 1996–1998, one hundred and twenty-four captive-bred and nine wild-born translocated bridled nailtail wallabies were released into three sites across Idalia National Park. Ten captive-bred wallabies were held in a 10-ha enclosure within the reserve for six months before release, and 85 were bred within the 10-ha enclosure. All of the 133 released wallabies were kept in a holding pen (30-m diameter) for one week at each site before release. Mammalian predators were culled at release sites. A total of 67 wallabies (58 captive-bred, nine wild-born) were radio-tagged and tracked every 2–7 days in 1996–1998. Wallabies were live-trapped at irregular intervals with 20–35 wire cage traps in 1997–1999.

A study in 1998–2001 on a grassland site in Montana, USA (10) found that after the release of captive-bred swift foxes *Vulpes velox* using holding pens prior to release, most animals survived for at least one to three years, and some successfully bred. One to three years after introduction, a maximum of 69 of the 76 reintroduced foxes were still alive. Over the three years after introduction, 24–29 cubs were born in the wild. In the summers of 1998–2000, a total of 76 foxes were held in pens at the release site and, after 10 days, were released. Twenty-four animals were radio-tracked in 1999–2001. Methods used in the study to determine mortality and breeding success were unclear.

A study in 1998–1999 in a grassland site in Jiangsu, China (11) found that following release of captive-bred animals after being held in pre-release pens, all Père David's deer *Elaphurus davidianus* survived for at least six weeks. Seven deer were released and all were still alive six weeks later. For 18 months prior to release, eight deer (one male, three female, and four immature animals) were held in a fenced enclosure. Seven deer were released into Dafeng Reserve in November 1998. One female was fitted with a radio-collar to enable location of the group. From November 1998 to April 1999, released deer were located at least three times/week.

A study in 1987–1994 in a grassland site in North Carolina, USA (12) found that following release of captive-bred animals, some of which were kept in holding pens and then provided supplementary food, 12 of 63 red wolves *Canis lupus rufus* survived for at least seven years, and some successfully reproduced. Seven years after wolves were first reintroduced, 12 of 63 translocated animals were still alive. By the same time, at least 66 pups had been born. Between October 1987 and December 1994, sixty-three captive-bred wolves were released. Twenty-nine wolves were held in pens (225 m^2) on site before release (duration: 14 days-49 months), and thirty-four animals were released on arrival at the site. An unspecified number of wolves were fitted with radio-collars. From October 1987 to December 1994, wolves were radio-tracked from the ground and from an aeroplane. Monitoring frequency was not specified. Supplementary food (deer carcasses) was provided at release sites for 1–2 months after release from the ninth release onwards.

A study in 1996–2001 of a wooded valley in a reserve in the Galilee region, Israel (13) found that most captive-bred Persian fallow deer *Dama mesopotamica* kept in holding pens prior to release survived for at least five years and over one-third of females observed 1–3 years after release reproduced. Sixty of 74 (81%) captive-bred deer (13 males, 47 females) survived for at least five years post-release. Six of 15 females observed 1–3 years after release had fawns with them. A total of 124 captive-bred Persian fallow deer were released into the wild in groups of 10–19 deer in the spring and autumn during each of five years in 1996–2000. The deer were held in an 11-ha enclosure for three months before release. Seventy-four deer (57 females, 17 males) were fitted with radio-collars. Released deer were monitored for five years post-release through radio-tracking, video and direct observation.

A controlled, before-and-after study in 2001 in five shrubland sites in Western Australia, Australia (14) found that captive-bred banded hare-wallabies *Lagostrophus fasciatus* and rufous hare-wallabies *Lagorchestes hirsutus*, some of which were placed in holding pens prior to release into a fenced peninsula (with predator controls, supplementary food and water), survived at least two months after being released, although rufous hare-wallabies lost body condition while awaiting release in holding pens. After 1–2 months, 10 of 16 rufous hare-wallabies and 12 of 18 banded hare-wallabies were still alive. Overall both rufous

and banded hare-wallabies recaptured had similar body conditions to when they were released regardless of whether they were initially put in holding pens, although rufous hare-wallabies lost 12% of body condition while waiting for release in holding pens (data presented as a body condition index; see paper for details). Sixteen captive-bred rufous hare-wallabies and 18 captive-born banded hare-wallabies were released at five sites in August 2001. Six rufous hare-wallabies and nine banded-hare wallabies were placed in separate 3-ha enclosures with electrified fencing for 10–19 days before release. Remaining animals were released directly into the wild. Supplementary food (kangaroo pellets, alfalfa) and water were made available to all hare-wallabies (those kept in holding pens and those not; feeding duration not given). Hare-wallabies were monitored by radio tracking (once/week for 1.5 years after release) and live-trapping (at 4 and 8–9 weeks after release). Release areas were within a fenced peninsula where multiple introduced mammals were controlled or eradicated.

A review of a study in 2001–2002 at a restored wetland in London, UK (15) found that using holding pens prior to release of captive-bred and translocated water voles *Arvicola terrestris* resulted in greater post-release survival than did releasing them directly into the wild. Voles released from pens were three times more likely to be recorded during the initial follow-up survey than were those released without use of pens (result presented as odds ratio). A total of 109 captive-bred and 38 wild-caught water voles were released in groups of 6–15 animals in May–July 2001. Prior to release, no water voles were present at the site. An unspecified number of animals were placed in an enclosure with food and shelter and allowed to burrow out at will. The remainder were released directly into the wild. Animals were monitored by live-trapping over three periods of five days, between autumn 2001 and early-summer 2002.

A study in 1995–2005 in 12 dry savanna and temperate grassland sites in South Africa (16) found that captive-bred and translocated African wild dogs *Lycaon pictus* which spent more time in holding pens had a higher survival rate after release. Wild dog families that had more time to socialise in holding pens prior to release into fenced areas had a higher survival rate than groups which spent less time in holding pens (data presented as model results). Overall, 85% of released animals and

their wild-born offspring survived the first six months after release/ birth, Released animals that survived their first year had a high survival rate 12–18 months (91%) and 18–24 months (92%) after release. Between 1995 and 2005, one hundred and twenty-seven wild dogs (79 wild-caught, 16 captive-bred, 16 wild-caught but captive-raised, 16 'mixed' pups) were translocated over 18 release events into 12 sites in five provinces of South Africa. Individuals were kept in pre-release pens for an average of 212 days, but groups were given between 15 and 634 days to socialise in pens prior to release. Animals were monitored for 24 months after release, and the 129 pups which they produced after release were monitored up to 12 months of age. Forty characteristics of the individual animals, release sites and methods of release were recorded, and their impact on post-release survival was tested.

A review of eight studies in 1989–2005 in eight grassland and woodland sites in Victoria, Australia (17) found that in one study, released captive-bred eastern-barred bandicoots *Perameles gunnii*, some of which were placed in a holding pen prior to release, survived at least one year and bred. Captive-bred bandicoots, some of which were released into a holding pen prior to release into the wild survived at least one year and both pouch young and wild-born adults were observed. In total 22 captive-bred bandicoots were released into a 585 ha fenced predator-free enclosure in 2004–2005. Initially four animals were placed in a 1 ha holding pen prior to release. The remaining released animals were not placed in a holding pen prior to release. Bandicoots were released in stages in each site. Red fox *Vulpes vulpes* were controlled. Bandicoots were monitored by live-trapping but frequency and methods are not detailed.

A study in 2006–2008 in nine areas around rivers in south-west Germany (18) found that most captive-bred European mink *Mustela lutreola* kept in holding pens prior to release survived at least one year after release. Of 48 captive-bred animals released, 36 were still alive after 12 months. All animals were microchipped and 33 were fitted with radio-transmitters. For two weeks before release, mink were kept in enclosures measuring 5 × 2 m, containing small trees, branches, and small streams. In May 2006–August 2007, forty-eight animals were released. They were radio-tracked twice each day, in April 2006–May 2008. Animals not bearing transmitters were surveyed using live traps.

A study in 2001–2005 of riparian scrub at a site in California, USA (19) found that captive-bred riparian brush rabbits *Sylvilagus bachmani riparius* kept longer in holding pens at the release site before release had greater survival rates than those kept in pens for shorter times. Survival increased with duration held in soft-release pens prior to release, especially for smaller animals (result presented as model coefficient). Survival increased with time since release, with four-week post-release survival (71%) being lower than average four-weekly survival over the following eight weeks (89%). Wild rabbits taken into a captive breeding program produced 476 offspring from November 2001 to July 2005. Of these, 325 were released, in July 2002–July 2005, to unoccupied habitat within the species' historic range. They were held in soft-release pens (0.3–0.4 ha) and released after 2–20 days. Survival was monitored by radio-tracking, at least twice weekly.

A controlled study in 1999–2001 on three grassland sites in an area in South Dakota, USA (20) found that captive-born black-footed ferret *Mustela nigripes* kits initially kept in holding pens had lower survival rates after release than did wild-born translocated kits. Thirty-day post-release survival of captive-born kits (66%) was lower than that of wild-born translocated kits at the same site (94%). Annual survival was also lower for captive-born kits (females: 44%; males: 22%) than for wild-born kits (females: 67%; males: 43%). Annual survival at the donor site remained high (females: 80%; males: 51%) whilst survival of translocated and released kits was comparable with that at an unmanipulated colony (females: 59%; males: 28%). Eighteen captive-bred ferrets were released along with 18 wild-born ferrets at a site from which the species was then absent. Captive-born ferrets were transferred to outdoor conditioning pens, sited on prairie dog colonies, when about 90 days old and then released on 29 September and 13 October 1999. Wild-born ferrets were released the day after capture. All were born in 1999. Ferrets at the release site, the donor site for wild-born kits and an unmanipulated site were monitored by radio-tracking and by reading transponder chips.

A study in 1991 at a grassland site in Wyoming, USA (21) found that released captive-born black-footed ferrets *Mustela nigripes* kept in holding pens in the release site (where predators had been controlled) had higher post-release mortality than did resident wild ferrets. The estimated one-month survival rate for captive-born released ferrets

(49%) was lower than that for free-ranging wild ferrets at their ancestral site (93%). Of animals known to have died, five were predated by coyotes *Canis latrans*, one by a badger *Taxidea taxus*, one by a golden eagle *Aquila chrysaetos* and two died of starvation. Black-footed ferrets were extirpated in the wild in 1985–1986. Thirty-seven captive-bred ferrets were released in September–November 1991, when 4–6 months old, onto a white-tailed prairie dog *Cynomys leucurus* colony. Before releases, 66 coyotes and 63 badgers were removed from the site. Ferrets spent two weeks in acclimatisation cages at the reintroduction site before release. Dead prairie dogs were provided in the cage for 10 days post-release. Ferrets were monitored by radio-tracking for ≤42 days after release.

A study in 1998–2010 in a desert site in South Australia (22) found that after being kept in a holding pen, all four mammal populations released into an invasive-species-free fenced enclosure survived for eight years and bred. After being kept in a holding pen prior to release into a fenced enclosure where red foxes *Vulpes vulpes*, cats *Felis catus* and rabbits *Oryctolagus cuniculus* had been eradicated, greater stick-nest rats *Leporillus conditor*, burrowing bettongs *Bettongia lesueur*, western barred bandicoots *Perameles bougainville* and greater bilbies *Macrotis lagotis* were detected for eight years, increased their distribution range within five years and produced a second generation within two years. In 1998–2005, nine captive-bred greater bilbies, eight wild-born greater stick-nest rats, 10 wild-born burrowing bettongs, and 12 wild-born western barred bandicoots were translocated into a 14-km^2 invasive-species-free fenced area. Rabbits, cats and foxes were eradicated within the fenced area in 1999. Animals were released into a 10-ha holding pen before full release after a few months. Between 2000 and 2010, tracks were surveyed annually along eight 1 km × 1 m transects.

A before-and-after study in 2007–2010 of a primarily woodland and shrubland site in Victoria, Australia (23) found that captive-bred brush-tailed rock-wallabies *Petrogale penicillata* placed in a holding pen prior to release exhibited stress levels consistent with maintaining good health. Stress index values measured from blood samples of released animals, were not significantly different to those of animals held in captivity before release. For both groups, the levels indicated lower levels of stress-induced cellular damage than the animals were able to mitigate. Of 41 captive-born wallabies, 24 (aged 1.1–4.3 years) were selected, following

health examinations, for transfer to a 1.3-ha pre-release enclosure. They were kept in this enclosure for 3–17 months. Shelter was provided in the enclosure but animals foraged on natural foods, except during trapping procedures. Twenty-one were then released between November 2008 and October 2010. Samples were taken from 11 that were subsequently recaptured, up to October 2010.

A study in 2007–2012 in a forest and grassland reserve in Córdoba, Argentina (24) found that captive-bred guanacos *Lama guanicoe* kept for 38–184 days in large holding pens before release had higher post-release survival than guanacos kept for 3–15 days in small holding pens. Of 25 guanacos kept for 38–184 days in large holding pens before release, 24 (96%) survived the first month of which 19 (79%) survived over one year after release. Of 113 guanacos kept for 3–15 days in small holding pens before release, only 24 (21%) survived the first month of which 17 (71%) survived over one year after release. In 2011 and 2012, twenty-five captive-bred guanacos were kept in a 20,000-m^2 holding pen for 38–184 days before release into a 24,774-ha national park. In 2007, 113 captive-bred guanacos were kept in a 1,200-m^2 holding pen and fed with alfalfa for 3–15 days before release into the same national park. Guanacos were marked and 42 individuals (6 in 2011 and 36 in 2007) were radio-tagged. Animals were monitored 2–3 times for 4–5 days during the first month post-release and 1–2 times each month for 2–3 days up to one year post-release.

A study in 2011–2014 of a dry dwarf-scrubland site in Saudi Arabia (25) found that captive-bred Arabian gazelles *Gazella arabica* kept in holding pens prior to release into a fenced reserve started breeding in the year following the first releases. Seven females gave birth in August–September of the year after the first releases and all calves survived to the year end at least. Of 49 gazelles released over three years, 10 had died by the time of the final releases. In 2011–2014, three groups of captive-born gazelles, totalling 49 animals, were released in a 2,244-km^2 fenced reserve. They were moved from a wildlife research centre and kept for 23 days to a few months in holding pens (500 × 500 m) prior to release at the reserve. Water and food were provided for three weeks following release. Released gazelles were radio-tracked from the ground and air.

A before-and-after study in 1985–2003 on a nature reserve in Xinjiang, China (26) found that following release of captive-bred animals from

a pre-release enclosure into the semi-wild (free-roaming in summer, enclosed in winter and provided with food), Przewalski's horses *Equus ferus przewalskii* increased in number. The first foals were born two years after the first releases. Over the following 11 years, 107 foals were born in the semi-wild with first-year survival of 75%. At this time, released animals formed 16 groups, comprising 127 individuals. From 2001–2013, eighty-nine horses from a captive-breeding centre were held in a pre-release enclosure (20 ha) for an unspecified period of time before being released into semi-wild conditions (free-roaming except in winter, when enclosed). The founders for the captive population were sourced from zoos in Europe and North America. The release site (and adjacent areas of Mongolia) were the last refuge of Przewalski's horse, before extinction in the wild in 1969. Released animals roamed freely from spring to fall, but were kept in a coral in winter, to enable supplementary feeding and to reduce competition with domestic horse herders.

A replicated study in 2011–2012 in two forest sites in Indiana, USA (27) found that when captive-bred Allegheny woodrats *Neotoma magister* were kept in holding pens prior to release, early survival rates were higher than those not kept in holding pens, but overall survival rates of captive-bred animals tended to be lower than those of wild resident woodrats after 4–5 months. In the first 14 days after release, seven of 16 (44%) captive-bred woodrats that were not initially kept in holding pens survived, compared to nine of 13 (69%) captive-bred woodrats that were initially kept in holding pens. After 4–5 months, captive-bred woodrats not initially kept in holding pens had significantly lower survival rates (19%) than wild-born, resident woodrats (56%). The 4-5-month survival rates of captive-bred woodrats initially kept in holding pens (31%) was also lower than wild-born, resident woodrats, but not statistically significantly lower. In April–August 2011 and 2012, a total of 29 captive-bred woodrats (>90 days old) were radio-tagged and released into two unconnected wild populations. Sixteen were directly released into the wild in 2011. Thirteen were held for two weeks in wire mesh enclosures (1.2 × 2.1 × 0.6 m) with nest boxes within the release area before release in 2012. In June–August 2011 and 2012, two samples of 16 and 17 wild-born woodrats, born that year, were radio-tagged. Captive-bred and wild-born woodrats were radio-tracked 1–7 times/week for 4–5 months after release/tagging.

A study in 2007–2014 in a grassland reserve in Corrientes Province, Argentina (28; same experimental set-up as 31) found that over half of released captive-reared or rehabilitated giant anteaters *Myrmecophaga tridactyla*, some of which were kept in holding pens and provided supplementary food, survived for at least six months. At least 18 of 31 released giant anteaters survived for a minimum of six months. Long term survival and the fate of the other 13 anteaters is not reported. In 2007–2013, thirty-one giant anteaters (18 males, 13 females; 1–8 years old) were released into a 124-km^2 private reserve. Hunting within the reserve was prohibited and livestock were absent. Twenty-two anteaters were wild-born but captive-reared, six were from zoos (origin not stated) and three were wild-born but rehabilitated in captivity from injuries. Of the 18 surviving anteaters, six had been released after a short period in a 0.5-ha pen at the release site and 12 after 7–30 days in a 7-ha pen. Supplementary food was provided for several weeks after release. In 2007–2014, thirteen anteaters were tracked for less than six months, and 18 were tracked for 6–46 months.

A study in 2006–2008 in a woodland and shrubland site in Northern Territory, Australia (29) found that captive-bred red-tailed phascogales *Phascogale calura* kept in pre-release pens prior to release into a fenced area with supplementary food and nest boxes survived for less than a year. Six captive-bred females survived for at least three months after release, with at least two of them carrying young. However, there were no sightings after the first year post-release, and the population is believed to have died out. Authors suggest that there may have been a shortage of tree hollows for nesting. In July 2006 and January–February 2007, thirty-two captive-bred phascogales were released into a 26-ha fenced reserve after spending either 10 days or over four months in a pre-release pen (3×6×2 or 4.5×3.0×2.2 m). Supplementary food was provided for one week after release. Feral cats were abundant outside of the fence. Eleven nest boxes were provided within 150m of the release pen. No information on monitoring is provided.

A randomized, controlled study in 2005 in a grassland and forest site in Victoria, Australia (30) found that captive-bred eastern barred bandicoots *Perameles gunnii* kept in holding pens prior to release into a fenced reserve had similar post-release survival and body weight compared to bandicoots released directly from captivity. Four out of six

bandicoots (67%) released after time in holding pens survived at least 22 days after release, which was similar to the five out of six bandicoots (83%) released directly that survived this period. Maximum weight loss (released from pen: 13%; released directly: 13% loss of weight when released) and final weight 3–4 weeks after release (released from pen: 97%; released directly: 98% of weight when released) were similar. Twelve adult captive-bred bandicoots were randomly divided into two groups of six. One group was kept in a 1-ha pre-release pen (500m from the eventual release site) for one week and provided supplementary food and water and the other group was released directly from captivity. Both groups were released simultaneously into a 170-ha fenced reserve, free of invasive predators. Bandicoots were radio-tracked daily, and were trapped and weighed every 4–5 days, for one month.

A controlled study in 2007–2012 in a grassland reserve in Corrientes, Argentina (31; same experimental set-up as 28) found that after being kept in holding pens and provided with supplementary food, captive-bred giant anteaters *Myrmecophaga tridactyla* released into the wild were less nocturnal in their activity patterns than were wild-born rehabilitated individuals. Captive-bred giant anteaters were proportionally less active at night than wild-born animals (43% vs 70% of activity records were at night). During 2007–2012, three captive-bred and four wild-born adult giant anteaters were released into a 124-km^2 private reserve. Wild-born animals were rehabilitated after being injured by hunters or in road accidents. Six anteaters (all wild-born and two captive-bred anteaters) were released after spending a short period of time in a 0.5 ha acclimatisation pen. The remaining 12 anteaters spent 7–30 days in a 7 ha holding pen at the release site prior to release. Supplementary food was provided in the holding pen and for several weeks after anteaters were released. Each of the seven anteaters was fitted with a radio-transmitter and tracked for 1–2 x 24 h periods/month in 2007 and 2011. The released anteaters were further monitored using 14 baited camera traps for an average of 336 days/trap in 2008–2012.

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14.27. Provide live natural prey to captive mammals to foster hunting behaviour before release

https://www.conservationevidence.com/actions/2518

- **Three studies** evaluated the effects of providing live natural prey to captive mammals to foster hunting behaviour before release. One study was in Spain[1], one was in the USA[2] and one was in Botswana[3].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (2 STUDIES)

- **Survival (2 studies):** Two studies in Spain[1] and Botswana[3] found that a rehabilitated Iberian lynx[1] and wild-born but captive-reared orphaned cheetahs and leopards[3] that were provided with live natural prey in captivity survived for between at least three months and 19 months after release.

BEHAVIOUR (1 STUDY)

- **Behaviour change (1 study):** A controlled study in the USA[2] found that captive-bred black-footed ferrets fed on live prairie dogs took longer to disperse after release but showed greater subsequent movements than did ferrets not fed with live prairie dogs.

Background

Predatory mammals held in captivity, either for rearing prior to release or for rehabilitation following injury or illness, may lose or not fully develop natural hunting abilities. This may reduce their chance of survival after release. Providing live prey to such animals in captivity may help them to retain or develop essential hunting skills.

