



REVIEW

Translocation of bats as a conservation strategy: previous attempts and potential problems

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ABSTRACT: Translocation is an increasingly popular conservation tool from which a wide range of taxa have benefited. However, to our knowledge, bats have not been translocated successfully. Bats differ behaviourally, morphologically and physiologically from the taxa for which translocation theory has been developed, so existing guidelines may not be directly transferable. We review previous translocations of bats and discuss characteristics of bats that may require special consideration during translocation. Their vagility and homing ability, coloniality, roost requirements, potential ability to transmit diseases, susceptibility to anthropomorphic impacts, and cryptic nature have implications for establishing populations, effects of these populations on the release site, and ability to monitor translocation success following release. We hope that our discussion of potential problems will be able to supplement the existing, more generic guidelines to provide a starting point for the planning of bat translocations.

KEY WORDS: Bat · Chiroptera · Translocation · Reintroduction · Relocation · Guidelines · Release strategy

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INTRODUCTION

Nearly 25 % of all bat species are considered threatened (Mickleburgh et al. 2002), and more research is required to develop strategies to avoid or mitigate threats to these species (Racey & Entwistle 2003). Translocation could be a useful strategy for the conservation of both micro- and megachiropteran bats; it is a powerful conservation tool that can be used to increase a species' range and number of populations to secure against catastrophes, establish populations in areas where the cause of decline can be managed, and allow gene flow amongst isolated populations suffering the negative effects of fragmentation (Griffith et al. 1989). As such, it has become a popular strategy for the conservation of a wide range of taxa, and is being used increasingly as habitats continue to degrade (IUCN 1998, Seddon et al. 2007).

Although translocation is a useful tool, it raises problems that *in situ* conservation strategies do not. For example, translocations are financially expensive, have unknown effects on the biological community at the release site, have negative effects relating to har-

vesting of the source population, require a suitable release site, require a founder group of sufficient size and composition to produce a viable population, and often have low success rates resulting from high dispersal or mortality following release. These issues have been discussed widely, and a number of reviews and articles that can guide the planning of translocations have been published (Griffith et al. 1989, Dodd & Seigel 1991, Short et al. 1992, Armstrong & Mclean 1995, Minckley 1995, IUCN 1998, Wolf et al. 1998, Fischer & Lindenmayer 2000, Letty et al. 2007).

Translocations of bats have only rarely been attempted, with limited success, and with little documentation. Furthermore, bats differ from the taxa for which translocation theory has been developed. As such, existing translocation theory may not be directly transferable (Racey & Entwistle 2003). Here, we review the limited information on previous bat translocations and discuss problems that may require special consideration when translocating bats rather than other taxa.

We have used the term 'translocation' to describe the movement of bats amongst natural areas for con-

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ervation purposes. Several other terms are used synonymously in the literature, most commonly 'relocation' and 'reintroduction,' although different authors have prescribed differing specific meanings depending on whether the release site is within the species' historic range (e.g. IUCN 1987, IUCN 1998). 'Translocation' has typically been used as an umbrella term for any movement, and we use it in this context.

PREVIOUS TRANSLOCATIONS OF BATS

Few examples of translocations of bats exist. A number of translocations of Asiatic pipistrelles *Pipistrellus javanicus* and free-tailed bats *Tadarida brasiliensis* to Hawaii were attempted in the late 19th century. None