A study in 1991–1992 in a shrubland and grassland site in Sierra Morena, Spain (1) found that a rehabilitated Iberian lynx *Lynx pardinus* that was provided with live natural prey to foster hunting behaviour survived at least three months after release. The lynx was still alive at least 93 days after release, and locations of the radio-collar suggested it had established a 220-ha territory. On 6 July 1991, a wounded male Iberian lynx kitten (approximately four months old, weighing 2.0 kg) was brought into captivity. The wounds were treated and after 43 days the lynx was moved to a 5 × 5 m outdoor enclosure. The lynx was initially fed dead prey but, after 15 days in the enclosure, it was given live rabbits *Oryctolagus cuniculus*. After 112 days the animal (weight = 4.9 kg) was fitted with a radio-collar and moved to a 1-ha enclosure where 100 live rabbits had been released. After 83 days in this enclosure, on 2 March 1992, the animal (weight = 6.0 kg) was released in a pine stand, 9 km from where it was originally found. It was monitored daily until the collar dropped off.

A controlled study in 1992 in a grassland area in Wyoming, USA (2) found that captive-bred black-footed ferrets *Mustela nigripes* fed on live white-tailed prairie dogs *Cynomys leucurus* took longer to disperse after release but showed greater subsequent movements than did black-footed ferrets not fed with live prairie dogs. Results were not tested for statistical

significance. Black-footed ferrets fed on live prairie dogs dispersed less on average during the first three days post-release (5.6 km) than did those with no experience with live prairie dogs (7.9 km). However, they had a greater average cumulative movement over any three-day period (21.2 km) than did those without live prairie dog experience (15.6 km). Between September and October 1992, twenty-nine 16.5–18-week-old captive-bred black-footed ferrets were radio-tagged and released into a 20,596-ha site. Seventeen ferrets had been fed live white-tailed prairie dogs weekly at 13–16 weeks and 12 had no experience with live prairie dogs. All ferrets were born and raised in indoor 1.5-m^2 cages. Ferrets were radio-tracked in October-November 1992.

A study in 2005–2009 in three dry savannah sites in Botswana (3) found that after being provided with live prey during captive rearing, orphaned cheetah *Acinonyx jubatus* and leopard *Panthera pardus* cubs successfully hunted live prey after release and survived for between 7 months and at least 19 months. All three cheetahs survived on naturally hunted prey after release. However, they were all shot and killed within seven months of release. The leopard hunted live prey, and remained alive 19 months after release. Three 3–6-month-old, wild-born cheetahs were taken into a rearing facility in January–February 2005. They were fed 1.5–3.0 kg of meat, six days/week. This decreased as live and dead rabbits, poultry and wild prey was gradually introduced. After 16 months, they were moved to a 100-ha enclosure stocked with live prey, primarily impalas *Aepyceros melampus* and tsessebes *Damaliscus lunatus*. They were released seven months later. The leopard was kept from October 2006 (when six months old) and released after 18 months in a holding facility stocked with live prey. Animals were satellite-tracked until death for the cheetahs (seven months) and for 19 months for the leopard (to November 2009).

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(2) Biggins D.E., Vargas A., Godbey J.L. & Anderson S.H. (1999) Influence of prerelease experience on reintroduced black-footed ferrets (*Mustela nigripes*). *Biological Conservation*, 89, 121–129.

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rehabilitation of orphaned large felids. *South African Journal of Wildlife Research*, 41, 11–20.

14.28. Train captive-bred mammals to avoid predators

https://www.conservationevidence.com/actions/2520

- **Two studies** evaluated the effects of training captive-bred mammals to avoid predators. One study was in Australia[1] and one was in the USA[2].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (1 STUDY)

- **Survival (1 study):** A randomized, controlled study in the USA[2] found that training captive-born juvenile black-tailed prairie dogs, by exposing them to predators, increased post-release survival.

BEHAVIOUR (1 STUDY)

- **Behaviour change (1 study):** A before-and-after study in Australia[1] found that rufous hare-wallabies could be conditioned to become wary of potential predators.

Background

Mammals raised in captivity, free of predators, may be poorly adapted if released into areas where they are likely to encounter predators. It may be possible to train captive animals to avoid predators once they are released. This intervention covers specifically training attempts on captive-bred mammals. For wild mammals, see: *Invasive and problematic species -Train mammals to avoid problematic species*.

A before-and-after study in 1992 on captive animals at a site in Australia (1) found that rufous hare-wallabies *Lagorchestes hirsutus* could be conditioned to become wary of potential predators. Hare-wallabies spent more time out of sight of a model of a fox *Vulpes vulpes* or cat

Felis catus after being subject to aversive conditioning (37–45%) than before (27–33%). Observations were made on 22 captive hare-wallabies. Training involved either a cat or fox model. One version appeared from a box at the same time as a loud noise and moved across the pen, accompanied by a recording of hare-wallaby alarm calls. The other model version jumped at hare-wallabies that approached to ≤3 m, with the animal squirted from a water pistol at the same time. Initial data collection was carried out over three nights, training (use of aversion techniques) was over three nights and subsequent behaviour in the presence of the model was measured on one night. Experiments were conducted in September–October 1992.

A randomized, controlled study in 2002–2003 on grassland at a captive facility and at a reintroduction site in New Mexico, USA (2) found that training captive-born juvenile black-tailed prairie dogs *Cynomys ludovicianus*, by exposing them to predators, enhanced post-release survival. Prairie dogs 'trained' using black-footed ferrets *Mustela nigripes*, red-tailed hawks *Buteo jamaicensis* and prairie rattlesnakes *Crotalus viridis* had greater survival one year post-release than did untrained prairie dogs (data not presented). During captive trials, only the hawk elicited fleeing behaviour. The rattlesnake caused trained juveniles to spend more time being vigilant and making alarm noises and to spend less time in shelters than untrained juveniles. In spring 2002, eighteen captive-born juvenile prairie dogs were randomly assigned to training or non-training groups. Both groups had four tests/week for two weeks. Each test involved either a predator stimulus for the training group (live ferret, live rattlesnake or stuffed red tailed hawk, each accompanied by prairie dog alarm calls) or a non-predator control for the untrained group (live desert cottontail *Sylvilagus audubonii*). Prairie dogs were then released into a vacant colony in June 2002. Post-release survival was determined by live-trapping.

(1) McLean I.G., Lundie-Jenkins G. & Jarman P.J. (1996) Teaching an endangered mammal to recognise predators. *Biological Conservation*, 75, 51–62.

(2) Shier D.M. & Owings D.H. (2006) Effects of predator training on behavior and post-release survival of captive prairie dogs (*Cynomys ludovicianus*). *Biological Conservation*, 132, 126–135.

14.29. Release captive-bred mammals into fenced areas

https://www.conservationevidence.com/actions/2521

- **Fourteen studies** evaluated the effects of releasing captive-bred mammals into fenced areas. Nine studies were in Australia[1,2,3,6,7,8,11,13,14] and one each was in Jordan[4], South Africa[5], the USA[9], Saudi Arabia[10] and Senegal[12].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (14 STUDIES)

- **Abundance (5 studies):** Four studies (one replicated) and a review in Australia[1,6,7], Jordan[4] and Senegal[12] found that after releasing captive-bred animals into fenced areas, a population of burrowing bettongs[1] increased, a population of Arabian oryx[4] increased six-fold in 12 years, a population of dorcas gazelle[12] almost doubled over four years, three populations of eastern barred bandicoot[6] initially increased and abundance of eastern barred bandicoots[7] increased.
- **Reproductive success (6 studies):** Four studies and a review in South Africa[5], Australia[6,14], Saudi Arabia[10] and Senegal[12] found that following release of captive-bred animals into fenced areas (in some cases with other associated management), African wild dogs[5], three populations of eastern barred bandicoot[6], dorcas gazelle[12] and most female black-footed rock-wallabies[14] reproduced, and Arabian gazelles[10] started breeding in the year following the first releases. A study in Australia[8] found that four of five mammal populations[8] released into a predator-free enclosure and one released into a predator-reduced enclosure reproduced, whereas two populations released into an unfenced area with ongoing predator management did not survive to reproduce.
- **Survival (10 studies):** A study in Australia[8] found that four of five mammal populations[8] released into a predator-free enclosure and one population released into a predator-reduced enclosure survived, whereas two populations released into an unfenced area with ongoing predator management did

not. Six studies (one controlled before-and-after study and two replicated studies) in Australia[2,3,6,7,14] and the USA[9] found that following release of captive-bred animals into fenced areas (in some cases with other associated management), a burrowing bettong[2] population, three eastern barred bandicoot[6] populations and over half of black-footed rock-wallabies[14] survived between one and eight years, most captive-bred hare-wallabies[3] survived at least two months, at least half of black-footed ferrets[9] survived more than two weeks, and bandicoots[7] survived at five of seven sites up to three years after the last release. One study in Australia[11] found that following release into fenced areas, a captive-bred population of red-tailed phascogales[11] survived for less than a year. A study in South Africa[5] found that captive-bred African wild dogs[5] released into fenced reserves in family groups had high survival rates. A randomized, controlled study in Australia[13] found that captive-bred eastern barred bandicoots[13] released into a fenced reserve after time in holding pens had similar post-release survival compared to bandicoots released directly from captivity.

- **Condition (1 study):** A randomized, controlled study in Australia[13] found that captive-bred eastern barred bandicoots released into a fenced reserve after time in holding pens had similar post-release body weight compared to those released directly from captivity.

BEHAVIOUR (0 STUDIES)

Background

Captive-bred mammals may be released into fenced areas. This may be done to keep them within a certain area (e.g. a game reserve), or to keep predators or other problem species out of an area to increase their chances of survival. Here fenced areas refer to those that are large enough to cover the home ranges of the target species. Studies that use smaller holding or pre-release pens before releasing captive-bred mammals into the wild are covered in *Use holding pens at release site prior to release of captive-bred mammals.*

See also: *Release translocated mammals into fenced areas.*

A study in 1993–1999 on an arid peninsula in Western Australia, Australia (1) found that following release into a fenced area where invasive species had been eradicated, a population of burrowing bettongs *Bettongia lesueur* increased. In 1999, six years after initial releases, the population was estimated at 263–301 bettongs, with 340 individuals born between 1995 and 1999. The population died out due to fox incursion in 1994, but was re-established with further releases. In 1990, a 1.6-m tall wire mesh fence (with an external overhang, an apron to prevent burrowing and two electrified wires) was erected to enclose a 12-km^2 peninsular, within which foxes *Vulpes vulpes* and cats *Felis catus* were eliminated by poisoning in 1991 and 1995, respectively. Outside the fence foxes were controlled by biannual aerial baiting with meat containing 1080 toxin, distributed at 10 baits/km^2 over 200 km^2. From October 1993, an additional 200 baits/month were distributed along the fence and roads across the study area. Cats were controlled by trapping and poisoning in a 100 km^2 buffer zone. In May 1992 and September 1993, twenty-two wild-caught bettongs were transferred to an 8-ha *in-situ* captive-breeding pen. In September 1993 and October 1995, 20 wild-caught bettongs were translocated to range freely in the reserve. From 1993–1998, one hundred and fourteen captive-bred bettongs were released. Artificial warrens, supplementary food and water were provided in 1993, but not for later releases. Eighty released bettongs were radio-tagged. From 1991–1995, European rabbits *Oryctolagus cuniculus* were controlled within the fenced area using 1080 'one shot' oats. Bettongs were monitored every three months using cage traps set over two consecutive nights, at both 100-m intervals along approximately 40 km of track, and at warrens used by radio-collared individuals.

A study in 1998–2000 in an arid protected area in Western Australia, Australia (2) found that after releasing captive-bred burrowing bettongs *Bettongia lesueur* into a fenced area without predators, the population persisted for at least eight years. In 1992 an unspecified number of bettongs were released onto a 1,200-ha peninsula, fenced to exclude predators. In July 1998, February and August 1999, and February 2000, the population was surveyed using unspecified methods.

A controlled before-and-after study in 2001 in five shrubland sites in Western Australia, Australia (3) found that most captive-bred banded hare-wallabies *Lagostrophus fasciatus* and rufous hare-wallabies

Lagorchestes hirsutus released into a fenced peninsula (with predator control, supplementary food and water and, in some cases, holding pens prior to release), survived at least two months, although rufous hare-wallabies lost body condition while awaiting release in holding pens. After 1–2 months, 10 of 16 rufous hare-wallabies and 12 of 18 banded hare-wallabies were still alive. Overall both rufous and banded hare-wallabies recaptured had similar body conditions to when they were released, although rufous hare-wallabies lost 12% of body condition while waiting for release in holding pens (data presented as a body condition index; see paper for details). Sixteen captive-bred rufous hare-wallabies and 18 captive-bred banded hare-wallabies were released at five sites in August 2001. Six rufous and nine banded-hare wallabies were placed in separate 3-ha enclosures with electrified fencing for 10–19 days before being released. Remaining animals were released directly into the wild. Supplementary food (kangaroo pellets, alfalfa) and water were made available to all hare-wallabies (those kept in holding pens and those not; duration of feeding not given). Hare-wallabies were monitored by radio tracking (once/ week for 1.5 years after release) and live-trapping (at 4 and 8–9 weeks after release). Release areas were within a fenced peninsula where multiple introduced mammals were controlled (cats *Felis catus* and goats *Capra hircus*) or eradicated (red fox *Vulpes vulpes*).

A study in 1978–1995 in a desert reserve in Jordan (4) found that following release into a fenced area, a population of captive-bred Arabian oryx *Oryx leucoryx* increased six-fold in 12 years. The herd numbered 186 animals in 1995, after being founded from 31 oryx in 1983. The project began in 1978, with 11 captive-bred founder animals (six females and five males) held in breeding pens. In 1983, thirty-one oryx were released from these pens into the 342-km^2 Shaumari Nature Reserve, but were fenced into a 22-km^2 sub-section of the reserve in 1984 to exclude domestic grazing animals. An additional three males were introduced in 1984. Release outside the fenced reserve was prevented by in influx of pastoralists displaced from a war zone. From 1997 to 2006, one hundred and five oryx were moved to other reserves to reduce overcrowding. By 2006, forty-three oryx remained in the reserve. Oryx numbers were obtained from the reserve records and independent reports.

A study in 1995–2005 in 12 dry savanna and temperate grassland sites in South Africa (5) found that translocated and captive-bred

African wild dogs *Lycaon pictus* released into fenced reserves in family groups had high survival rates and bred successfully. Eighty-five percent of released animals and their wild-born offspring survived the first six months after release/birth. Released animals which survived their first year had a high survival rate 12–18 months (91%) and 18–24 months (92%) after release. Additionally, groups which had more time to socialise in holding pens prior to release had higher survival rates (data presented as statistical models). Between 1995 and 2005, one hundred and twenty-seven wild dogs (79 wild-caught, 16 captive-bred, 16 wild-caught but captive-raised, 16 'mixed' pups) were translocated over 18 release events into 12 sites in five provinces of South Africa. Animals were monitored for 24 months after release, and the 129 pups which they produced after release were monitored up to 12 months of age. Forty characteristics of the individual animals, release sites and methods of release were recorded, and their impact on post-release survival was tested.

A review of eight studies in 1989–2005 in eight grassland and woodland sites in Victoria, Australia (6) found that three captive-bred eastern barred bandicoot *Perameles gunnii* populations that were released into fenced areas with associated management survived between 1 and 15 years, animals were breeding and populations increased in size at least initially. In two studies, bandicoots were released into fenced areas and populations increased for at least five years after releases began and there was evidence of breeding and wild-born pouch young maturing to adults. These populations subsequently declined to low numbers 12–15 years after the original releases began. A further population released into a fenced area survived at least one year and both pouch young and wild-born adults were observed. Of five studies where bandicoots were not released into a fenced area, one population survived over at least seven years, two populations were extinct after five years, and two populations declined and management ceased (due to low detection rates) after 9–10 years. Between 22 and 207 bandicoots were released into three fenced areas (100–585 ha) and 50 to 103 bandicoots were released into unfenced areas (85–500 ha) in 1989–2005. All bandicoots were captive-bred. Bandicoots were released in stages in each site. Red fox *Vulpes vulpes* were controlled in all three fenced areas and four of five unfenced areas. Supplementary food was provided in two of the fenced

areas (in one for 6–10 days after release, the other was not specified). In most sites, bandicoots were monitored by live-trapping but frequency and methods are not detailed.

A replicated study in 1990–2001 in seven grassland, wetland and forest sites in Victoria, Australia (7) found that using predator-proof fencing alongside regular predator control increased abundance of captive-bred eastern barred bandicoots *Perameles gunnii* released into the wild and that bandicoots were recorded at five of seven sites up to three years after the last release. Greater amounts of predator control had a positive influence on the number of bandicoot signs found at each site (Sites with 0–2 methods of regular predator control: 0 bandicoots/site; sites with 3+ methods, including predator-proof fencing: 0.3–2 bandicoots/site). Bandicoot signs were found in five of the seven release sites (average 0.3–2 signs/quadrat) but no signs were detected in two sites. At each of seven sites (88–500 ha), 50–129 captive-bred eastern barred bandicoots were released between 1990 and 1999. Combinations of regular predator control methods were employed (e.g. poisoning, shooting, destruction of red fox *Vulpes vulpes* dens) differed between the sites (1 site: no predator control; 1 site: 2 methods used; 2 sites: 3 methods used (including 1 site with partial fencing); 3 sites: 4 methods used (including 1 site with full predator-proof fencing). Bandicoot signs (fresh diggings and scats) were collected at 10 randomly distributed 5-m^2 quadrats/site on two occasions in 2000–2001.

A study in 1998–2010 in a desert site in South Australia (8) found that four of five mammal populations released into a predator-free enclosure and one population released into a predator-reduced enclosure survived, increased their distribution and produced a second generation, whereas two populations released into an unfenced area with ongoing predator management did not persist. After release into a fenced enclosure where red foxes *Vulpes vulpes*, cats *Felis catus* and rabbits *Oryctolagus cuniculus* had been eradicated, greater stick-nest rats *Leporillus conditor*, burrowing bettongs *Bettongia lesueur*, western barred bandicoots *Perameles bougainville* and greater bilbies *Macrotis lagotis* were detected for eight years, increased their distribution within five years and reproduced within two years. Numbats *Myrmecobius fasciatus* were only detected for three years and did not produce a second generation. Burrowing bettongs released into a fenced enclosure with cats and

rabbits but no foxes survived and increased their distribution over at least three years and produced a second generation within two years. Greater bilbies and burrowing bettongs released into an unfenced area with some predator management did not survive to produce a second generation or increase their distribution. In 1998–2005, five numbats, 106 greater stick-nest rats (6 captive-bred individuals), 30 burrowing bettongs, 12 western barred bandicoots and nine greater bilbies (all captive-bred) were released into a 14-km^2 invasive-species-free fenced area. Rabbits, cats and foxes were eradicated within the fenced area in 1999. All western barred bandicoots and greater bilbies, and some greater stick-nest rats (8 individuals) and burrowing bettongs (10 individuals) were put into a 10-ha holding pen before full release after a few months. All other animals were released directly into the larger fenced area. In 2004–2008, thirty-two greater bilbies and 15 burrowing bettongs were translocated to an unfenced area (200 km^2) where invasive predators (cats and foxes) were managed with lethal controls and dingoes *Canis lupus dingo* were excluded by a fence on one side. In 2008, sixty-six burrowing bettongs were translocated to a 26 km^2 fenced area which contained small cat and rabbit populations as a result of previous eradication attempts. Between 2000 and 2010, animals were monitored using track counts, burrow monitoring and radio-tracking.

A replicated study in 1996–1997 in three grassland sites in South Dakota, USA (9) found that at least half of captive-bred black-footed ferrets *Mustela nigripes* released into fenced areas where predators were managed survived more than two weeks. At each of the three sites, 48% (12 of 25), 50% (9 of 18) and 89% (32 of 36) of captive-bred ferrets released into the wild survived for at least two weeks (long-term survival is not reported). Overall, twenty-four ferrets were killed by native predators (mostly great-horned owls *Bubo virginianus* and coyotes *Canis latrans*) and the cause of death of two others could not be determined. A total of 79 captive-bred black-footed ferrets were released across three mixed-grass prairie sites (18–36 ferrets/site) in September–October 1996 and October–November 1997. A 107 cm high electric fence was installed in each release site (creating 2 km^2 enclosures) and activated 1–2 weeks prior to ferrets being released. Ferrets were able to move in and out of the fenced areas. Low-to-moderate lethal coyote control took place for 2–3 weeks each year prior to ferrets being released. Each of the 79 ferrets

was radio-tagged and tracked every 5–30 min/night for two weeks post-release in 1996–1997.

A study in 2011–2014 of a dry dwarf-scrubland site in Saudi Arabia (10) found that captive-bred Arabian gazelles *Gazella arabica* released into a fenced reserve after being kept in holding pens started breeding in the year following the first releases. Seven females gave birth in August–September of the year after the first releases and all calves survived to the year end at least. Of 49 gazelles released over three years, 10 had died by the time of the final releases. In 2011–2014, three groups of captive-born gazelles, totalling 49 animals, were released in a 2,244-km^2 fenced reserve. They were moved from a wildlife research centre and kept for 23 days to a few months in holding pens (500 × 500 m) prior to release at the reserve. Water and food were provided for three weeks following release. Released gazelles were radio-tracked from the ground and air.

A study in 2006–2015 in two woodland and shrubland sites in Western Australia and Northern Territory, Australia (11) found that following release into fenced areas, a captive-bred population of red-tailed phascogales *Phascogale calura* survived for less than a year, whereas a translocated population survived for more than five years. A population of phascogales established from wild-caught animals survived longer (>5 years) than a population established from captive-bred animals (which had been kept in pre-release pens and given supplementary food; < 1 year). Authors suggest that the unsuccessful site may also have had a shortage of tree hollows for nesting. In July 2006 and January–February 2007, thirty-two captive-bred phascogales were released into a 26-ha fenced reserve (outside which feral cats *Felis catus* were abundant) after spending either 10 days or over four months in a pre-release pen (3×6×2 or 4.5×3×2.2 m). Eleven nest boxes were provided within 150m of the release pen, and supplementary food was provided for one week after release. In April 2009 and June 2010, twenty-seven wild-caught phascogales were released into a 430-ha fenced reserve with 22 nest boxes, but with no pre-release pen or supplementary food. From November 2010–January 2013, thirteen additional boxes were installed inside (four) and outside (nine) the fenced area at this site. Phascogales were monitored after each release using radio-collaring or Elliott live traps, and through periodic monitoring of the nest boxes.

A study in 2009–2013 in a restored savanna site in Katané, Senegal (12) found that a population of captive-bred dorcas gazelle *Gazella dorcas neglecta* released into a fenced area reproduced successfully and almost doubled in number over four years. Over four years after release, the gazelle population increased from 26 to 50 individuals. Thirty-one births and 15 deaths were recorded. Twenty-three (nine male, 14 female) captive-bred dorcas gazelles were released into a fenced enclosure in March 2009 and a further three males were released in November 2010. The enclosure was initially 440 ha but was enlarged by 200 ha in 2010. Released gazelles shared the enclosure with scimitar-horned oryx *Oryx dammah*, mhorr gazelles *Nanger dama mhorr* and red-fronted gazelles *Eudorcas rufifrons*. Small and medium-sized animals, including predators, could pass through the enclosure fence. Natural vegetation was restored prior to the release. Dorcas gazelles were ear-tagged and monitored through direct observations twice daily during 2–3 surveys/season from June 2009 to March 2013.

A randomized, controlled study in 2005 in a grassland and forest site in Victoria, Australia (13) found that captive-bred eastern barred bandicoots *Perameles gunnii* released into a fenced reserve after time in holding pens had similar post-release survival and body weight compared to bandicoots released directly from captivity. Four out of six bandicoots (67%) released after time in holding pens survived at least 22 days after release, which was similar to the five out of six bandicoots (83%) released directly that survived this period. Maximum weight loss (released from pen: 13%; released directly: 13% loss of weight when released) and final weight 3–4 weeks after release (released from pen: 97%; released directly: 98% of weight when released) were similar. Twelve adult captive-bred bandicoots were randomly divided into two groups of six. One group was kept in a 1-ha pre-release pen (500m from the eventual release site) for one week and provided supplementary food and water and the other group was released directly from captivity. Both groups were released simultaneously into a 170-ha fenced reserve, free of exotic predators. Bandicoots were radio-tracked daily, and were trapped and weighed every 4–5 days, for one month.

A study in 2011–2014 in a semi-arid area in South Australia, Australia (14) found that over half of captive-reared black-footed rock-wallabies *Petrogale lateralis* released into a large fenced area survived at least 20

months and most females reproduced. Ten (five males, five females) of 16 captive-raised black-footed rock-wallabies (63%) survived at least 20 months after release into a fenced area. All five females that survived reproduced within 2–6 months of release. Over three years, 28 births from nine females were recorded. Between March 2011 and July 2012, sixteen captive-reared black-footed rock-wallabies (eight males, eight females; 1–5 years old) were released into a 97-ha fenced area. The fence included a floppy overhang to deter predator entry. Ten of the 16 black-footed rock-wallabies were wild-born and fostered by yellow-footed rock-wallaby *Petrogale xanthopus* surrogate mothers in captivity. Introduced predators, common wallaroos *Macropus robustus* and European rabbits *Oryctolagus cuniculus* were removed from the enclosure by September 2012. Supplementary water was provided in five 8-l tanks that were monitored with camera traps in 2011–2014. Wallabies were fitted with radio-collars and tracked 1–7 times/week in 2011–2014. Trapping was carried out on seven occasions in 2011–2014.

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14.30. Provide supplementary food during/after release of captive-bred mammals

https://www.conservationevidence.com/actions/2527

- **Fifteen studies** evaluated the effects of providing supplementary food during/after release of captive-bred mammals. Four studies were in Australia[2,9,10,14], two were in each of the USA[5,8], China[7,12] and Argentina[13,15], and one was in each of Poland[1], the UK[3,4], Oman[6] and Saudi Arabia[11].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (14 STUDIES)

- **Abundance (5 studies):** Four studies (one replicated, one before-and-after study) and one review in Poland[1], Oman[6], China[7,12] and Australia[10] found that following provision of supplementary food (and in one case water) to released captive-bred animals, populations of European bison[1] increased more than six-fold over 20 years, Arabian oryx[6] increased over 14 years, eastern-barred bandicoots[10] increased for the first five years before declining, Père David's deer[7] increased more than six-fold over 12 years and Przewalski's horses (enclosed in winter)[12] increased over 11 years.
- **Reproductive success (9 studies):** Eight studies (including two replicated and one before-and-after study) and one review in Poland[1], the UK[3,4], China[7,12], the USA[8], Australia[2,10] and Saudi Arabia[11] found that following the provision of supplementary food (and in one case water or artificial nests) after release of captive-bred animals, some from holding pens, European bison[1], European otters[3,4], Père David's deer[7], eastern-barred bandicoots[10], Przewalski's horses[12] and some captive-bred red wolves[8] successfully reproduced, Arabian gazelles[11] started breeding in the year following releases and sugar gliders[2] established a breeding population.
- **Survival (6 studies):** Four of six studies (one controlled, before-and-after study) in the UK[4], USA[5,8], Argentina[13] and Australia[9,14] found that following the provision of supplementary food (and in one case water or nest boxes) after release of captive-bred animals, many from holding pens, 19% of red wolves[8] survived for at least seven years, Eurasian otters[4] survived for at least two years, over half the giant anteaters (some rehabilitated)[13] survived for at least six months and hare-wallabies[9] survived at least two months. Two of the studies found that red-tailed phascogales[14] survived for less than a year and most Mexican wolves[5] survived less than eight months.

BEHAVIOUR (1 STUDY)

- **Behaviour change (1 study):** A controlled study in Argentina[15] found that after being provided with supplementary food and kept in holding pens, released captive-bred giant anteaters were less nocturnal in their activity patterns than released wild-born rehabilitated individuals.

Background

Mammals that are captive-bred are especially vulnerable immediately after release. At this time, they may struggle to find natural food in an unfamiliar area. Furthermore, if the time they spend looking for food is increased, this may make them more vulnerable to predation. Hence, providing supplementary food at and after the period of release may improve longer term survival prospects.

See also: *Provide supplementary food during/after release of translocated mammals.*

A study in 1952–1973 in a mixed forest site in Białowieża, Poland (1) found that captive-bred European bison *Bison bonasus* provided with supplementary food after being released into the wild bred successfully and the population increased more than six-fold over 20 years. The population increased to 253 individuals (112 males, 141 females) during 20 years in which 38 captive-bred bison were released. A total of 316 births and 67 deaths were recorded. In 1952–1972, thirty-eight captive-bred bison were released from reserves into the western Białowieża Primeval Forest (580 km^2 area). Supplementary food (hay) was provided each winter. Numbers of bison and the number of births and deaths in the population were counted by observers each year in 1952–1973.

A study in 1979–1981 at a young planted native forest reserve in Victoria, Australia (2) found that released, captive-bred sugar gliders *Petaurus breviceps* provided with supplementary food and artificial nest hollows appeared to establish a breeding population. In the third year after releases began, approximately 37 sugar gliders were recorded. Of 17 females caught, 10 were over one year old. All six females that were

over two years old had bred. Seven of the 32 animals caught had been wild-bred in the year after the first releases. Sugar gliders were almost all located near to where artificial nest hollows were installed and 58 of 70 were either occupied or showed signs of recent occupation. On a 130-ha island of planted native forest (trees ≤17 years old), 26 captive-bred juvenile gliders (12 male, 14 female) were released in February 1979. Thirty-four (21 male, 13 female) were released in January–February 1980. Twelve (six male, six female) were released in February 1981. Seventy artificial nest hollows (boxes, hollow branches and pipes) were installed. Supplementary food was provided at release points during winters of 1979 and 1980. Gliders were surveyed in May 1981, by live-trapping, using 54 traps for up to four nights, supplemented by sightings of animals flushed from nest hollows.

A replicated study in summer 1983–1984 at a riparian site in East Anglia, UK (3) found that captive-bred European otters *Lutra lutra* provided with supplementary food after being kept in a pre-release pen bred successfully following release. Footprints of at least one otter cub were found in the year after release. Otters settled near the release site, but ranged along 32 km of river over the first 100 days after release. In July 1983, three 18-month-old captive-bred otters (one male, two female) were released. Before release, they were held together in a pen at the release site, for an unspecified period of time. After release, supplementary food was provided in the pens for 12 days. The male otter was radio-tracked for 50 nights after release. Local bridges were monitored for 100 days after release for signs of otter faeces.

A study in 1983–1985 along a river on the Norfolk-Suffolk border, UK (4) found that following the short-term provision of supplementary food after release from holding pens, captive-bred Eurasian otters *Lutra lutra* survived at the release site for at least two years and reproduced. The otters survived in the release area at least 28 months after release. Breeding was confirmed the summer after release and suspected again the following summer. On the first night, otters were fed prior to being released. They returned to feed on the second, third and fifth to seventh nights but after that food was untouched. Spraint analysis suggested they were catching fish from the fourth night. One male and two female otters (captive-bred and unrelated) were kept in a large pen with a pool where they had limited contact with humans from

10 months to 18 months of age. In June 1983, at 18 months, they were moved to a 9 × 15-m pre-release pen, 10 m from a river bank, on a river island. After 20 days, the pen door was fixed open. Food was placed in the pen daily for 12 days after release in diminishing quantities and uneaten food was cleared away. The male was radio-tracked for 50 days from 5 July 1983. Otter signs (especially spraints) were then monitored until 1985.

A study in 1998 in a grassland, shrubland and forest reserve in Arizona, USA (5) found that most captive-bred Mexican wolves *Canis lupus baileyi* provided with supplementary food after being kept in holding pens and released in groups did not survive over eight months after release into the wild. Out of 11 captive-bred Mexican wolves released, six (55%) were illegally killed within eight months, three (27%) were returned to captivity and two (18%) survived in the wild for at least one year (long-term survival not reported). Three weeks after their release, three individuals from one family group killed an adult elk *Cervus canadensis*. Two females gave birth two months after release but only one pup survived. Eleven wolves in three family groups were released in March 1998. Before release, wolves were kept for two months in pre-release holding pens, where they were fed carcasses of native prey. Carcasses were provided as supplementary food for two months post-release when sufficient killing of prey was confirmed. The released wolves were fitted with radio-collars. No monitoring details are provided.

A study in 1982–1996 of a large desert area in Oman (6) found that a reintroduced captive-bred Arabian oryx *Oryx leucoryx* population initially provided with supplementary food and water grew in number over 14 years, but then declined, due to poaching. Oryx numbers in the wild peaked at >400 animals, 1–14 years after release of 40 animals. Poachers (capturing live animals, especially females, for international trade) then removed at least 200 oryx over the next three years. Animals were taken back into captivity to re-establish a captive breeding program. Seventeen years after releases began, the captive population was 40, and approximately 104 remained in the wild, with a high male:female sex ratio. Arabian oryx became extinct in Oman in 1972. Founders for the initial captive herd were sourced from international collections. Forty individually marked oryx were

released in 1982–1995. A sample of wild-born animals was individually marked to retain the marked proportion at 20–30%. The original released herd was provided with food and water for seven months after release. Population estimates were derived from sightings using mark-recapture analysis.

A replicated study in 1985–1997 in two grassland reserves in Jiangsu and Beijing, China (7) found that captive-bred Père David's deer *Elaphurus davidianus* released into the wild and provided with supplementary food in the winter bred successfully and increased in number more than six-fold over 12 years. In one reserve, numbers of Père David's deer were more than six times higher 12 years after release (127 deer) than at the time of release (20 deer). At a second reserve, numbers were more than seven times higher 11 years after release (302 deer) than at the time of release (39 deer). Average annual birth and death rates were 53% and 9% respectively at one site, and 54% and 3% at the other. Wild offspring translocated from the first site to another fenced area in China survived at least two years post-relocation and reproduced in the second year. In 1985–1987, thirty-seven captive-bred deer were released into a reserve (60 ha). In 1986, thirty-nine captive-bred deer were released into three fenced paddocks (each 100 ha) at a second reserve. In 1992–1996, twenty-one deer from one population and 134 deer from the other were moved to other sites. Supplementary food was provided in both reserves during the winter. The deer populations were monitored for 11–12 years after release in 1985–1997. Details of monitoring methods are not provided.

A study in 1987–1994 in a grassland site in North Carolina, USA (8) found that having provided supplementary food after release (after some animals were kept in holding pens), 12 of 63 captive-bred red wolves *Canis lupus rufus* survived for at least seven years, and some animals successfully reproduced. Seven years after wolves were first reintroduced, 12 of 63 translocated animals were still alive. By the same time, at least 66 pups had been born. Between October 1987 and December 1994, sixty-three captive-bred wolves were released. Twenty-nine wolves were held in pens (225 m^2) on site before release (duration: 14 days-49 months), and 34 animals were released on arrival at the site. An unspecified number of wolves were fitted with radio-collars. From October 1987 to December 1994, wolves were radio-tracked from the

ground and from an aeroplane. Monitoring frequency was not specified. Supplementary food (deer carcasses) was provided for 1–2 months after release from the ninth release onwards.

A controlled, before-and-after study in 2001 in five shrubland sites in Western Australia, Australia (9) found that most captive-bred banded hare-wallabies *Lagostrophus fasciatus* and rufous hare-wallabies *Lagorchestes hirsutus* provided with supplementary food and water (and in some cases having been in holding pens) survived at least two months after being released into a fenced peninsula where predators had been controlled. After 1–2 months, 10 of 16 rufous hare-wallabies and 12 of 18 banded hare-wallabies were still alive. Overall both rufous and banded hare-wallabies recaptured had similar body conditions to when they were released, although rufous hare-wallabies lost 12% of body condition while waiting for release in holding pens (data presented as a body condition index; see paper for details). Sixteen captive-bred rufous hare-wallabies and 18 captive-bred banded hare-wallabies were released at five sites in August 2001. Six rufous and nine banded-hare wallabies were placed in separate 3-ha enclosures with electrified fencing for 10–19 days before being released. Remaining animals were released directly into the wild. Supplementary food (kangaroo pellets, alfalfa) and water were made available to all hare-wallabies (those in holding pens and those not; duration of feeding not given). Hare-wallabies were monitored by radio tracking (once per week for 1.5 years after release) and live-trapping (at 4 and 8–9 weeks after release). Release areas were within a fenced peninsula where multiple introduced mammals were controlled or eradicated.

A review of eight studies in 1989–2005 in eight grassland and woodland sites in Victoria, Australia (10) found that in two studies where captive-bred eastern-barred bandicoots *Perameles gunnii* were given supplementary food as part of a release program, the populations survived and bred in the wild, increasing for the first five years prior to declining. Two captive-bred bandicoot populations provided with supplementary food increased for at least five years after releases began and there was evidence of breeding and wild-born pouch young maturing to adults. These populations subsequently declined to low numbers 12–15 years after the original releases began. Between 174 and 207 bandicoots were released into 100–300 ha fenced predator-free

enclosures in 1989–2004. Bandicoots were released in stages in each site. Supplementary food was provided in both sites (in one for 6–10 days after release, the other was not specified). Red fox *Vulpes vulpes* were controlled in both sites. Bandicoots were monitored by live-trapping but frequency and methods are not detailed.

A study in 2011–2014 of a dry dwarf-scrubland site in Saudi Arabia (11) found that captive-bred Arabian gazelles *Gazella arabica* provided supplementary food and water after release into a fenced reserve started breeding in the year following the first releases. Seven females gave birth in August–September of the year after the first releases and all calves survived to the year end at least. Of 49 gazelles released over three years, 10 had died by the time of the final releases. In 2011–2014, three groups of captive-born gazelles, totalling 49 animals, were released in a 2,244-km^2 fenced reserve. They were moved from a wildlife research centre and kept for 23 days to a few months in holding pens (500 × 500 m) prior to release at the reserve. Water and food was provided for three weeks following release. Released gazelles were radio-tracked from the ground and air.

A before-and-after study in 1985–2003 on a nature reserve in Xinjiang, China (12) found that following release of captive-bred Przewalski's horses *Equus ferus przewalskii* into the semi-wild (free-roaming in summer, enclosed in winter and provided with food), animals reproduced and numbers increased. The first foals were born two years after the first releases. Over the following 11 years, 107 foals were born in the semi-wild with first-year survival of 75%. At this time, released animals formed 16 groups, comprising 127 individuals. From 2001–2013, eighty-nine horses from a captive-breeding centre were held in a pre-release enclosure (20 ha) for an unspecified period of time before being released into semi-wild conditions. Released animals roamed freely from spring to fall, but were kept in a coral in winter, to enable supplementary feeding and to reduce competition with domestic horse herders. The founders for the captive population were sourced from zoos in Europe and North America. The release site (and adjacent areas of Mongolia) were the last refuge of Przewalski's horse, before extinction in the wild in 1969.

A study in 2007–2014 in a grassland reserve in Corrientes Province, Argentina (13; same experimental set-up as 15) found that over half of

released captive reared or rehabilitated giant anteaters *Myrmecophaga tridactyla*, some of which were provided supplementary food and initially kept in holding pens, survived for at least six months. At least 18 of 31 (58%) released giant anteaters survived for a minimum of six months. Long term survival and the fate of the other 13 anteaters is not reported. In 2007–2013, thirty-one giant anteaters (18 males, 13 females; 1–8 years old) were released into a 124-km^2 private reserve. Hunting within the reserve was prohibited and livestock were absent. Twenty-two anteaters were wild-born but captive-reared, six were from zoos (origin not stated) and three were wild-born but rehabilitated in captivity from injuries. Of the 18 surviving anteaters, six had been released after a short period in a 0.5-ha pen at the release site and 12 after 7–30 days in a 7-ha pen. Supplementary food was provided for several weeks after release. In 2007–2014, thirteen anteaters were tracked for less than six months, and 18 were tracked for 6–46 months.

A study in 2006–2008 in a woodland and shrubland site in Northern Territory, Australia (14) found that captive-bred red-tailed phascogales *Phascogale calura* that were initially given supplementary food when released into a fenced area with nest boxes, having been kept in pre-release pens, survived for less than a year. Six captive-bred females survived for at least three months after release, with at least two of them carrying young. However, there were no sightings after the first year post-release, and the population is believed to have died out. Authors suggest that there may have been a shortage of tree hollows for nesting. In July 2006 and January–February 2007, thirty-two captive-bred phascogales were released into a 26-ha fenced reserve after spending either 10 days or over four months in a pre-release pen (3×6×2 or 4.5×3×2.2 m). Supplementary food was provided for one week after release. Feral cats were abundant outside of the fence. Eleven nest boxes were provided within 150m of the release pen. No information on monitoring is provided.

A controlled study in 2007–2012 in a grassland reserve in Corrientes, Argentina (15; same experimental set-up as 13) found that after being provided with supplementary food and kept in holding pens, captive-bred giant anteaters *Myrmecophaga tridactyla* released into the wild were less nocturnal in their activity patterns than were wild-born rehabilitated individuals. Captive-bred giant anteaters

were proportionally less active at night (43% activity records were at night) than wild-born animals (70% of activity records). During 2007–2012, three captive-bred and four wild-born adult giant anteaters were released into a 124-km^2 private reserve. Wild-born animals were rehabilitated after being injured by hunters or in road accidents. Six anteaters (all wild-born and two captive-bred anteaters) were released after spending a short period of time in a 0.5 ha acclimatisation pen. The remaining 12 anteaters spent 7–30 days in a 7-ha holding pen at the release site prior to release. Supplementary food was provided in the holding pen and for several weeks after anteaters were released. Each of the seven anteaters was fitted with a radio-transmitter and tracked for 1–2 x 24 h periods/month in 2007 and 2011. The released anteaters were further monitored using 14 baited camera traps for an average of 336 days/trap in 2008–2012.

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Release captive-bred/translocated mammals

14.31. Release translocated/captive-bred mammals in areas with invasive/problematic species eradication/control

https://www.conservationevidence.com/actions/2469

- **Twenty-two studies** evaluated the effects of releasing translocated or captive-bred mammals in areas with eradication or control of invasive or problematic species. Sixteen studies were in Australia[1–7,9,11,14,17–22], four were in the USA[10,12,13,16], and one in the UK[8,15].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (21 STUDIES)

- **Abundance (4 studies):** A replicated study in Australia[9] found that increasing amounts of regular predator control increased

population numbers of released captive-bred eastern barred bandicoots. Two studies in Australia[1,4] found that following eradication[1] or control[4] of invasive species, a population of translocated and released captive-bred burrowing bettongs[1] increased and a population of translocated western barred bandicoots[4] increased over four years. A study in Australia[14] found that following the release of captive-bred bridled nailtail wallabies and subsequent predator controls, numbers increased over a three years, but remained low compared to the total number released.

- **Reproductive success (2 studies):** A study in Australia[11] found that four of five captive-bred mammal populations released into a predator-free enclosure and one population released into a predator-reduced enclosure produced a second generation, whereas two populations released into an unfenced area with ongoing predator management did not survive to reproduce. A study in Australia[22] found that most female captive-reared black-footed rock-wallabies released into a large predator-free fenced area reproduced.
- **Survival (18 studies):** Ten studies (one controlled, three replicated, two before-and-after studies) in Australia[3,4,5,6,9,17,18,22], and the UK[8,15] found that following the eradication/control of invasive species (and in some cases release into a fenced area), a translocated population of woylies[3], western barred bandicoots[4] and red-tailed phascogales[18] survived over four years, released captive-bred eastern barred bandicoots[9] survived up to three years at five of seven sites, offspring of translocated golden bandicoots[17] survived three years, over half of released captive-reared black-footed rock-wallabies[22] survived over two years, captive-bred water voles[8] survived for at least 20 months[15] or over 11 months at over half of release sites, most released captive-bred hare-wallabies[6] survived at least two months, most captive-bred eastern barred bandicoots[5,20] survived for over three weeks. A replicated study in Australia[19] found that after the control of invasive species, four translocated populations of burrowing bettongs died out within four months. A review of studies in Australia[7]

found that in seven studies where red fox control was carried out before or after the release of captive-bred eastern-barred bandicoots, survival varied. A study in Australia[11] found that four of five captive-bred mammal populations released into a predator-free enclosure and one population released into a predator-reduced enclosure survived, whereas two populations released into an unfenced area with ongoing predator management did not. A study in Australia[2] found that captive-bred bridled nailtail wallabies released from holding pens in areas where predators had been controlled had similar annual survival rates to that of wild-born translocated animals. Two studies (one replicated) in the USA[10,12] found that where predators were managed, at least half of released captive-bred black-footed ferrets survived more than two weeks[12], but that post-release mortality was higher than resident wild ferrets[10]. A before-and-after study in the USA[13] found following the onset of translocations of black bears away from an elk calving site, survival of the offspring of translocated elk increased.

- **Condition (2 studies):** A study Australia[17] found that wild-born golden bandicoots, descended from a translocated population released into a predator-free enclosure, maintained genetic diversity relative to the founder and source populations. A replicated, before-and-after study in Australia[21] found that one to two years after release into predator-free fenced reserves, translocated eastern bettongs weighed more and had improved nutritional status compared to before release.

BEHAVIOUR (1 STUDY)

- **Behaviour change (1 study):** A replicated, before-and-after study in the USA[16] found that translocated Utah prairie dogs released after the control of native predators into an area with artificial burrows showed low site fidelity and different pre- and post-release behaviour.

Background

Mammals are sometimes wild-caught and translocated, or bred in captivity and released to areas where invasive predators or problematic native species have been eradicated or controlled, to re-establish populations that have been lost, or augment an existing population. Alternatively, ongoing predator control may be undertaken during and after releases. This action includes studies describing or comparing the effects of projects that release mammals after the eradication or control of invasive or problematic species, and studies where the problematic species has been controlled shortly after the release of the species of concern. However, it does not include such projects undertaken on islands, those are discussed under *Release translocated/captive-bred mammals to islands without invasive predators.*

A study in 1993–1999 on an arid peninsula in Western Australia, Australia (1) found that following eradication of invasive species from a fenced area, a released population of burrowing bettongs *Bettongia lesueur* increased. In 1999, six years after initial releases, the population was estimated at 263–301 bettongs, with 340 individuals born between 1995 and 1999. The population died out due to fox incursion in 1994, but was re-established with further releases. In 1990, a 1.6-m tall wire mesh fence (with an external overhang, an apron to prevent burrowing and two electrified wires) was erected to enclose a 12-km^2 peninsular, within which foxes *Vulpes vulpes* and cats *Felis catus* were eliminated by poisoning in 1991 and 1995, respectively. Outside the fence foxes were controlled by biannual aerial baiting with meat containing 1080 toxin, distributed at 10 baits/km^2 over 200 km^2. From October 1993, an additional 200 baits/month were distributed along the fence and roads across the study area. Cats were controlled by trapping and poisoning in a 100 km^2 buffer zone. In May 1992 and September 1993, twenty-two wild-caught bettongs were transferred to an 8-ha *in-situ* captive-breeding pen. In September 1993 and October 1995, twenty wild-caught bettongs were translocated to range freely in the reserve. From 1993–1998, one hundred and fourteen captive-bred bettongs were released.

Artificial warrens and supplementary food and water were provided in 1993, but not for later releases. Eighty released bettongs were radio-tagged. From 1991–1995, European rabbits *Oryctolagus cuniculus* were controlled within the fenced area using 1080 'one shot' oats. Bettongs were monitored every three months using cage traps set over two consecutive nights, at both 100-m intervals along approximately 40 km of track, and at warrens used by radio-collared individuals.

A study in 1996–1999 at a woodland reserve in Queensland, Australia (2) found that captive-bred bridled nailtail wallabies *Onychogalea fraenata* released from holding pens in areas where mammalian predators had been controlled had similar annual survival rates to that of wild-born translocated animals. Over four years, the average annual survival of released captive-bred bridled nailtail wallabies (57–92%) did not differ significantly from that of wild-born translocated animals (77–80%). In 1996–1998, one hundred and twenty-four captive-bred and nine wild-born translocated bridled nailtail wallabies were released into three sites across Idalia National Park. Ten captive-bred wallabies were held in a 10-ha enclosure within the reserve for six months before release, and 85 were bred within the 10-ha enclosure. All of the 133 released wallabies were kept in a holding pen (30-m diameter) for one week at each site before release. Mammalian predators were culled at release sites. A total of 67 wallabies (58 captive-bred, nine wild-born) were radio-tagged and tracked every 2–7 days in 1996–1998. Wallabies were live-trapped at irregular intervals with 20–35 wire cage traps in 1997–1999.

A study in 1992–1996 in a forest reserve in Western Australia, Australia (3) found that following baiting with poison to control red foxes *Vulpes vulpes*, a translocated population of woylies *Bettongia penicillata* persisted over four years. Four years after translocation into a site where red foxes were controlled, eight woylies were captured in one part of the site and 59 in another part. Foxes were controlled using poisoned baits started in 1985 in one part of the Boyagin Nature Reserve (4,780 ha) and in 1989 in another part of the reserve. Baits (1080-poison meat baits or intact fowl eggs) were deployed monthly. Forty woylies (28 female, 12 male) were translocated to the reserve in 1992. No further details of the translocation are provided. Woylies were live-trapped over 150 trap nights in each part of the reserve in 1996, using baited wire cage traps set at 100-m intervals. Traps were set at dusk and cleared each morning.

A study in 1995–1999 on an arid peninsula in Western Australia, Australia (4) found that following control of invasive species, a translocated population of western barred bandicoots *Perameles bougainville* persisted and increased in numbers over four years. Six out of 14 translocated western barred bandicoots (43%) survived over one month after release into a predator-free enclosure. From 51 bandicoots then released from this enclosure, the population increased to an estimated 130 individuals by two years after releases commenced. In 1995–1996, fourteen bandicoots were trapped in Dorre Island and released into a 17-ha enclosure. Invasive predators were unable to enter the enclosure and European rabbits *Oryctolagus cuniculus* and Gould's monitors *Varanus gouldii* were controlled by trapping. In 1997 and 1999, bandicoots were released from this enclosure into the larger study area, a 12-km^2 mainland peninsula. This was fenced to exclude alien predators, though was occasionally accessed by foxes *Vulpes vulpes* and cats *Felis catus*. Bandicoots were monitored by radio-tracking within the predator-free enclosure. Following release, they were live-trapped at three-month intervals, over 2–4 nights, on a 50-m grid.

A study in 2001 in a grassy woodland site in Melbourne, Australia (5) found that following control of red foxes *Vulpes vulpes,* and release of captive-bred animals, most eastern barred bandicoots *Perameles gunnii* survived for at least five weeks. After five weeks, seven of 10 released bandicoots were known to be alive. Despite control, red foxes were recorded in all monitoring locations. In May 2001, poison-laced baits were buried at 28 locations, 180 m apart, in an effort to control red foxes. In July 2001, ten captive-bred eastern barred bandicoots were released into a 400-ha reserve. To monitor bandicoot survival, 180 live traps, baited with oats, peanut butter and honey, were distributed over a 9-ha area. Trapping was carried out on seven occasions over a five-week period, with traps set for two consecutive days each time and with two to four days between trapping. Twenty-nine 1-m^2 pads, covered in sand, were placed close to vehicle tracks and the presence of fox prints was recorded every weekday, in March–August 2001.

A controlled, before-and-after study in 2001 in five shrubland sites in Western Australia, Australia (6) found that following control of introduced mammals, most captive-bred banded hare-wallabies *Lagostrophus fasciatus* and rufous hare-wallabies *Lagorchestes hirsutus*

survived at least two months after being released into a fenced peninsula (some from holding pens and all with supplementary food and water provided). After 1–2 months, 10 of 16 rufous hare-wallabies and 12 of 18 banded hare-wallabies were still alive. Overall both rufous and banded hare-wallabies recaptured had similar body conditions to when they were released, although rufous hare-wallabies lost 12% of their body condition while waiting for release in holding pens (data presented as a body condition index; see paper for details). Sixteen captive-bred rufous hare-wallabies and 18 captive-bred banded hare-wallabies were released at five sites in August 2001. Six rufous hare-wallabies and nine banded-hare wallabies were placed in separate 3-ha enclosures with electrified fencing for 10–19 days before being released. Remaining animals were released directly into the wild. Supplementary food (kangaroo pellets, alfalfa) and water were made available to all hare-wallabies (those kept in holding pens and those not; feeding duration not given). Hare-wallabies were monitored by radio tracking (once/week for 1.5 years after release) and live-trapping (at 4 and 8–9 weeks after release). Release areas were within a fenced peninsula where multiple introduced mammals were controlled (cats *Felis catus* and goats *Capra hircus*) or eradicated (red fox *Vulpes vulpes*).

A review of eight studies in 1989–2005 in eight grassland and woodland sites in Victoria, Australia (7) found that in seven studies where red fox *Vulpes vulpes* control was carried out before or after the release of captive-bred eastern-barred bandicoots *Perameles gunnii*, survival rates of populations varied. In sites with fox control, two bandicoot populations increased for at least five years after releases began and there was evidence of breeding and wild-born pouch young maturing to adults. These populations subsequently declined to low numbers 12–15 years after the original releases began. A further population survived at least one year and both pouch young and wild-born adults were observed. However, two populations went extinct after five years, and two populations declined and management ceased (due to low detection rates) after 9–10 years. In a site without proactive fox control, released bandicoots survived and bred for at least seven years with the population comprising 74% wild-born offspring two years after releases began. Between 22 and 207 bandicoots were released into sites (85–585 ha) with fox control and 85 bandicoots were released a site

with no proactive fox management (200 ha) in 1989–2005. Captive-bred bandicoots were released in stages in each site. Red fox *Vulpes vulpes* were controlled by shooting, use of 1080 poison bait, or a combination thereof before and/or after releases. In two sites with fox control, invasive European rabbits *Oryctolagus cuniculus* were also culled. Supplementary food was provided in two sites with fox management (in one for 6–10 days after release, the other was not specified). In most sites, bandicoots were monitored by live-trapping but frequency and methods are not detailed.

A replicated study in 2005–2008 at 12 riverside sites in the Upper Thames region, UK (8) found following American mink *Neovison vison* control, captive-bred water voles *Arvicola terrestris* survived over 11 months at more than half of release sites. Water voles persisted over 11 months at seven out of 12 sites (58%). Voles were released at 12 sites where previous populations had been eradicated due to mink predation. Sites were >5 km apart and comprised suitable riparian habitat on which mink control took place. Either 44 or 45 voles were released at each site, in early May of 2005–2007. Release sites had 20–22 predator-proof release pens. Pens were 120 × 120 cm cross section, 60 cm high and buried 15–20 cm into the ground. Food and water was provided for seven days but most voles burrowed out of pens within 2–3 days. Voles were monitored monthly for five months post-release, using live traps, 15 m apart along each site, over four days. Sites were checked for vole signs in the April after release.

A replicated study in 1990–2001 in seven grassland, wetland and forest sites in Victoria, Australia (9) found that increasing amounts of regular predator control increased population numbers of released captive-bred eastern barred bandicoots *Perameles gunnii*,and bandicoots were recorded at five of seven sites up to three years after the last release. Greater amounts of predator control had a positive influence on the number of bandicoot signs found at each site (Sites with 0–2 methods of regular predator control: 0 bandicoots/site; sites with 3+ methods: 0.3–2 bandicoots/site). Bandicoot signs were found in five of the seven release sites (average 0.3–2 signs/quadrat) but no signs were detected in two sites. At each of seven sites (88–500 ha), 50–129 captive-bred eastern barred bandicoots were released between 1990 and 1999. Combinations of regular predator control methods employed (e.g. poisoning, shooting,

destruction of red fox *Vulpes vulpes* dens) differed between the sites (1 site: no predator control; 1 site: 2 methods used; 2 sites: 3 methods used (including 1 site with partial fencing); 3 sites: 4 methods used (including 1 site with full predator-proof fencing). Bandicoot signs (fresh diggings and scats) were collected at 10 randomly distributed 5-m^2 quadrats/site on two occasions in 2000–2001.

A study in 1991 at a grassland site in Wyoming, USA (10) found that following predator management, captive-born black-footed ferrets *Mustela nigripes* released from holding pens had higher post-release mortality than did resident wild ferrets. The estimated one-month survival rate for captive-born released ferrets (49%) was lower than that for free-ranging wild ferrets at their ancestral site (93%). Of animals known to have died, five were predated by coyotes *Canis latrans*, one by a badger *Taxidea taxus*, one by a golden eagle *Aquila chrysaetos* and two died of starvation. Black-footed ferrets were extirpated in the wild in 1985–1986. Thirty-seven captive-bred ferrets were released in September–November 1991, when 4–6 months old, onto a white-tailed prairie dog *Cynomys leucurus* colony. Before releases, 66 coyotes and 63 badgers were removed from the site. Ferrets spent two weeks in acclimatisation cages at the reintroduction site before release. Dead prairie dogs were provided in the cage for 10 days post-release. Ferrets were monitored by radio-tracking for ≤42 days after release.

A study in 1998–2010 in a desert site in South Australia (11) found that four of five captive-bred mammal populations released into a predator-free enclosure and one population released into a predator-reduced enclosure survived, increased their distribution and produced a second generation, whereas two populations released into an unfenced area with ongoing predator management did not persist. After release into a fenced enclosure where red foxes *Vulpes vulpes*, cats *Felis catus* and rabbits *Oryctolagus cuniculus* had been eradicated, greater stick-nest rats *Leporillus conditor*, burrowing bettongs *Bettongia lesueur*, western barred bandicoots *Perameles bougainville* and greater bilbies *Macrotis lagotis* were detected for eight years, increased their distribution within five years and produced a second generation within two years, but numbats *Myrmecobius fasciatus* were only detected for three years and did not produce a second generation. Burrowing bettongs released into a fenced enclosure with cats and rabbits but no foxes survived and increased their

distribution over at least three years and produced a second generation within two years. Greater bilbies and burrowing bettongs released into an unfenced area with some predator management did not survive to produce a second generation or increase their distribution. In 1998–2005, five numbats, 106 greater stick-nest rats (6 captive-bred individuals), 30 burrowing bettongs, 12 western barred bandicoots and nine greater bilbies (all captive-bred) were released into a 14-km^2 invasive-species-free fenced area. Rabbits, cats and foxes were eradicated within the fenced area in 1999. All western barred bandicoots and greater bilbies, and some greater stick-nest rats (8 individuals) and burrowing bettongs (10 individuals) were put into a 10-ha holding pen before full release after a few months. All other animals were released directly into the larger fenced area. In 2004–2008, thirty-two greater bilbies and 15 burrowing bettongs were translocated to an unfenced area (200 km^2) where invasive predators (cats and foxes) were managed with lethal controls and dingoes *Canis lupus dingo* were excluded by a fence on one side. In 2008, sixty-six burrowing bettongs were released into a 26 km^2 fenced area which contained small cat and rabbit populations as a result of previous eradication attempts. Between 2000 and 2010, animals were monitored using track counts, burrow monitoring and radio-tracking.

A replicated study in 1996–1997 in three grassland sites in South Dakota, USA (12) found that at least half of captive-bred black-footed ferrets *Mustela nigripes* released into an area where predators were managed survived more than two weeks. At each of the three sites, 48% (12 of 25), 50% (9 of 18) and 89% (32 of 36) of captive-bred ferrets released into the wild survived for at least two weeks (long term survival is not reported). Overall, twenty-four ferrets were killed by native predators (mostly great-horned owls *Bubo virginianus* and coyotes *Canis latrans*) and the cause of death of two others could not be determined. A total of 79 captive-bred black-footed ferrets were released across three mixed-grass prairie sites (18–36 ferrets/site) in September–October 1996 and October–November 1997. Low-to-moderate lethal coyote control took place for 2–3 weeks each year prior to ferrets being released. A 107 cm high electric fencing was installed in each release site (creating 2 km^2 enclosures) and activated 1–2 weeks prior to ferrets being released. Ferrets were able to move in and out of the fenced areas. Each of the

79 ferrets was radio-tagged and tracked every 5–30 min/night for two weeks post-release in 1996–1997.

A before-and-after study in 2006–2008 in a temperate forest area in Tennessee and North Carolina, USA (13) found following the onset of translocations of black bears *Ursus americanus* away from an elk *Cervus canadensis* calving site, survival of the offspring of translocated elk increased. A higher proportion of elk calves survived their first year during bear translocations (69%) than before (59%). In 2001–2002, fifty-two elk were translocated to the Great Smoky Mountains National Park. Calf survival was monitored in 2001–2006 in a previous study that indicated that black bears predated nine out of 13 elk calves killed by predators. In 2006–2008, forty-nine black bears were relocated >40 km away from the elk calving area. In 2006–2008, forty-nine elk births were documented from which 42 recently-born calves were radio-collared. Calf survival was monitored by radio-tracking and visual observation.

A study in 2001–2008 in a forest reserve in Queensland, Australia (14) found that following the release of captive-bred bridled nailtail wallabies *Onychogalea fraenata* and subsequent predator controls, numbers increased over a three-year period, but remained low compared to the total number released. Three years after the last release event, the estimated bridled nailtail wallaby population (31 individuals) was higher than at the time of the last release (15 individuals) but was lower than the total number that had been released (166 individuals). In 2001–2005, groups of 1–20 captive-bred wallabies were released on 14 occasions into a 565-ha private forest reserve. Ninety-seven wallabies were kept in two 50 × 50-m predator-proof holding pens for one week before release. Sixty-nine wallabies infested with parasites were treated before release. Predator control was carried out in 2004–2008. Wallabies were trapped in a 2-km^2 area with 5–45 wire cage traps during 7–22 nights on eight occasions in 2005–2008.

A before-and-after study in 2006–2010 in a river catchment in Herefordshire, UK (15) found that alongside control of invasive American mink *Neovison vison*, a released captive-bred water vole *Arvicola amphibius* population persisted for at least 20 months. Following releases of water voles over three years along a river where American mink were being controlled, the population persisted through to 20 months after the final release. At this time, voles occupied 13.3 km

of river and authors reported that numbers remained fairly constant. Between March 2006 and February 2010, one hundred and fifteen mink were captured. Mink control entailed use of 44–114 mink rafts along 63–203 km of river within the catchment. Seven hundred captive-bred water voles were released, along the main channel of the River Dore, in August–September of 2006–2008. Voles were released from boxes in groups of up to six animals/box. Boxes were ≥25 m apart. Food was provided daily until voles vacated boxes (typically within three days). Vole signs (food stores, feedings signs and faeces) were monitored annually, each April or May, in 2007–2010.

A replicated, before-and-after study in 2010–2011 in two grassland sites in Utah, USA (16) found that translocated Utah prairie dogs *Cynomys parvidens* released after the control of native predators into an area with artificial burrows showed low release site fidelity and different pre-and post-release behaviour. After translocation in both family groups and groups of unrelated individuals, prairie dogs spent more time being vigilant (48%) than they had done before translocation (22%). Only 50 out of 779 were still present at the release sites two months after release. In July 2010 and 2011, three hundred and seventy-nine and 400 prairie dogs were caught on a golf course using baited Tomahawk wire box-traps. Individuals were marked with hair dye and ear tags and released the same day at two sites with artificial burrow systems, with up to 10 animals/burrow. Each site had four release areas at least 200 m apart, each containing five burrows, 4 m apart. Each burrow consisted of a 30 × 45 × 30 cm box, buried 1.8m deep, and with two entrances (10-cm diameter and 4-m long) made from plastic tubing. Extra holes were left in the box and tubing to allow burrow expansion. Burrow entrances were protected from predators by mesh cages. At each site, two release areas were used for family groups and two were used for non-related groups. Predator removal of coyote *Canis latrans* and badgers *Taxidea taxus* was conducted for several weeks before and after prairie dog release. In September 2010 and 2011, prairie dogs were trapped, using 100 traps/site, during two sessions of four days each to determine site retention.

A study in 2010–2013 at a grassland and woodland site in Western Australia, Australia (17) found that wild-born golden bandicoots *Isoodon auratus*, descended from a translocated population which

had been released into a predator-free enclosure, maintained genetic diversity relative to the founder and source populations and persisted for three years. For four measures of genetic diversity (allelic richness, the number of effective alleles per locus, observed heterozygosity and expected heterozygosity) there were no significant differences between descendants from translocated animals, founder animals that were translocated or source populations (see paper for details). The population size was estimated at 249 bandicoots in 2013. One hundred and sixty bandicoots were trapped on Barrow Island, which has a large population, in February 2010. They were released into a 1,100-ha enclosure free from introduced predators within 24 h of capture. Genetic material was sampled by ear punch biopsy from 57 founders in 2010 and from 67 wild-born progeny trapped in 2010–2012.

A study in 2010–2014 in a woodland and shrubland site in Western Australia, Australia (18) found that following the control of invasive red foxes *Vulpes vulpes* and provision of nest boxes, a translocated population of red-tailed phascogales *Phascogale calura* survived for more than four years. Four years after the first release at least 16 phascogales were present at the site, and 90% of 30 nest boxes showed signs of use. In May 2010, twenty wild-caught phascogales were released into a 389-ha unfenced reserve, and a further 10 were released in May 2011. Poison baiting was used to control foxes on the reserve until 2012, but was suspended due to a possible positive effect on feral cats. In May 2014, phascogales were monitored using Elliott live traps (400 trap nights), and nest box checks.

A replicated study in 2013 at a desert site in South Australia, Australia (19) found that four translocated populations of burrowing bettongs *Bettongia lesueur* released after controlling invasive foxes *Vulpes vulpes* and cats *Felis catus* died out within four months. There was no significant difference in post-release survival for a large release (bettongs last recorded 42 days after the final release) and three smaller releases (bettongs persisted 41–53 days after releases). At the three smaller release areas, bettongs persisted for 53 days at the site where fewer predator tracks were recorded and for 2–10 days at two sites where more predator tracks were recorded. A total of 1,492 bettongs were translocated and released into rabbit warrens. At one 250-ha site, 1,266 bettongs were released in July–October 2013. In October–December

2013, five releases of 29–56 bettongs were made at three smaller sites, 4 km apart. From May–December 2003 feral cats *Felis catus* and foxes *Vulpes vulpes* were intensively controlled in a 500-km^2 area by 428 hours of shooting patrols. Bettong survival was monitored using track counts, camera trapping, warren monitoring and live-trapping.

A replicated study in 2005 in a grassland and forest site in Victoria, Australia (20) found that most captive-bred eastern barred bandicoots *Perameles gunnii* translocated into a fenced reserve where invasive predators had been eradicated survived more than 22 days after release. Nine out of 12 captive-bred bandicoots survived at least 22–26 days after release, when their radio transmitters fell off. Two individuals died within three weeks of release (one was predated by a native eastern quoll *Dasyurus viverrinus* and one was injured during trapping). The twelfth individual was returned to captivity after losing 21% of its body weight in 10 days. The nine bandicoots which survived had lost 7–19% of their body weight 6–8 days after release, but recovered to 97–98% of their pre-release weight by day 22–26. Twelve captive-bred bandicoots were released into a 170-ha fenced reserve, free of invasive predators. Six of the 12 were kept in a 1-ha pre-release pen for one week and provided with supplementary food and water. Bandicoots were radio-tracked daily, and were trapped and weighed every 4–5 days, for one month.

A replicated, before-and-after study in 2011–2013 in two forest and grassland sites in the Australian Capital Territory, Australia (21) found that one to two years after release into predator-free fenced reserves, translocated eastern bettongs *Bettongia gaimardi* weighed more and had improved nutritional status. Translocated eastern bettongs weighed more (1.8 kg) one to two years after release than before they were released (1.7 kg). Various blood characteristics changed after release, suggesting that translocated bettongs had improved nutritional status (see original paper for details). Comprehensive health assessments were completed on 30 bettongs captured in Tasmania before release (July-October 2011 and April-September 2012) and 12–24 months after release (May–November 2013) into two predator-free reserves. In one reserve, bettongs (8 males, 10 females) received no supplementary food and the population was unmanaged. In the second reserve, bettongs (5 males, 7 females) were housed in small groups in 2.6–9.4-ha enclosures and provided supplementary food.

A study in 2011–2014 in a semi-arid area in South Australia (22) found that over half of captive-reared black-footed rock-wallabies *Petrogale lateralis* released into a large predator-free fenced area survived for at least two years and most females reproduced. Ten (five males, five females) of 16 rock-wallabies (63%) survived more than two years after being released. All five females that survived reproduced within 2–6 months of release. Over three years, 28 births from nine females were recorded. Between March 2011 and July 2012, sixteen captive-reared black-footed rock-wallabies (eight males, eight females; 1–5 years old) were released in three groups into a 97-ha fenced area. Ten of the 16 rock-wallabies were wild-born and fostered by yellow-footed rock-wallaby *Petrogale xanthopus* surrogate mothers in captivity. Introduced predators, common wallaroos *Macropus robustus* and European rabbits *Oryctolagus cuniculus* were removed from the enclosure. Supplementary water was provided in five 8-l tanks that were monitored with camera traps in 2011–2014. Rock-wallabies were fitted with radio-collars and tracked 1–7 times/week in 2011–2014. Trapping was carried out on seven occasions in 2011–2014.

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14.32. Release translocated/captive-bred mammals to islands without invasive predators

https://www.conservationevidence.com/actions/2464

- **Six studies** evaluated the effects of releasing translocated or captive-bred mammals to islands without invasive predators. The six studies were in Australia[1,2,3,4,5,6].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (7 STUDIES)

- **Abundance (2 studies):** A study in Australia[5] found that following release of captive-bred dibblers on to an island free of introduced predators, numbers increased. A replicated study in Australia[1] found that following release of captive-bred and wild-born brush-tailed bettong onto islands free of foxes or cats, numbers increased on two of four islands.
- **Reproductive success (3 studies):** A study in Australia[4] found that captive-bred proserpine rock-wallabies released on an island without introduced predators established a breeding population. Two studies in Australia[3,5] found that following release on to islands without invasive predators, captive-bred rufous hare-wallabies[3] and captive-bred dibblers[5] reproduced.

- **Survival (3 studies):** A review of 28 translocation studies in Australia[2] found that 67% of marsupial populations translocated to islands without predators survived more than five years, compared to 0% translocated to islands with predators and 20% translocated to the mainland. A study in Australia[3] found that most captive-bred rufous hare-wallabies released on an island without non-native predators survived more than a year. A replicated study in Australia[6] found that wild-born golden bandicoots descended from translocated populations released onto two predator-free islands persisted for 2–3 years.
- **Condition (1 study):** A replicated study in Australia[6] found that wild-born golden bandicoots descended from translocated populations that had been released onto two predator-free islands, maintained genetic diversity relative to founder and source populations.

BEHAVIOUR (0 STUDIES)

Background

Mammals are sometimes wild-caught and translocated or bred in captivity and released to islands that are free of invasive predators to give them the best chance of establishing breeding populations and persisting. These could either be islands that have never had non-native predators introduced to them or those from which non-native predators have been eradicated.

See also: *Release translocated/captive-bred mammals in areas with invasive/problematic species eradication/control.*

A replicated study in 1979–1984 of shrubland and grassland on five islands in South Australia, Australia (1) found that captive-bred and wild-born brush-tailed bettong *Bettongia penicillata* populations released onto islands free of foxes *Vulpes vulpes*, rabbits *Oryctolagus cuniculus* or cats *Felis catus* increased in number on two of the four islands on which they were released and monitored. On one island, seven founders

increased to ≥53 animals in four years. On a second island, 10 founders increased to 12 animals (five born on the island), 14 months later. Forty released on a third island declined to one after two years. Six released on a fourth island were predated by dogs *Canis lupus familiaris* after an unspecified period. On a fifth island, where 11 were released, animals persisted for up to 12 months, but were not formally monitored. Releases were of captive-bred animals, except those on the second island, which were wild-bred offspring from the population established on the first island. Releases were made in 1979–1983 and were monitored, primarily by live-trapping, up to April 1984. The results of this study are also included in (2).

A review of 28 translocation studies in 1905–1990 on islands and mainland Australia (2) found that eight of 12 marsupial populations translocated to islands without predators survived more than five years, none of six populations translocated to islands with predators survived and two of 10 translocations to the mainland survived more than five years. One of 12 populations of marsupials translocated to islands with no predators recorded survived at least 1–5 years, four survived 6–20 years and four survived >20 years (outcome of three translocations unknown). Five of six populations of marsupials translocated to islands with predators survived <1 year and one population survived 1–5 years. Three of 10 populations of marsupials translocated to the mainland survived <1 year, four survived 1–5 years and two survived 6–20 years (outcome of 1 translocation unknown). Translocations took place in 1905–1988 and included: banded hare-wallaby *Lagostrophus fasciatus*, black-flanked rock-wallaby *Petrogale lateralis*, bridled nail-tail wallaby *Onychogalea fraenata,* brush-tailed bettong ('woylie') *Bettongia penicillata*, brush-tailed rock-wallaby *Petrogale penicillata*, burrowing wallaby *Bettongia lesueur*, parma wallaby *Macropus parma*, quokka *Setonix brachyurus*, red-bellied pademelon *Thylogale billardierii*, rufous hare-wallaby *Lagorchestes hirsutus,* tammar wallaby *Macropus eugenii*, and western grey kangaroo *Macropus fuliginosus*. Predators were recorded as limiting factors in six island studies and were controlled in two mainland studies. Numbers of translocated animals ranged from 4–113, except for quokkas, of which 673 were translocated (see original paper for details).

A study in 1998–2001 on an offshore island dominated by grassland in Western Australia, Australia (3) found that following release on an island without non-native predators, most captive-bred rufous hare-wallabies ('mala') *Lagorchestes hirsutus* survived over one year after release and some reproduced. Twenty-four (80%) of 30 rufous hare-wallabies survived at least one year after release. Rufous hare-wallabies were still present on the island three years post-release and animals had reproduced in the wild. In June 1998, thirty captive-bred rufous hare-wallabies from a captive colony were released on to a 520-ha predator-free island, part of the Montebello Islands Conservation Park. Animals were transported in 5 × 3 m holding pens and were ear-tagged and fitted with a radio-collar before release. Hare-wallabies were released within 20 hours of capture and fruit, alfalfa and water were made available to them immediately after release. They were monitored every two days for 10 days and intermittently for up to three years post-release.

A study in 1998–2002 on an offshore island in Queensland, Australia (4) found that captive-bred proserpine rock-wallabies *Petrogale persephone* released on an island without introduced predators established a breeding population. No statistical tests were carried out and no data on population size are provided. Four rock-wallabies were born on the island, 3–4 years after the translocation of 27 animals commenced. However, nine rock-wallaby deaths were recorded over the study period (33% of all animals released). Between 1998 and 2002, twenty-seven rock-wallabies were translocated from the Queensland mainland to Hayman Island. Feral goats *Capra hircus* were eradicated before the release. Released individuals were radio-tracked over three-day periods at three-week intervals in 1998–1999, over one day every month in 2000 and over one day every two months in 2001. Remote video surveillance was used occasionally in 2001 to confirm breeding.

A study in 1998–2001 on an offshore predator-free island dominated by shrubland in Western Australia, Australia (5) found that following release on to an island free of introduced predators and rodents, captive-bred dibblers *Parantechinus apicalis* reproduced and numbers increased. Three years after the first release, more dibblers were confirmed to be alive on the island (67 animals) than in the first year of releases (26 animals). After three years, the proportion of females showing signs

of recent reproduction (90%) was higher than after one year (20%). Of animals released in the first year, 10 of 26 survived for at least 12 months. Between 1998 and 2000, eighty-eight captive-bred dibbers were released on an 11-ha offshore island, free of introduced predators and rodents. All dibblers were individually marked and one-third was fitted with radio-collars. Twenty-five dibblers were radio-tracked for two weeks. For three to four nights, on 10 occasions from November 1998 to October 2001, up to 100 live traps were set across the island. New animals caught were marked to enable individual identification and females were examined for signs of recent breeding.

A replicated study in 2010–2013 on two islands in Western Australia, Australia (6) found that wild-born golden bandicoots *Isoodon auratus*, descended from translocated populations which had been released onto two predator-free islands, maintained genetic diversity relative to founder and source populations and persisted for 2–3 years. For four measures of genetic diversity (allelic richness, the number of effective alleles/locus, observed heterozygosity and expected heterozygosity) there were no significant differences between descendants from translocated animals, founder animals that were translocated or source populations (see paper for details). On the larger island, the population size was estimated to be 280 animals in 2013. No estimate is provided for the smaller island. Bandicoots were trapped on Barrow Island, which has a large population, in February 2010 (165 animals) and July 2011 (92 animals). Within 24 h of capture they were released on two other islands (1,020 and 261 ha) where non-native predators had been eradicated or had never been recorded. Genetic material was sampled by ear punch biopsy from 38 and 49 founders in 2010 and 2011, and from 44 and 39 wild-born offspring in 2010–2012.

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14.33. Release translocated/captive-bred mammals in family/social groups

https://www.conservationevidence.com/actions/2463

- **Twenty-six studies** evaluated the effects of releasing translocated or captive-bred mammals in family or social groups. Eleven were in the USA[1,2,4,5,7,8,10,14,16,21,24], seven were in South Africa[6a,6b,12,17,19,20a,20b] and one was in each of Poland[3], Zimbabwe[9], along the USA–Canada border[11], Russia[13], Italy[15], Canada[18], China[22] and India[23].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (22 STUDIES)

- **Abundance (4 studies):** A study in the USA[1] found that a translocated population of Rocky Mountain bighorn sheep released in groups increased at a similar rate to that of a population newly established through natural recolonization. A replicated, controlled study in the USA[14] found that after translocating black-tailed prairie dogs in social groups to areas with artificial burrows, colonies increased in size over four years. A replicated study in Canada[18] found that following translocation of elk, most of which had been kept in holding pens in groups, numbers increased at two of four sites. A study in the USA[10] found that following the release of captive-reared bighorn sheep in groups, the overall population declined over 14 years.

- **Reproductive success (11 studies):** A study in the USA[10] found that captive-reared bighorn sheep released in groups had similar population recruitment rates compared to wild-reared sheep. A replicated, paired study in the USA[16] found that black-tailed prairie dogs translocated as family groups had higher reproductive success than those translocated in non-family groups. A replicated study in the USA[4] found that translocated gray wolves had similar breeding success when adult family groups were released together from holding pens or when young adults were released directly into the wild. Six of eight studies (one replicated) in Poland[3], Russia[13], South Africa[6b,12,17,19], the USA[8] and the USA–Canada border[11] found that when translocated and/or captive-bred animals were released in social or family groups, cheetahs[6b], European bison[13], lions[17], African wild dogs[19], most European beavers[3] and some swift foxes[11] reproduced successfully. One study found that one of two translocated Cape buffalo[12] groups released after being held in a holding pen formed a single herd and reproduced, while the other scattered and escaped the reserve. One study found that no Gunnison's prairie dogs[8] reproduced during the first year.
- **Survival (19 studies):** One of three studies (one controlled, before-and-after) in the USA[2,10,24] found that when translocated or captive-bred animals were released in family or social groups, captive-reared bighorn sheep[10] had similar survival compared to wild-reared sheep, whereas two found lower survival compared to wild white-tailed deer[2] and San Joaquin kit foxes[24]. Three replicated studies (one controlled, one paired) in the USA[4,5,16] found that when translocated as a social or family group, black-tailed prairie dogs[16] had higher and white-tailed deer[5] and gray wolves[4] had similar survival rates to those translocated as unrelated groups[5,16] or individuals[4]. Ten studies (one replicated) in Poland[3], Russia[13], Italy[15], South Africa[6a,6b,17], the USA[8], USA–Canada border[11], China[22] and India[23] found that when translocated and/or captive-bred animals were released in social or family groups, a population of Przewalski's horses[22] and European

bison[13] persisted 5–11 years, lions[17], most swift foxes[11] and European beavers[3] and half or more cheetahs[6a,6b] survived for at least one year, and one-horned rhinoceroses[23] and over half of Gunnison's prairie dogs[8] and Eurasian badgers[15] survived at least 1–6 months. Three studies in the USA[7] and South Africa[20a,20b] found that when translocated or captive-bred animals were released in family or social groups (some provided with artificial refuges and/or supplementary food), most Mexican wolves[7] did not survive over eight months and all rock hyraxes[20a,20b] died within 90 days. A study in South Africa[19] found that translocated and captive-bred African wild dogs released in family groups into fenced reserves had high survival rates.

- **Condition (1 study):** A study in China[22] found that following the release of captive-bred Przewalski's horses in groups, the population had a lower genetic diversity than two captive populations.

BEHAVIOUR (4 STUDIES)

- **Behaviour change (4 studies):** Two replicated, controlled (one before-and-after) studies in the USA[5,21] found that when translocated as a social or family group, white-tailed deer[5] had similar average dispersal distances and Utah prairie dogs[21] had similar release site fidelity and post-release behaviour compared to those translocated as unrelated groups. One found that deer translocated together did not stay together, whether they had previously been part of the same social group or not. A study in Zimbabwe[9] found that a translocated lion family joined with immigrant lions and formed a new pride. A study in South Africa[17] found that translocated lions that were released in groups that had already been socialised and formed into prides, established stable home ranges.

Background

Mammals are sometimes wild-caught and translocated or bred in captivity and released to re-establish populations that have been lost, or to augment an existing population. This action includes studies describing or comparing the effects of translocating or releasing mammals in family or social groups. This includes releasing known family or social groups and releasing captive-bred social animals in groups. It also includes releasing groups of animals or coalitions, including pairs that were captured or housed and then released together with the intention of forming a social group/pair, even if the animals did not know each other prior to capture.

See also: *Release translocated/captive-bred mammals in larger unrelated groups.*

A study in 1960–1985 of forest and grassland across a mountain range in Montana, USA (1) found that a translocated population of Rocky Mountain bighorn sheep *Ovis canadensis* released in groups increased at rate similar to that of a population newly established through natural recolonization. Following translocation of 37 adult sheep and 30 lambs, the population reached 54 sheep and 43 lambs seven years later, though was estimated at 31 sheep and 12 lambs the following year. A naturally recolonized population increased from 30 sheep at establishment to 77 sheep and 49 lambs 22 years later (the same year that the population peaked in the translocated population) though declined to 33 sheep and 15 lambs the following year. Sheep populations were studied in a 3,000-km^2 study area. The translocated population (released in 1976) was surveyed seven times between 1976 and 1985. The recolonized population (established in 1958–1960 and occupying a separate part of the study area) was surveyed 11 times between 1960 and 1985. Surveys were carried out on the ground or by helicopter, usually on winter ranges. Weather frequently hampered surveys of the translocated population.

A study in 1984–1987 in two shrubland ranches in Texas, USA (2) found that most captive-bred white-tailed deer *Odocoileus virginianus*

released in groups that had been reared together died within one year of release, whereas all monitored wild deer survived at least one year. Eight out of 13 (62%) captive-bred white-tailed deer died within one year post-release but all 20 wild deer survived. Thirteen captive-bred white-tailed male deer (average age: 1.7 years) were released into two ranches (extending over 25,900 ha and 15,379 ha) in January 1987. Additionally, 20 wild male deer were caught and released. In 1984–1986, ten captive-bred deer were removed from their mothers at 2–4 days old and bottle-raised by humans. Three others were raised by their mothers until four months old. After removal from their mothers, captive-bred deer were kept in 1.2-ha pens. All deer were ear-tagged and fitted a radio-collar. Deer were radio-tracked after release, on average every 25 days, from an airplane. A two-month hunting season was in place on both ranches during 1987.

A replicated study in 1975–1985 in a river basin in north-eastern Poland (3) found that most translocated and captive-bred European beavers *Castor fiber* released in pairs or family groups survived over one year after release and reproduced in the wild. Ten years after the release of 168 Europeans beavers (74 pairs or families), 108 were found to be established in 64 families. Reproduction was detected in nine of 16 areas where releases occurred and by the end of 1985, forty-four new colonies had established in the reintroduction areas. The average reproduction rate of captive-bred beavers was higher (2.1 kits/litter) than wild-born beavers (1.8 kits/litter; results were not statistically compared). Twenty-two translocated beavers (14%) died during the first year in the wild. In total, 51 beavers died or were lost following translocation. In 1975–1985, a total of 168 European beavers (74 pairs) were released into 16 regions within the Vistula river basin. Release sites had abundant willow *Salix* spp. and alder *Alnus* spp. thicket. Beavers were released in small populations of two to 11 pairs (usually 4 pairs), 2–20 km apart. Eleven individuals were captive-born and the remainder were caught in the wild and translocated. Beavers were monitored annually.

A replicated study in 1995–1996 in two forest sites in Idaho and Wyoming, USA, (4) found that translocated gray wolves *Canis lupus* had similar survival rates and breeding success in the first two years after release when adult family groups were released together from holding pens or when young adults were released directly into the wild. No statistical analyses were conducted. Thirty out of 35 young adult wolves

released directly into the wild were still alive seven months after the last releases, and had produced up to 40 pups from 3–8 pairs. Thirty-one adult wolves released from holding pens in family groups had produced 23 pups four months after the last releases. From these 54 animals, nine had died. Six of the seven adult pairs released together from holding pens remained together, and five of these pairs established territories in the vicinity of the pens. Wolves were wild-caught from Canada in January 1995 and 1996. In Idaho, young adults were directly released in January 1995 and 1996. In Wyoming, family groups of 2–6 wolves spent 8–9 weeks in 0.4-ha chain-link holding pens before release in March 1995 and April 1996. Wolves were radio-tracked every 1–3 weeks until August 1996.

A replicated controlled study in 1993–1995 in a mixed hardwood and conifer forest reserve in New York, USA (5) found that white-tailed deer *Odocoileus virginianus* translocated as a social group did not differ in survival or average dispersal distance compared to deer translocated as an unrelated group and deer translocated together did not stay together, regardless of whether they had previously been part of the same social group or not. Survival rates in the first year after release were similar for translocated deer from the same social group (6/12 individuals, 50%) as for those from unrelated social groups (3/5 individuals, 60%). Survival rates of translocated deer were lower than resident deer in 1993–1995 (75–88%). Deer released together did not remain together regardless of whether they had originated from the same social group or not. The average dispersal distance of deer translocated as a social group (24 km) was similar to those translocated in a group of unrelated deer (22 km). Between May-June 1994, seventeen female white-tailed deer were caught and translocated 60 km from one hardwood and coniferous forest to another (1,133 ha). Twelve were translocated from the same social group (released in groups of 1–5 animals) and five were unrelated animals (released in a group of 3 animals or individually). Each deer was ear-tagged and radio-collared. Resident deer were radio-tracked 5–15 times/week in the source forest April-August 1993–1995 and translocated deer were radio-tracked in the destination forest 1–15 times/week in May-August 1994 and 1995, every few months in September-December 1994 and 1–8 times/month in January-March 1995.

A study in 1994–1998 in a savannah reserve in North West province, South Africa (6a) found that after being kept in groups (some family

groups, some unrelated groups) in holding pens, approximately half of translocated cheetahs *Acinonyx jubatus* survived at least 18 months, of which half died within three years. Nine of 19 cheetahs survived 19–24 months, of which six were cubs that matured to independence, but only four cheetahs were known to still be alive at the end of the study period. Six cheetahs survived in the reserve less than one year, of which one died after a few weeks and two were removed to a captive breeding facility. The fate of four released cheetahs was unknown. In total 19 cheetahs were released into a game reserve between October 1994 and January 1998. Cheetahs were initially placed in 1 ha holding pens with electrified fencing for 4 weeks to several months. Cheetahs were mostly rescued wild-caught animals, except for one that was habituated to humans (and had to be removed after 2 weeks). Cheetahs were either held in family groups (mothers with cubs) or as coalitions (of adult males). One animal/group was radio collared for monitoring.

A study in 1981–1998 in a savannah reserve in North West province, South Africa (6b) found that following the release of rehabilitated and captive-bred cheetahs *Acinonyx jubatus* in groups (family and unrelated) and individually, most adults survived at least one year and animals bred in the wild. Most rehabilitated adult females (3 of 4) and all rehabilitated adult males (4 of 4) survived at least one year. Two rehabilitated adult females produced a second litter within two years of release. Three of 10 cubs released survived to independence, including a female who then raised her own litter of cubs to independence. The total population numbered 17 cheetahs one year after the end of a five year release program, compared to 18 animals released. An earlier release in the same National Park found that captive-bred cheetahs had bred successfully but most animals were subsequently removed to protect ungulate populations. Between 1995 and 1997, eighteen cheetahs (4 adult males, 4 adult females and 10 dependent cubs) were introduced to a National Park (55, 000 ha) from a rehabilitation facility (it is unclear whether the animals were wild caught, captive bred or reared in captivity). Cheetahs were released in family groups (mothers with cubs), in unrelated groups (of males) or individually. In 1981–1982, seven cheetahs were released from a captive-breeding facility and after a period of time (not specified), seven cheetahs were removed leaving three males in a group behind. Individuals were monitored by radio-tracking.

A study in 1998 in a grassland, shrubland and forest reserve in Arizona, USA (7) found that most captive-bred Mexican wolves *Canis lupus baileyi* released in family groups (initially into holding pens and provided with supplementary food) did not survive over eight months after release into the wild. Out of 11 captive-bred Mexican wolves released, six (55%) were illegally killed within eight months, three (27%) were returned to captivity and two (18%) survived in the wild for at least one year. Three weeks after their release, three individuals from one family group killed an adult elk *Cervus canadensis*. Two females gave birth two months after release but only one pup survived. Eleven wolves in three family groups were released in March 1998. Before release, wolves were kept for two months in pre-release holding pens, where they were fed carcasses of native prey. Carcasses were provided as supplementary food for two months post-release when sufficient killing of prey was confirmed. The released wolves were fitted with radio-collars. No monitoring details are provided.

A study in 1997 in one desert grassland site in New Mexico, USA (8) found that over half of the translocated Gunnison's prairie dogs *Cynomys gunnisonii* released in family groups survived at least six months, but none reproduced during the first year. Thirty-six out of 60 (60%) translocated prairie dogs survived the first summer after being released into the wild, but no young were born during this period. In spring 1997 sixty prairie dogs (30 male, 30 female) were translocated to a 3.5 ha area in a former prairie dog colony site. Individuals were released with family members or near neighbours, into the existing burrows of a former prairie dog colony. Prairie dogs were monitored during summer and autumn 1997 but monitoring details are not provided.

A study in 1997–1998 on a savanna estate in Zimbabwe (9) found that a translocated lion *Panthera leo* family kept in a holding pen prior to release joined with immigrant lions and formed a new pride. A lioness was translocated with three cubs (one male, two female). Within 45 days, seven male lions were close by and the female mated with one of these. The male cub moved away and the pride then comprised the female and daughters with two adult male lions. A wild lioness joined the pride 1.7 months after release, but was killed by a snare after six months. After 12–13 months, the original lioness had three new cubs and her daughters each also had litters. Resident lions on the estate were eliminated in 1995. In January 1997, a lioness and three cubs were

translocated from communal land to a holding pen and were released on the estate after 90 days. Lions were monitored through to May 1998 by radio-tracking and direct observation.

A study in 1985–1998 in a shrub-dominated mountain area in California, USA (10) found that captive-reared bighorn sheep *Ovis canadensis* released into the wild in groups had similar survival and population recruitment rates compared to wild-reared sheep, but the overall population declined over 14 years. Captive-reared released and wild-reared bighorn sheep had similar average annual survival (captive-reared: 80%; wild-reared: 81%) and recruitment rates (captive-reared: 0.14 lambs/adult female; wild-reared: 0.14 lambs/adult female). However, despite releases, the overall population at the study site declined over 14 years from an estimated 40 sheep in 1985 to 22 sheep in 1998. In 1985–1998, seventy-four captive-reared bighorn sheep were released at three sites in a 70-km^2 area. Captive-reared sheep included 49 captive-born and 25 wild-born lambs brought into captivity at 1–5 months of age. Captive-reared sheep were released in 33 groups of 1–6 animals, mostly when one year old. Water was provided at the release site for 3–20 days post-release. Released sheep were ear-tagged and radio-collared and monitored at least once/week during each of 14 years in 1985–1998. Survival and reproduction were compared with those of 43 wild-reared sheep radio-tracked in the study area during the same time period.

A study in 1994–1998 at seven temperate grassland sites along the USA–Canada border (11) found that most translocated swift foxes *Vulpes velox*, which had been held in captivity prior to release and were released in social groups, survived for at least one year, and some reproduced near release sites. Eleven of 18 (61%) translocated swift foxes survived at least one year after release. Of these, 60% of animals translocated as juveniles went on to reproduce, as did 33% of translocated adults. In 1994–1996, foxes were captured in Wyoming, USA, and were fitted with radio-collars while being held in captivity for 22–57 days. In autumn 1994–1996, animals were released in mixed-gender groups of up to three individuals which had been trapped in close proximity. Release sites were located in areas with pre-existing, but small, fox populations and with low numbers of predators and high prey availability. Foxes were monitored by visual surveys and ground-based and aerial radio-tracking.

A study in 2000–2003 in a mixed karoo grassland reserve in Northern Cape Province, South Africa (12) found that one out of two translocated Cape buffalo *Syncerus caffer* groups released into a fenced reserve (after being held in a holding pen) formed a single herd, stayed in the reserve and reproduced, while the other scattered and escaped the reserve. One group of 10 translocated animals formed a single herd (along with the two remaining animals from the previous introduction) and over 10 months no animals died or escaped. A year after the introduction, five calves were born. One month after release, a second group of four buffalo had split into two solitary animals and a pair formed by one male and one female. One of the solitary animals was not seen again, the second solitary male animal was located two years after release on a neighbouring farm and released into the second group of translocated animals in May 2003. The pair escaped the reserve three times in 13 months. After the third escape, the male was moved to a different reserve and a new male introduced to form a herd with the remaining female. Four subadult buffalos (2 male, 2 female) were placed in a holding pen in July 2000 and released in August into a fenced 12,000-ha reserve. A second group of seven adult and three subadult animals (4 male, 6 female) was placed into a holding pen in August 2002 and released into a 200 ha area in September before being completely released in October 2002. Both groups were monitored weekly with telemetry until October 2003.

A study in 1996–2002 of forest in a national park in Oryol Oblast, Russia (13) found that a population of captive-bred European bison *Bison bonasus* released in groups persisted five to six years post-release and bred in the wild. The first calf was born in the second year after releases began and after six years, 30 calves had been born. The total population numbered 68 individuals (6–36 individuals/group) after six years. Sixty-five captive-bred bison were released in four groups in 1996–2001. Bison were monitored by visual observations and tracking.

A replicated, controlled study in 1999–2003 on a grassland site in Montana, USA (14) found that after translocating black-tailed prairie dogs *Cynomys ludovicianus* in social groups to areas with artificial burrows, colonies increased in size over four years. Six colonies receiving translocated prairie dogs grew more in area over four years (total growth 72 ha, 924% of pre-translocation area) than did 20 similar-sized colonies, which did not receive translocated prairie dogs (total growth 27 ha, 93% increase). Two active colonies (with existing prairie

dog populations at the start of the study) that each received 120 prairie dogs increased more over four years (total increase 37 ha, 971% of pre-translocation area) than did two active colonies each receiving 60 prairie dogs (total growth 31 ha, 768%). An inactive colony that received no prairie dogs remained inactive. In June–July 1999, prairie dogs were released into pre-existing burrows (up to eight prairie dogs/burrow) or drilled holes (8 cm diameter × 60 cm deep, 45° below horizontal, up to two prairie dogs/hole, 30 holes/site). Colony size was measured four years later. Nine experimental colonies, three each occupying areas of 0 ha (inactive), 0.1–2.0 ha and 2.0–6.6 ha, were studied. In each size class, translocations to the three colonies were of 0, 60 and 120 prairie dogs. Growth-rates of 20 non-supplemented colonies were also monitored.

A study in 2001–2005 in a mixed forest and farmland site in northern Italy (15) found that just over half of translocated Eurasian badgers *Meles meles* released in groups into holding pens with supplementary food survived at least one month after release. Seven out of 12 badgers survived for 1–9 months, after which monitoring equipment stopped operating. One badger died almost immediately after release due to unknown causes. Two badgers escaped (one after the first month, the other after unknown period). The fate of three other badgers was unknown. One pair of translocated animals reproduced in the wild four years after release. From March 2001 to May 2004, twelve badgers were captured at four sites in northern Italy. Badgers were fitted with radio-collars and transported 20–40 km to the release site where they were kept in a 350 m^2 enclosure in a wooded area in their release groups (2001: 2 individuals, 2002: 4 individuals, 2003: 2 individuals; 2004: 4 individuals) and provided supplementary food for 3–10 weeks before release. Seven of the 12 badgers were located once/week, for up to nine months after release.

A replicated, paired study in 2001–2003 in 10 grassland sites in New Mexico, USA (16) found that black-tailed prairie dogs *Cynomys ludovicianus* translocated as family groups had higher survival and reproductive success than black-tailed prairie dogs translocated in non-family groups. Prairie dogs translocated as a family had higher post-release survival to the following spring (39–62%) and higher reproductive success (2.2–3.9 pups/female) than did those translocated as non-family groups (survival: 7–19%; reproductive success: 0.2–3.4 pups/female). Ten sites in Vermejo Park Ranch, Colfax County, from

which prairie-dogs were absent but which were within the historical range, were selected. Four hundred and eighty-four wild-caught black-tailed prairie dogs were translocated in family groups into five sites (87–100/site) and 489 were translocated as non-family groups into five sites (88–103/site). Translocations took place in June–August of 2001 and2002. Survival and reproductive success were measured by trapping marked animals during the spring in the year after release (in May–July 2002 and May-June 2003).

A study in 1992–2004 in a grassland reserve in KwaZuluNatal Province, South Africa (17) found that translocated lions *Panthera leo* that were released in groups that had already been socialised and formed into prides, established stable home ranges, reproduced successfully and survived at least a year. Of 15 lions released, all except three, which were removed for killing a tourist, survived ≥398 days post-release. Average post-release survival was ≥1,212 days. At least 95 cubs from 25 litters were documented from the population over the 13-year study. Excluding cubs translocated to other sites or those still <18 months old at the end of the study, 51 of 65 cubs (78%) reached 18 months of age. Seven lions were released in May 1992, six in February 1993 and two in January 2003. Releases were into a fenced reserve (initially 176 km^2, then extended to 210 km^2). Before release, lions were held in groups, each in an 80-m^2 acclimation pen, for 6–8 weeks. During this time, socialization occurred and stable prides were formed. Eleven of the founder lions were radio-tracked and other animals were monitored by direct observations.

A replicated study in 1998–2004 within four largely forested areas in Ontario, Canada (18) found that following translocation elk *Cervus canadensis*, most of which had been kept in holding pens in groups, remained present at all recipient sites and numbers increased at two of them. By 3–6 years after translocations, elk populations had increased at two sites and decreased at two. From 443 elk translocated, the population at the end of the study was estimated at 375–440 animals. Between 1998 and 2004, forty-one percent of translocated elk died. Causes of death included 10% lost to wolf predation, 5% to emaciation and 5% were shot. Elk were translocated from a site in Alberta, Canada in 1998–2001 in nine releases. Transportation took 24–58 hours. Elk were held in pens at recipient sites for up to 16 weeks before release (some were released immediately) but the effect of holding pens was not tested. Of 443 elk

released, 416 were monitored by radio-tracking. The overall population was estimated in March 2004.

A study in 1995–2005 in 12 dry savanna and temperate grassland sites in South Africa (19) found that translocated and captive-bred African wild dogs *Lycaon pictus* released in family groups into fenced reserves had high survival rates and bred successfully. Eighty-five percent of released animals and their wild-born offspring survived the first six months after release/birth. Released animals that survived their first year had a high survival rate 12–18 months (91%) and 18–24 months (92%) after release. Additionally, groups that had more time to socialise in holding pens prior to release had higher survival rates (data presented as statistical models). Between 1995 and 2005, a total of 127 wild dogs (79 wild-caught, 16 captive-bred, 16 wild-caught but captive-raised, 16 'mixed' pups) were translocated over 18 release events into 12 sites in five provinces of South Africa. Animals were monitored for 24 months after release, and the 129 pups which they produced after release were monitored up to 12 months of age. Forty characteristics of the individual animals, release sites and methods of release were recorded, and their impact on post-release survival was tested.

A study in 2007 at rocky outcrops on a reserve in KwaZulu-Natal Province, South Africa (20a) found that all translocated rock hyraxes *Procavia capensis* that were released as a group, having been kept in a holding pen, died (or were presumed to have died) within 18 days of release. Eight of nine wild translocated hyraxes died within 18 days of release and the other was presumed to have died. The group split up and were not seen together after release. In October 2007, nine hyraxes (one juvenile, three sub-adults and five adults) were caught in baited mammal traps (90 × 31 × 32 cm) in an area where they were abundant, and moved 150 km to a 656-ha reserve where the species was nearly extinct. Hyraxes were kept together in a holding cage (185 × 185 × 185 cm) for 14 days before release. They were monitored daily for one week, and then every few days by direct observation and radio-tracking.

A study in 2005–2006 at rocky outcrops on a reserve in KwaZulu-Natal Province, South Africa (20b) found that translocated rock hyraxes *Procavia capensis* that were released in a social group after being held in captivity, and were provided with an artificial refuge and supplementary food after release, all died (or were presumed to have died) within 87 days of release. Eighty-seven days after the release of 17 hyraxes, none

could be relocated. In July 2005, ten adult hyraxes were caught in baited mammal traps (90 × 31 × 32 cm) in an area where they were abundant, and held in captivity for 16 months, during which time three died. The remaining seven were released in November 2006, along with the eight juveniles and two pups born to them in captivity, to a 656-ha reserve where the species was nearly extinct. For four months prior to release, the group was housed together in an outdoor cage (5.9 × 2.5 × 3.2 m). Hyraxes were released into a hay-filled hutch which was left in place for several months, and were provided with cabbage for one week after release. Hyraxes were monitored by direct observations and by walking regular transects, daily for the first week but decreasing to monthly by the end of the study.

A replicated, controlled, before-and-after study in 2010–2011 in two grassland sites in Utah, USA (21) found no differences in the release site fidelity or post-release behaviour of translocated Utah prairie dogs *Cynomys parvidens* released in family groups or in groups composed of non-related individuals. Similar numbers of prairie dogs released in family groups (24 out of 386, 6%) and in non-related groups (26 out of 393, 7%) were still present at the release sites two months after release. Additionally, the post-release behaviour did not differ between groups, but both groups behaved differently post-release than pre-release (data presented as model results). In July 2010 and 2011, three hundred and seventy-nine and 400 prairie dogs were caught on a golf course using baited Tomahawk wire box-traps. Individuals were marked with hair dye and ear tags and released the same day at two sites with artificial burrow systems, with up to 10 animals/burrow. Each site had four release areas at least 200 m apart, each containing five burrows, 4 m apart. Each burrow consisted of a 30 × 45 × 30 cm box, buried 1.8m deep, and with two entrances (10-cm diameter and 4-m long) made from plastic tubing. Burrow entrances were protected from predators by mesh cages. At each site, two release areas were used for family groups and two for non-related groups. Predator removal of coyote *Canis latrans* and badgers *Taxidea taxus* was conducted for several weeks before and after prairie dog release. In September 2010 and 2011, prairie dogs were trapped, using 100 traps/site, during two sessions of four days each to determine site retention.

A study in 2001–2012 in a desert reserve in Xinjiang province, China (22) found that following the release of captive-bred Przewalski's

horses *Equus ferus przewalskii* in groups, the population persisted at least 11 years but had a lower genetic diversity than two captive populations. Over 11 years after being reintroduced, the population of Przewalski's horses increased from 27 to 99 individuals. However, reintroduced horses had a lower genetic diversity (3.3 alleles/locus) than captive horses (3.4–3.8 alleles/locus), although the result was not tested for statistical significance. In 1985–1994, two captive populations of Przewalski's horses (founded with 22 and 18 horses imported from zoos) were established at two captive breeding facilities. In 2001, twenty-seven horses (16 females, 11 males) born in captivity within the latter population were released in small groups into a 17,330-km^2 reserve. Details on horse surveys are not provided. In 2010–2012, faecal samples were collected from 116 captive horses (66 and 50 horses from each of the two captive populations) and 52 reintroduced horses. Genetic diversity was estimated for 10 microsatellite loci.

A study in 2008–2012 in a grassland reserve in Assam, India (23) found that translocated greater one-horned rhinoceros *Rhinoceros unicornis*, some of which were cow-calf pairs, all survived at least 90 days after release. All 18 rhinoceroses survived more than >90 days after being released. During the first day after release, rhinoceroses dispersed an average of 2.4 km from the release site. Sixteen out of 18 rhinoceroses moved in the same direction to the bank of a river. Most cow-calf pairs separated after release, but were reunited within 24 hours. Between April 2008 and March 2012, twelve adult rhinoceroses and six calves (2–3 years old) were translocated from Kaziranga National Park and Pobitora Wildlife Sanctuary to the 519-km^2 Manas National Park. Rhinoceroses were released in groups of 2–4, often containing cow-calf pairs. Animals were radio-collared and located three times/day over 90 days after release. Tracking was carried out by foot, elephant back, motorcycle or vehicle.

A controlled, before-and-after study in 1989–1992 on a hilly grassland and scrubland site in California, USA (24) found that the survival of translocated San Joaquin kit foxes *Vulpes macrotis mutica* kept in pairs in holding pens prior to release was lower than that of resident animals. The survival of 40 translocated foxes in the first year after release (six alive, 32 dead, two unknown) was lower than that of 26 resident foxes (13 alive, 13 died), but did not change with the length of time spent in holding pens. Eleven pups born in the holding pens and released with

their parents all died within 17 days of release. Only four foxes were known to breed after release, all with resident foxes. At the end of the study (1992) one fox was known to be alive and 36 (out of 40) were known to have died. Causes of death were predation (20 foxes), road accidents (two foxes) and death during trapping operations (one fox). The cause of death was unknown for 13 foxes. In August and December 1988 and January 1989, and from June–October 1989, foxes were caught and translocated up to 50 km to a 19,120-ha reserve. Foxes were kept in male–female pairs in holding pens (6.1 × 3.1–6.1 × 1.8 m) for 32–354 days before release in spring and summer 1990 (12 adults, 1 pup) and 1991 (28 adults, 10 pups). Foxes were monitored by radio-tracking 4–5 days/week after release.

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14.34. Release translocated/captive-bred mammals in larger unrelated groups

https://www.conservationevidence.com/actions/2462

- **Five studies** evaluated the effects of releasing translocated or captive-bred mammals in larger unrelated groups. Two studies were in South Africa[2,3], one was in Namibia and South Africa[4], one was in the USA[1] and one was in Australia[5].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (5 STUDIES)

- **Reproductive success (3 studies):** A replicated, paired sites study in the USA[1] found that black-tailed prairie dogs translocated in larger groups had higher reproductive success than smaller groups. A study in South Africa[3] found that Cape buffalo translocated to a fenced reserve as a larger group formed a single herd and reproduced, whilst a smaller group separated. A study in South Africa[2] found that rehabilitated and captive-bred cheetahs released in groups (unrelated and family) and as individuals reproduced.
- **Survival (4 studies):** A replicated, paired sites study in the USA[1] found that black-tailed prairie dogs translocated in larger groups had higher initial daily survival rate than smaller groups. Two studies (one controlled) in Namibia and South Africa[4] and Australia[5] found that releasing translocated black rhinoceroses[4] and burrowing bettongs[5] in larger groups did not increase survival. A study in South Africa[2] found that most adult rehabilitated and captive-bred cheetahs released in groups (unrelated and family) and as individuals survived at least one year.

BEHAVIOUR (2 STUDIES)

- **Behaviour change (2 studies):** A replicated, paired sites study in the USA[1] found that black-tailed prairie dogs translocated in larger groups attracted more immigrants than smaller groups. A study in South Africa[3] found that Cape buffalo translocated as a larger group formed a single herd and stayed in the fenced reserve, whilst a smaller group scattered and escaped the reserve.

Background

Mammals are sometimes wild-caught and translocated or bred in captivity and released to re-establish populations that have been lost, or to augment an existing population. This action includes studies comparing the effects of translocating or releasing mammals in larger, unrelated groups (i.e. not family or social groups), rather than in smaller groups (which might include as few as one animal). This may be done for a variety of reasons, such as increased protection against predators, greater access to potential mates or social groups and an increased chance of establishing self-sustaining breeding populations.

Studies of unrelated translocated mammals that were held together to form social groups prior to release, or unrelated captive-bred animals raised and released together are described in *Release translocated/captive-bred mammals in family/social groups*.

Studies of releases of unrelated animals that were not held together, and where the effect of group size was not tested, are described in *Translocate to re-establish or boost population in native range* and *Release captive-bred individuals to re-establish or boost population in native range.*

A replicated, paired sites study in 1990–1991 in three grassland sites in Colorado, USA (1) found that larger groups of translocated black-tailed prairie dogs *Cynomys ludovicianus* attracted more immigrants and had higher reproductive success and initial daily survival rate than

smaller groups. Over one year, prairie dogs translocated in groups of 59 individuals attracted more immigrants (13.7) than those translocated in groups of 30 (4.0) or 10–11 (1.5). Reproductive success was higher in prairie dogs translocated as groups of 59 individuals (0.79 pups/animal released) than groups of 10–11 (0.28 pups/animal released), but similar to those released as groups of 30 individuals (0.62 pups/animal released). Groups of 59 prairie dogs had higher daily survival rates in the first 23–51 days after release (99.1%) than groups of 30 (98.5%) or 10 prairie dogs (97.7%) but by the second monitoring period (139–142 days later) daily survival rates were the same for all three groups sizes (99.8%). Between July and October 1990, six groups of 10–11, three of 30 and three of 59 prairie dogs were released into three experimental blocks with four plots (2–6 ha depending on group size) in each (2 containing 10–11 prairie dog groups, 1x 30 prairie dog group and 1x 59 prairie dog group, randomly assigned), within a 69-km^2 military area. Prairie dogs were trapped four times during one year post-release, using 1.5 traps/released individual, over four days.

A study in 1981–1998 in a savannah reserve in North West province, South Africa (2) found that following the release of rehabilitated and captive-bred cheetahs *Acinonyx jubatus* in groups (unrelated and family) and as individuals, most adults survived at least one year and animals had reproduced in the wild. Most rehabilitated adult females (3 of 4) and all rehabilitated adult males (4 of 4) survived at least one year. Two rehabilitated adult females produced a second litter within two years of release. Three of 10 cubs released survived to independence, including a female who raised a litter of cubs to independence. The total population numbered 17 cheetahs one year after the end of a five year release program, compared to 18 animals released. An earlier release in the same National Park found that captive-bred cheetahs had bred successfully but most animals were subsequently removed to protect ungulate populations. Between 1995 and 1997, eighteen cheetahs (4 adult males, 4 adult females, 10 dependent cubs) were introduced to a National Park (55, 000 ha) from a rehabilitation facility (unknown if wild-born or captive-bred). Cheetahs were released in family groups (mothers with cubs), in unrelated groups (of males) or individually. In 1981–1982, seven cheetahs were released from a captive-breeding facility and after an unspecified period of time, seven cheetahs were

removed leaving a group of three males. Individuals were monitored by radio-tracking.

A study in 2000–2003 in a mixed karoo grassland reserve in Northern Cape Province, South Africa (3) found that a larger group of translocated Cape buffalo *Syncerus caffer* released into a fenced reserve (after being held in a holding pen) formed a single herd and stayed in the reserve and bred, whilst a smaller group scattered and escaped the reserve. A group of 10 translocated animals formed a single herd (with two previously released animals) and over 10 months all animals survived and remained in the reserve. A year after release, five calves were born. One month after release, a group of four buffalo had split into two solitary animals and a male-female pair. One of the solitary animals was not seen again, the second solitary male was located two years after release on a neighbouring farm and was released into the second group of translocated animals in May 2003. The pair escaped the reserve three times in 13 months. After the third escape, the male was moved to a different reserve and a new male introduced to form a herd with the remaining female. Four subadult buffalo (2 male, 2 female) were placed in a holding pen in July 2000 and released in August into a fenced 12,000-ha reserve. A second group of seven adult and three sub-adult animals (4 male, 6 female) was placed into a holding pen in August 2002 and released into a 200 ha area in September before being completely released in October 2002. Both groups were monitored weekly using radio-tracking until October 2003.

A study in 1981–2005 of 81 reserves across Namibia and South Africa (4) found that releasing translocated black rhinoceros *Diceros bicornis* in larger groups did not affect survival in the first year post-release. Seventy-four of 682 translocated black rhinoceroses died during the first year post-release, but the number of individuals released together did not affect survival in the first year (data reported as statistical result). First-year post-release mortality was higher when animals were released into reserves occupied by other rhinoceroses (restocking, 13.4% mortality of 268 animals) than releases into new reserves (reintroduction, 7.9% mortality of 414 animals). At least 243 rhinoceroses survived at least 10 years after release. For restocking events, first-year post-release mortality was higher in rhinoceroses less than two years old (59%) than in all other age classes (9–20%), but there was no difference for

reintroductions. Data on 89 reintroduction and 102 restocking events of black rhinoceroses into 81 reserves from 1981–2005 were compiled from the Namibia and South Africa Rhino Management Group reports. Animals were released in groups of one to 30 individuals, and reserves received up to five releases. Translocations were considered as different if the releases of individuals to the same reserve were more than 1 month apart. Deaths were detected by reserve staff. The location of reserves included in the study is not provided.

A controlled study in 2013 at a desert site in South Australia, Australia (5) found that releasing translocated animals in a larger group, to swamp predator activities, did not promote population persistence of burrowing bettongs *Bettongia lesueur*. There was no significant difference in post-release persistence between a large release (bettongs last recorded 42 days after the final release) and three smaller releases (bettongs persisted 41–53 days after releases). A total of 1,492 bettongs were translocated between July and December 2013 and released into rabbit warrens. The large release was of 1,266 bettongs, released in July–October 2013 in a 250-ha unfenced area. Three smaller releases, of 48–56 bettongs, occurred in October 2013, at sites 4 km from the large release and from each other. Following no bettong records at two of these sites for ≥7 weeks, further releases of 29 and 39 animals were made in December 2013. From May–December 2003 feral cats *Felis catus* and foxes *Vulpes vulpes* were intensively controlled in a 500-km^2 area by 428 hours of shooting patrols. Bettong persistence was monitored using track counts, camera trapping, warren monitoring and live-trapping.

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(2) Hofmeyr M. & van Dyk G. (1998) *Cheetah introductions to two north west parks: case studies from Pilanesberg National Park and Madikwe Game Reserve*. Proceedings of a Symposium on Cheetahs as Game Ranch Animals, Onderstepoort, 23 & 24 October 1998, 60–71.

(3) Venter J.A. (2004) Notes on the introduction of Cape buffalo to Doornkloof Nature Reserve, Northern Cape Province, South Africa. *South African Journal of Wildlife Research*, 34, 95–99.

(4) Linklater W.L., Adcock K., du Preez P., Swaisgood R.R., Law P.R., Knight M.H., Gedir J.V. & Kerley G.I. (2011) Guidelines for large herbivore

translocation simplified: black rhinoceros case study. *Journal of Applied Ecology*, 48, 493–502.

(5) Bannister H.L., Lynch C.E. & Moseby K.E. (2016) Predator swamping and supplementary feeding do not improve reintroduction success for a threatened Australian mammal, *Bettongia lesueur*. *Australian Mammalogy*, 38, 177–187.

14.35. Release translocated/captive-bred mammals into area with artificial refuges/breeding sites

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- **Seventeen studies** evaluated the effects of releasing translocated or captive-bred mammals into areas with artificial refuges or breeding sites. Five studies were in the USA[4,5,9,13,16], three were in Australia[1,3,15], three were in Spain[6,12,14], two were in the UK[2,17] and one was in each of Ireland[7], South Africa[8], Hungary[10] and Slovakia, the Czech Republic and Poland[11].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (15 STUDIES)

- **Abundance (5 studies):** Two of three studies (two replicated, two controlled) in Spain[6,12] and the USA[16] found that translocation release sites with artificial burrows provided had higher abundances of European rabbits[12] and densities of California ground squirrels[16] compared to those without. The other study[6] found that abundance of European rabbits following translocation was similar with and without artificial burrows provided. A replicated, controlled study in the USA[4] found that after translocating black-tailed prairie dogs to areas with artificial burrows, colonies increased in size. A before-and-after study in Spain[14] found that translocating European rabbits into areas with artificial refuges to supplement existing populations did not alter rabbit abundance, although two of three populations persisted for at least three years.
- **Reproductive success (4 studies):** Three studies in Australia[1], Ireland[7] and the UK[17] found that released captive-bred sugar

gliders[1], most translocated female red squirrels[7] and some translocated pine martens[17] provided with nest boxes and supplementary food reproduced. A study of 12 translocation projects in Slovakia, the Czech Republic and Poland[11] found that translocated European ground squirrels released initially into enclosures or burrows with retention caps reproduced after release, whereas those without enclosures or burrows dispersed from release sites.

- **Survival (9 studies):** Five of eight studies in Australia[1,15], the USA[5,9], UK[2,17], Ireland[7] and South Africa[8] found that at release sites with artificial refuges, and in some cases food provided, a population of captive-bred sugar gliders[1] survived at least three years, two of three populations of red-tailed phascogales[15] survived for more than four years, most translocated black bears[5] survived at least one year and over half translocated red squirrels[7] and pine martens[17] survived 8–12 months. Three studies found that at release sites with artificial refuges, food and in one case water provided, no translocated red squirrels[2] survived more than five months, all translocated rock hyraxes[8] died within three months and most translocated Tipton and Heermann's kangaroo rat spp.[9] died within five days. A randomised, replicated, controlled study in Hungary[10] found that translocated European ground squirrels released into plugged artificial burrows had higher recapture rates than those released into unplugged artificial burrows.

BEHAVIOUR (3 STUDIES)

- **Use (2 studies):** Two studies in Australia[1,3] found that released captive-bred sugar gliders used artificial nest boxes provided.
- **Behaviour change (1 study):** A replicated, before-and-after study in the USA[13] found that translocated Utah prairie dogs released into an area with artificial burrows, after the control of native predators, tended to leave the release site and spent more time being vigilant than before.

Background

Mammals that are translocated or captive-bred and released are especially vulnerable immediately after release. At this time, they may struggle to find shelter in an unfamiliar area, or there may be few suitable refuges/breeding sites available in the new area. Furthermore, if the time they spend looking for suitable shelter or breeding sites is increased, this may make them more vulnerable to predation. Hence, providing artificial refuges or breeding sites in the release area may improve longer-term survival and reproductive rates.

See also: *Habitat restoration and creation — Provide artificial refuges/breeding sites, provide artificial dens or nest boxes on trees, provide more small artificial breeding sites rather than fewer large sites.*

A study in 1979–1981 of a young planted native forest reserve in Victoria, Australia (1) found that a population of released, captive-bred sugar gliders *Petaurus breviceps* provided with artificial nest boxes and supplementary food survived, bred and used the nest boxes. In the third year after releases began, 37 individuals were recorded. Seven animals had been wild-born in the year after release and six females >2 years old showed signs of having reproduced. Occupation by sugar gliders or signs of previous occupation were recorded in 30 of 38 boxes, all three terra-cotta pipes and in 10 of 14 artificial hollow limbs. On a 130-ha island of planted native forest (trees ≤17 years old), 72 sugar gliders were released in January or February of 1979 (26 individuals), 1980 (34 individuals) and 1981 (12 individuals). Seventy boxes, pipes or hollowed limbs (dimensions not provided) were installed on trees, 3–7 m above the ground. Supplementary food was provided at release points during winters of 1979 and 1980. Gliders and artificial nest boxes were surveyed in May 1981.

A study in 1993–1994 on a forested peninsula in Dorset, UK (2) found that none of the translocated red squirrels *Sciurus vulgaris* provided with nest boxes, supplementary food and water (in and once released from pre-release pens) survived over five months after release. Out of 14 translocated red squirrels, 11 (79%) survived over one week, three

(21%) survived >3 months and none survived >4.5 months. At least half of the 14 squirrels were killed by mammalian predators. Intact carcasses that were examined showed signs of weightloss and stress (see original paper for details). Between October and November 1993, fourteen wild-born red squirrels were released into an 80-ha forest dominated by Scots pine *Pinus sylvestris*. The forest had no red squirrels but had introduced grey squirrels *Sciurus carolinensis*. Capture and release sites were similar habitats. Squirrels were transported in wooden nest boxes filled with dry hay. Squirrels were placed with their nest boxes into 1.5 × 1.5 × 1.5 m weldmesh pens surrounded by electric fencing for 3–6 days before release. Squirrels were kept individually except for 2 males who shared a pen. Supplementary food comprised a mixture of seeds, nuts and fruit on trays and in feed hoppers. After release, squirrels continued to have access to food, water and nest boxes inside the pens and outside (20–100 m away). All squirrels were radio-tagged and located 1–3 times/day, for 10–20 days after release and thereafter every 1–2 days.

A study in 1996 of a forest in Victoria, Australia (3) found that nest boxes were used by a population of released captive-bred sugar gliders *Petaurus breviceps*. Twenty out of 67 nest boxes were occupied by sugar gliders. Additionally, 18 boxes were occupied by feral honeybees *Apis mellifera*, a potential competitor for use of boxes. Boxes used by sugar gliders were positioned higher (average 4.5 m) than boxes used by honeybees (average 3.5 m). The site was formerly logged and had subsequently been replanted. Sixty-seven boxes were inspected in July 1996. Boxes had been installed, and captive-bred sugar gliders released in 1979–1982. Boxes were 10–27 l in capacity. Fifty-three boxes were positioned 3–5 m above ground. Seven were >5 m high and seven were <3m high, including three that had fallen to the ground.

A replicated, controlled study in 1999–2003 on a grassland site in Montana, USA (4) found that after translocating black-tailed prairie dogs *Cynomys ludovicianus* in social groups to areas with artificial burrows, colonies increased in size over four years. Six colonies receiving translocated prairie dogs grew more in area over four years (total growth 72 ha, 924% of pre-translocation area) than did 20 similar-sized colonies that did not receive translocated prairie dogs (total growth 27 ha, 93% increase). Two active colonies (with existing prairie dog populations at the start of the study) that each received 120 prairie

dogs increased more over four years (total increase 37 ha, 971% of pre-translocation area) than did two active colonies each receiving 60 prairie dogs (total growth 31 ha, 768%). An inactive colony that received no prairie dogs remained inactive. In June–July 1999, prairie dogs were released into pre-existing burrows (up to eight prairie dogs/burrow) or drilled holes (8 cm diameter × 60 cm deep, 45° below horizontal, up to two prairie dogs/hole, 30 holes/site). Colony size was measured four years later. Nine experimental colonies, three each occupying areas of 0 ha (inactive), 0.1–2.0 ha and 2.0–6.6 ha, were studied. In each size class, translocations to the three colonies were of 0, 60 and 120 prairie dogs. Growth-rates of 20 non-supplemented colonies were also monitored.

A study in 2000–2003 in temperate forest in a wildlife refuge in Arkansas, USA (5) found that most translocated black bears *Ursus americanus* released into man-made dens survived at least one year after release. The first-year post-release survival rate for translocated adult female bears was 62%. For those surviving >1 year after release, second-year survival was 91%. The first-year survival rate of translocated cubs was 75%. Of eight documented adult female mortalities, at least three were due to poaching. Four bears returned to their capture site. In March 2000–April 2002, twenty-three wild adult female black bears and their 54 cubs were captured in White River National Wildlife Refuge and released, 160 km away, into man-made dens at Felsenthal National Wildlife Refuge. Radio-telemetry was used track bears and gather movement data weekly, through to January 2003.

A controlled study in 1999–2002 in a shrubland site in Huelva, Spain (6) found that providing artificial warrens to translocated European rabbits *Oryctolagus cuniculus* did not increase their abundance relative to those translocated without provision of artificial warrens. Over the three-year study, average rabbit pellet density in translocation plots where warrens were provided (4.4 pellets/m^2) was not significantly different to that in plots where warrens were not provided (5.0 pellets/m^2). The study was conducted in four 4-ha square plots (1–6 km apart) in Doñana National Park. Eight artificial warrens, with internal galleries and multiple entrances, were built in each of two plots. Two batches of rabbits, each totalling 64–67 animals, were translocated into each of two plots (one with and one without warrens) each winter from 1999–2000 to 2001–2002. Translocation plots were switched after the first winter,

such that translocations in the second and third winter were into plots where no translocations were made in the first winter. Between September 1999 and November 2002, rabbit abundance was estimated every two months by counting the number of pellets in 33 fixed-position 0.5-m diameter sampling points/plot. Wild rabbits were present in all plots prior to translocations beginning.

A study in 2005–2007 in a mixed conifer forest in Galway, Ireland (7) found that over half of translocated red squirrels *Sciurus vulgaris* provided with nest boxes and supplementary food (in and once released from holding pens) survived over eight months after release and most females reproduced during that period. At least 10 out of 19 (53%) translocated squirrels survived over eight months post-release and five out of nine translocated females (56%) were lactating 5–7 months after release. In August 2006, seven juvenile squirrels were caught. At least one squirrel was still alive at the release location two years after the original release. Two squirrels died while in the release pen or shortly afterwards. Another four squirrels died 1–2 months after release. Nineteen squirrels were translocated to a nature reserve (19 ha) in the middle of a 789-ha commercial pine plantation, 112 km from the capture site. Individuals were marked, radio-tagged and kept on average for 46 days in one of two pre-release enclosures (3.6 × 3.6 × 3.9 m high). Enclosures contained branches, platforms, nest boxes, and supplementary feeders (containing nuts, maize, seeds and fruit). Supplementary food (50/50 peanut/maize mix) was provided in six feeders in the nature reserve until July 2006. Twenty nest boxes were also provided. Squirrels were radio-tracked in September and November 2005 and February and May 2006, and were trapped in February, May and August 2006 and observed once in October 2007.

A study in 2005–2006 at rocky outcrops on a reserve in KwaZulu-Natal Province, South Africa (8) found that translocated rock hyraxes *Procavia capensis* that were provided with an artificial refuge and food after release in a social group, having been held in captivity, all died (or were presumed to have died) within 87 days of release. Eighty-seven days after the release of 17 hyraxes, none could be relocated. In July 2005, ten adult hyraxes were caught in baited mammal traps (900 × 310 × 320 mm) in an area where they were abundant, and held in captivity for 16 months, during which time three died. The remaining

seven were released in November 2006, along with the eight juveniles and two pups born to them in captivity, to a 656-ha reserve where the species was nearly extinct. For four months prior to release, the group was housed together in an outdoor cage (5.9 × 2.5 × 3.2 m). Hyraxes were released into a hay-filled hutch which was left in place for several months, and were provided with cabbage for one week after release. Hyraxes were monitored by direct observations and by walking regular transects, daily for the first week but decreasing to monthly by the end of the study.

A study in 2001 in a grassland and shrubland site in California, USA (9) found that most Tipton kangaroo rats *Dipodomys nitratoides nitratoides* and Heermann's kangaroo rats *Dipodomys heermanni* ssp. translocated into artificial burrows provided with supplementary food died within five days of release. All four Tipton kangaroo rats were predated within five days of translocation, and only one out of seven Heermann's kangaroo rats survived over 45 days. Three Heermann's kangaroo rats were predated, two died as a result of aggression from other Heermann's kangaroo rats, and the fate of one was unknown. In September 2001, four juvenile Tipton kangaroo rats and three Heermann's kangaroo rats were captured and held in captivity for two months before release at a protected site in November. In December 2001, a further four Heermann's kangaroo rats were caught and translocated to the same site. All 11 animals were fitted with a radio-transmitter and ear tags, and monitored for seven days in captivity prior to release. The release site was already occupied by Heermann's kangaroo rats. Animals were released into individual artificial burrows (two 90-cm-long cardboard tubes with a chamber about 30 cm below the surface), dug 10–15 m apart and provided with seeds. Burrows were plugged with paper towels until dusk. Animals were radio-tracked every 1–8 days for 18–45 days after release.

A randomised, replicated, controlled study in 2000 in a grassland site in central Hungary (10) found that translocated European ground squirrels *Spermophilus citellus* released into plugged artificial burrows had higher recapture rates than did ground squirrels released into unplugged artificial burrows. From four to 10 days after release, a higher proportion of ground squirrels released into plugged artificial burrows were recaptured (19 out of 60, 32%) than squirrels released into

unplugged artificial burrows (6 out of 57, 11%). The highest recapture rate came from the group released into plugged burrows in the morning (15 out of 30). From 22–24 April 2000, one hundred and seventeen wild-caught European ground squirrels were translocated to a fenced 40-ha protected grassland. Four 40 × 40-m grid cells were established, each containing vertical, artificial burrows (50 cm long, 4.5 cm diameter) spaced 4.5 m apart. Sixty animals were released into burrows plugged with wood caps (from which they could only exit by digging out) across two grid cells and 57 into unplugged artificial burrows in the other two grid cells. One individual was released/burrow. Approximately half the squirrels were released in the afternoon on the day of capture. Animals to be released in the morning were kept in individual wire cages (10 × 10 × 40 cm) for one night and provided with fresh apple slices prior to release. From 28 April–2 May, squirrels were recaptured with snares to record retention.

A study of 12 translocation projects in 1989–2010 in 14 grassland sites in Slovakia, the Czech Republic and Poland (11) found that translocated European ground squirrels *Spermophilus citellus* released initially into enclosures or burrows with retention caps ('soft-release') reproduced on site after release, but individuals released without an initial preadaptive period or support after release ('hard-release') dispersed from release sites. Translocations in which at least 23 individuals/season were released into enclosures or capped abandoned/artificial burrows led to reproduction (results reflect statistical model outcomes). However, animals released without initial containment did not settle at release sites. The study analysed data from 12 projects, involving release of ground squirrels at 14 sites. Around 2,500 grounds squirrels were released (4–1,057 individuals/project; 4–136 individuals/release season). Animals were 'soft-released' in eleven projects, 'hard-released' in two and combined hard and soft-released in one project. Three releases involved both captive-bred and wild-bred individuals. The remainder were of wild-bred translocated animals.

A replicated, site comparison study in 2008–2012 in 32 shrubland sites in Andalusia, Spain (12) found that release sites with shelter and artificial warrens provided had higher abundances of European rabbits *Oryctolagus cuniculus* following translocation. There were more rabbit latrines at sites where artificial warrens and wooden branches

were provided (1.6–7.1 latrines/km) than at sites where they were not provided (0.3–3.4 latrines/km), although the size of the effect was less when scrub coverage was high (see original paper for details). In 2008–2009, between 75 and 90 rabbits/ha were released inside 32 fenced plots (0.5–7.7 ha). Artificial warrens and wooden branches were added within a 500-m radius of some plots and, in some sites, scrubland was cleared to create pasture (number of plots/treatment not stated). Twelve plots had no wooden branches or artificial warrens (wooden pallets covered with stones, branches and earth) added. From the end of the 2009 breeding season, small gates on fences were opened and the rabbits could disperse into adjacent areas. Relative rabbit abundance was estimated by latrine counts, in four 500-m transects outside each plot, in the summers of 2008–2009 and 2012. Scrub cover was classified as low (0–30% coverage), medium (30–60%) and high (>60%).

A replicated, before-and-after study in 2010–2011 in two grassland sites in Utah, USA (13) found that translocated Utah prairie dogs *Cynomys parvidens* released into an area with artificial burrows after the control of native predators tended to leave the release site and spent more time being vigilant than before. Only 50 out of 779 (6%) were still present at the release sites two months after release. After translocation in both family groups and groups of unrelated individuals, prairie dogs spent more time being vigilant (48%) than they had done before translocation (22%). In July 2010 and 2011, prairie dogs (379 and 400) were caught on a golf course using baited Tomahawk wire box-traps. Individuals were marked with hair dye and ear tags and released the same day at two sites with artificial burrow systems, with up to 10 animals/burrow. Each site had four release areas at least 200 m apart, each containing five burrows, 4 m apart. Each burrow consisted of a 30 × 45 × 30 cm box, buried 1.8m deep, and with two entrances (10-cm diameter and 4-m long) made from plastic tubing. Extra holes were left in the box and tubing to allow burrow expansion. Burrow entrances were protected from predators by mesh cages. At each site, two release areas were used for family groups and two were used for non-related groups. Predator removal of coyote *Canis latrans* and badgers *Taxidea taxus* was conducted for several weeks before and after prairie dog release. In September 2010 and 2011, prairie dogs were trapped, using 100 traps/site, during two sessions of four days each to determine numbers remaining at the site.

A before-and-after study in 2004–2007 in three mixed pasture and scrubland sites in southwest Spain (14) found that translocating European rabbits *Oryctolagus cuniculus* into areas with artificial refuges to supplement existing populations did not alter rabbit abundance, though populations persisted at two of three sites for at least three years. Three years after artificial warrens were built and rabbits were released, rabbit abundance was not significantly different to that before warrens were built (no data reported). In two of three sites, the rabbit population persisted for at least three years, but at one site no rabbits were seen three years after release. In 2004, at three sites, 20–72 artificial warren tubes were installed. In autumn 2004, wild translocated rabbits were released at each site and, in autumn 2005, more rabbits were released at two of the sites. In total, 150–387 rabbits were released at each site. Rabbit presence was detected at two of the sites before releases of translocated animals. In June–September of 2004–2007, rabbit droppings were counted along 10–12 transects, each 500 m long.

A study in 2006–2015 in three woodland and shrubland sites in Western Australia and Northern Territory, Australia (15) found that following release into areas with artificial refuges, two translocated populations of red-tailed phascogales *Phascogale calura* survived for more than four or five years, but one captive-bred population survived for less than a year. The two populations of phascogales established from wild-caught animals survived longer (4–5 years) than one population established from captive-bred animals (which had been kept in pre-release pens and given supplementary food; < 1 year). Authors suggest that the unsuccessful site may also have had a shortage of tree hollows for nesting. In July 2006 and January–February 2007, thirty-two captive-bred phascogales were released into a 26-ha fenced reserve (outside which feral cats were abundant) after spending either 10 days or over four months in a pre-release pen (3×6×2 or 4.5×3×2.2 m). Supplementary food was provided for one week after release. In April 2009 and June 2010, twenty-seven wild-caught phascogales were released into a 430-ha fenced reserve. In May 2010 and May 2011, thirty wild-caught phascogales were released into a 389-ha unfenced reserve, where poison baiting was used to control foxes *Vulpes vulpes* until 2012, but this was suspended due to a possible positive effect on feral cats *Felis catus*. Wild-caught animals had no pre-release pen or supplementary food. Nest

boxes (11–35/site) were provided in every reserve. Phascogales were monitored after each release using radio-collaring or Elliott live traps, and through periodic monitoring of the nest boxes.

A replicated, controlled study in 2011–2014 of two areas of grassland and scrubland in southern California, USA (16) found that where holes were drilled into the soil, densities of translocated California ground squirrels *Otospermophilus beecheyi* were higher than where no holes were drilled. Two years after management commenced, there were more squirrel burrows in drilled areas (43–124/subplot) than in areas that had not been drilled (11–122/subplot). Six plots each comprised a 0.8-ha circle, divided into three equal wedge-shaped subplots. Subplots were mown (in May, for two years, at 7.5–15 cm height, with cut material removed) and were either drilled with a soil auger (20 holes/subplot) or not drilled. The third subplot (data not presented here) was not mown and did not have holes drilled. Management commenced in 2011 (two plots) and 2012 (four plots). Squirrels were translocated into plots at a rate of 30–50/plot. Squirrel abundance was determined by counting squirrel burrows.

A study in 2015–2016 in a wooded mountain region in central Wales, UK (17) found that some translocated pine martens *Martes martes* held in pre-release pens and then provided with supplementary food and nest boxes survived and bred in the first year after release. At least four out of 10 females that had been kept in pre-release pens survived and bred the year after release. Around 10–12 months after release, 14 out of 20 martens were alive and in good condition. Twelve were within 10 km of their release site. Six martens died in the first year, two had a fungal infection two weeks after release. Authors suggest this may have been due to damp conditions in November. From September–November 2015, twenty breeding-age (>3-years-old) pine martens were caught in Scotland, health checked, microchipped and fitted with a radio-collar, and in some cases a GPS logger. Martens were transported overnight to Wales, and held in individual pre-release pens (3.6 × 2.3 × 2 m) for up to seven nights. Males' pens were within 500 m of a female, but >2 km from the nearest male. Releases took place in autumn, and supplementary food was provided for 2–6 weeks after release (for as long as it continued to be taken). Den boxes were provided within 50 m of each release pen. Martens were radio-tracked until home-ranges were established, then

located daily–weekly. Intensive tracking of females was carried out in March to locate breeding sites. Hair tubes and camera traps were used to monitor breeding success. A further 19 martens were released using the same procedure in September–October 2016.

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14.36. Release translocated/captive-bred mammals at a specific time (e.g. season, day/night)

https://www.conservationevidence.com/actions/2447

- **Seven studies** evaluated the effects of releasing translocated or captive-bred mammals at a specific time (season or day/night). Three studies were in the USA[3,5,6] and one each was in the UK[1], Canada[2], Ireland[4] and Hungary[7].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (7 STUDIES)

- **Survival (7 studies):** Four of five studies in the UK[1], Canada[2] and the USA[3,4,6] found that translocated common dormice[1], black bears[3] and Canadian lynx[6] and captive-bred swift foxes[2] released in a specific season had higher survival rates than those released during another season. The other study[4] found that red squirrels translocated in autumn and winter had

similar survival rates. A randomised, replicated, controlled study in Hungary[7] found that translocated European ground squirrels released during the morning had higher recapture rates than those released during the afternoon. A study in the USA[5] found that most translocated kangaroo rats released at dusk in artificial burrows supplied with food died within five days of release.

- **Condition (1 study):** A study in the UK[1] found that common dormice translocated during summer lost less weight than those translocated during spring.

BEHAVIOUR (2 STUDIES)

- **Behaviour change (2 studies):** Two studies in the UK[1] and USA[3] found that common dormice translocated during spring[1] and black bears translocated during winter[3] travelled shorter distances[1] or settled closer to the release site[3] than those translocated during summer.

Background

Mammals are sometimes wild-caught and translocated or bred in captivity and released to re-establish populations that have been lost, or augment an existing population. This action includes studies describing or comparing the effects of translocation projects that release mammals at specific times, such as in specific seasons or at certain times of day or night.

A study in 1991–1992 in a woodland reserve in Somerset, UK (1) found that common dormice *Muscardinus avellanarius* translocated during spring had lower survival rates, lost more weight and travelled shorter distances than dormice translocated during summer. Overall, five of seven dormice (57%) released in spring survived the first 10 days post release compared to seven of eight (80%) dormice released in summer. Common dormice translocated in spring lost more weight (0.30 g/day) than did dormice translocated in summer (0.14 g/day). However, they moved shorter daily distances from their release site (spring translocation: 119 m/day; summer translocation: 292 m/day).

Seven dormice were translocated in spring (between 30 May and 28 June 1991) and 10 in summer (between 24 August and 30 September 1992) to a 9-ha strip of woodland and scrub. Dormice were caught during the morning, moved to the release site and placed there by early afternoon, in the nestbox in which they had been captured. Individuals were fitted with radio-transmitters and followed for 10–20 nights. Dormice were weighed until 10–14 days after release.

A replicated, controlled study in 1987–1991 in three grassland sites in Alberta, Canada (2) found that, after one year, survival of captive-bred swift foxes *Vulpes velox* released in autumn was greater than that of captive-bred swift foxes released in spring. No statistical analyses were performed. At least 10 out of 71 (14%) swift foxes released in autumn survived over one year post-release, compared with at least one out of 27 (4%) of those released in spring. Eighty-one captive-born swift foxes were released in autumn and 41 were released in spring. They were provided with supplementary food for 1–8 months. Swift foxes were radio-collared and 98 were monitored from the ground and air for over one year.

A study in 1995–1999 in a forested area of Kentucky and Tennessee, USA (3) found that black bears *Ursus americanus* translocated during winter had higher survival rates and settled closer to the release area than did bears translocated in summer. First-year post-release survival of winter-released bears (88%) was higher than that of summer-released bears (20%). Winter-released bears remained closer to release sites during the two weeks after emergence from dens (0.4–3.6 km) than did summer-released bears during the two weeks after release (1.1–15.8 km). Eight adult female bears (five with 13 cubs in total and three assumed to be pregnant) were translocated to artificial dens in a 780-km^2 study area in January–March 1996 and March 1997. Six adult female bears were released in June–August 1996, following two weeks in acclimation pens at release sites. Bears were radio-tracked daily on release, reducing gradually to twice/week, until December 1999. Post-release survival was calculated with emigration included within mortality.

A study in 2005–2007 in a mixed conifer forest in Galway, Ireland (4) found that red squirrels *Sciurus vulgaris* translocated in September and October had similar survival rates compared to squirrels translocated in December. The survival rate to the following May of red squirrels

translocated in September and October (78%, 7/9 individuals) was not statistically different to that of squirrels released in December (50%, 5/10 individuals). In August 2006, seven juvenile squirrels were caught and at least one squirrel was still alive in the release location two years after the original release. Nineteen squirrels were translocated to a nature reserve (19 ha) in the middle of a 789-ha commercial pine plantation, 112 km from the capture site. Squirrels were kept for an average of 46 days in one of two pre-release enclosures (3.6 × 3.6 × 3.9 m high). Enclosures contained branches, platforms, nest boxes, and supplementary feeders. Food and nest boxes were also provided in the periphery of the release site. Nine squirrels were released in September or October 2005 and 10 in December 2005. Squirrels were radio-tracked in September and November 2005 and February and May 2006, and were trapped in February, May and August 2006 and observed once in October 2007.

A study in 2001 in a grassland and shrubland site in California, USA (5) found that most translocated Tipton kangaroo rats *Dipodomys nitratoides nitratoides* and Heermann's kangaroo rats *Dipodomys heermanni* ssp. released at dusk in artificial burrows supplied with food died within five days of release. All four Tipton kangaroo rats were predated within five days of translocation, and only one out of seven Heermann's kangaroo rats survived over 45 days. Three Heermann's kangaroo rats were predated, two died as a result of aggression from other kangaroo rats, and the fate of one was unknown. In September 2001, four juvenile Tipton kangaroo rats and three Heermann's kangaroo rats were captured and held in captivity for two months before release at a protected site in November. In December 2001, a further four Heermann's kangaroo rats were caught and translocated to the same site. All 11 animals were fitted with a radio-transmitter and ear tags, and monitored for seven days in captivity prior to release. The release site was already occupied by Heermann's kangaroo rats. Animals were released into individual artificial burrows (two 90-cm-long cardboard tubes with a chamber about 30 cm below the surface), dug 10–15 m apart and provided with a paper towel and seeds. Burrows were plugged with paper towels until dusk. Animals were radio-tracked every 1–8 days for 18–45 days after release.

A study in 1999–2007 in montane forest in Colorado, USA (6) found that translocated Canadian lynx *Lynx canadensis* held in captivity and

released in spring had higher survival rates in the first year than those released at other times of year. Lynx released in spring after >45 days in captivity near the release location had lower monthly mortality rates (0.4–2.8% in 2000–2006) than lynx held for up to seven days in captivity near the release location (20.5% in 1999) and not released in spring. Overall, 117 of 218 released lynxes (53%) survived to at least 1–8 years after release. From 1999 to 2006, two hundred and eighteen lynx were translocated to Colorado from Canada and USA. Lynx were held in captivity near their source location (for 3–68 days) prior to transfer to a holding facility (with 40 x 2.4 x 1.2 m pens with ceilings) in Colorado (100 km from release site). Time in the Colorado holding facility varied (5–137 days): release within seven days following veterinary inspection (4 individuals in 1999); release after 3 weeks (9 individuals in 2000); release after >3 weeks in the spring (1 April-31 May; 28 individuals in 2000); release in spring after >3 weeks in captivity but excluding any juvenile females or pregnant females (177 individuals in 2000–2006). Lynx were fed a diet of rabbit and commercial carnivore food while in captivity. Lynx were monitored for the first year following release using radio-telemetry (1,878 locations/month recorded).

A randomised, replicated, controlled study in 2000 in a grassland site in central Hungary (7) found that translocated European ground squirrels *Spermophilus citellus* released during the morning had higher recapture rates than ground squirrels released during the afternoon. From four to 10 days after release, a higher proportion of ground squirrels that had been released in the morning were recaptured (18 out of 58, 29%) than those released in the afternoon (7 out of 59, 12%). The highest recapture rate came from the group released in the morning in to plugged burrows (15 out of 30, 50%). From 22–24 April 2000, one hundred and seventeen wild-caught European ground squirrels were translocated to a fenced 40-ha protected grassland. Four 40 × 40-m grid cells were established, each containing vertical, artificial burrows (50 cm long, 4.5 cm diameter) spaced 4.5 m apart. Fifty-nine animals were released into burrows in two grid cells during the afternoon on the day of capture and 58 into burrows in the other two grid cells the morning after capture. Animals to be released in the morning were kept in individual wire cages (10 × 10 × 40 cm) for one night and provided with fresh apple slices prior to release. One individual was released/

burrow. Approximately half the burrows for each release group were plugged with wood caps so that squirrels could only exit by digging out. From 28 April–2 May, squirrels were recaptured with snares.

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14.37. Release translocated/captive-bred mammals to areas outside historical range

https://www.conservationevidence.com/actions/2443

- **Seven studies** evaluated the effects of releasing translocated or captive-bred mammals to areas outside their historical range. Three studies were in Australia[2,6,7], one study was in each of Kenya[1], France[3] and South Africa[4], and one was a review of studies in Andorra, Spain and France[5].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (7 STUDIES)

- **Abundance (5 studies):** Three of four studies in Kenya[1], Australia[2], France[3], and South Africa[4] found that after translocating mammals to areas outside their historical range, populations increased for Alpine marmots[3], most of 22 herbivorous species[4] and bridled nailtail wallabies[2] (including captive and enclosure bred animals). A study in Kenya[1] found that a population of translocated roan persisted for more than six years but did not increase. A review of studies in Andorra, Spain and France[5] found that following translocation to areas outside their native range, alpine marmots had similar densities and family group sizes to those of populations in their native range.
- **Reproductive success (1 study):** A study in Kenya[1] found that a population of roan translocated into an area outside their native range persisted and bred for more than six years.
- **Survival (3 studies):** A study in Australia[2] found that captive-bred, translocated and enclosure born bridled nailtail wallabies released into areas outside their historical range had annual survival rates of 40–88% over four years. A study in Australia[6] found that most captive-bred Tasmanian devils released into an area outside their native range survived over four months. A study in Australia[7] found that half the captive-bred and wild-caught translocated eastern barred bandicoots released to a red fox-free island outside their historical range survived for at least two months.

BEHAVIOUR (0 STUDIES)

Background

Endangered species are sometimes translocated from other areas or bred in captivity for release into their former range. Sometimes, though, the former range remains unsuitable for the species, for example through presence of an invasive predator. In such cases, releases to sites outside the former range may be considered, if these potentially offer better conditions for persistence of the species.

A study in 1970–1978 in a grassland and forest reserve in southeast Kenya (1) found that after release of translocated roan *Hippotragus equinus* into an area outside their native range, the population persisted and bred for more than six years. Only eight out of the original 38 translocated roan could be located 18 months years after the last release. However, six years after the last translocations, roan numbers had increased to 22. From 1973–1976, at least 15 calves were born, of which one-third survived to nine months of age. Between 1970 and 1972, 38 roan were released in Shimba Hills National Reserve, where there is no evidence for their existence since at least 1885. Animals were captured in the Ithanga Hills, by funnelling them into a 2.5-acre corral using horses, trucks and a helicopter. Prior to release roan were kept in a 30-acre holding pen. Roan were monitored between June 1973 and January 1978, but no further monitoring details are provided.

A study in 1996–1999 in a woodland reserve in Queensland, Australia (2) found that translocated, captive-bred and enclosure born bridled nailtail wallabies *Onychogalea fraenata* released into areas outside their historical range had annual survival rates of 40–88% and the population increased three-fold over four years. The average annual survival of bridled nailtail wallabies varied by release group between 40 and 88%. During four years, in which 133 wallabies were released, the population increased to approximately 400 individuals. In 1996–1997, nine wild-born translocated and 39 captive-bred bridled nailtail wallabies were released in three sites across Idalia National Park. In 1997–1998, eighty-five wallabies born (from captive animals) within a 10-ha enclosure on the reserve were also released. All released wallabies were kept in a holding pen (30 m diameter) for a week at each site before release. Mammalian predators were culled at release sites. Wallabies were individually marked with ear tags. A total of 37 wallabies (9 wild-born translocated, 28 captive-bred) were radio-tagged and tracked every 2–7 days in 1996–1998. Wallabies were live-trapped at irregular intervals with 20–35 wire cage traps in 1997–1999. Vehicle spotlight surveys were carried out 3–4 times/year in 1996–1999.

A study in 1980–2007 in a mountain grassland site in the Mézenc Massif, France (3) found that after the release of translocated Alpine marmots *Marmota marmota* into a site outside their historical range, numbers increased more than four-fold over 27 years. Twenty-seven years

after the onset of the translocation, marmot numbers had increased to 492, from the 108 originally released. Population growth fluctuated over time with some population declines in 1990, 1993, 1997 and 2001 (see original paper for details). In 1980, eleven marmots were translocated into a mountain area outside their historical range. This was followed by seven reinforcements (translocation dates not provided), with a total of 108 translocated individuals by 2001. Marmots were monitored discontinuously until 1988, and then annually (five times through spring to autumn). Monitoring details are not provided.

A study in 1949–2001 in South Africa (4) found that following translocations outside of the species' native ranges, population sizes of most of 22 species of herbivorous mammals increased. Following translocation, 82 out of 125 populations (66%) of 22 species of mammals (white rhinoceros *Ceratotherium simum*, mountain zebra *Equus zebra*, plains zebra *Equus quagga*, giraffe *Giraffa camelopardalis,* African buffalo *Syncerus caffer* and 17 species of antelope) had positive growth rates (data presented as results of population growth models). Seventeen of the 22 species were introduced outside of their historical range. Population models were based on long-term monitoring data from 178 populations relocated to 24 reserves in 1949–1978 (see original paper for modelling details). Only translocations with five or more consecutive years of monitoring results were included (125 translocations, monitoring data duration: 5–47 years). Translocation details are not provided but authors state that most translocated populations began with fewer than 15 individuals and that most reserves contained water impoundments and lacked top predators, such as lions *Panthera leo* or spotted hyenas *Crocuta crocuta*.

A review of studies in 1948–2003 in nine mountain grassland sites in the Pyrenees in Andorra, Spain and France (5) found that following translocation to areas outside their native range, alpine marmots *Marmota marmota* had similar densities and family group sizes to those of populations in their native range. Average marmot densities and family group sizes did not differ significantly between translocated populations (0.9 individuals/ha; 5 individuals/group) and populations within their native range (1.4 individuals/ha; 6 individuals/group). Between 1948 and 1988, around 500 alpine marmots were translocated to multiple sites across the Pyrenees in areas outside their native range.

In 1965–2003, nine marmot populations (comprising 2–14 family groups) were monitored for 1–2 years in the introduced range and 11 populations (3–50 family groups) were monitored for 1–13 years in their native range (French, German, Italian and Swiss Alps). Monitoring methods are not provided.

A study in 2012–2013 on an offshore island in Tasmania, Australia (6) found that most captive-bred Tasmanian devils *Sarcophilus harrisii* released into an area outside their native range survived over four months after release. Fourteen out of 15 captive-bred Tasmanian devils survived >4 months (122 days) after release. In November 2012, fifteen captive-bred Tasmanian devils were released onto a 9,650-ha island reserve, 12 km off the Tasmanian mainland. Seven individuals were from a captive breeding facility, where animals were raised in groups of 1–4 in 1-ha pens. Eight were from a captive breeding facility were animals were raised in groups of 20–25 in 22-ha enclosures. Animals that shared pens in captivity were released together. Supplementary wallaby meat (20 kg) was provided at two-week intervals. Tasmanian devils were monitored for 122 days through video footage obtained at feeding sites. Individuals were identified by unique markings and scars.

A study in 2012–2013 on an island with mixed forest and grassland vegetation in Victoria, Australia (7) found that, following releases of captive-bred and wild-caught translocated eastern barred bandicoots *Perameles gunnii* to a red fox *Vulpes vulpes*-free island outside of the species' historical range, half of animals survived for at least two months. Nine out of 18 released bandicoots were still alive two months after release while seven survived at least 100 days. Deaths included two to cat predation and two to disease (toxoplasmosis). Between July and September 2012, eighteen eastern barred bandicoots were released on a fox-free island outside of the historical range of the species with 9,000 ha of potentially suitable habitat. Four animals were captive-bred and 14 animals were translocated from a reintroduction site on the mainland. All were fitted with radio-transmitters and PIT-tags to allow tracking and identification of individuals. Each bandicoot was radio-tracked from the day after its release until November 2012.

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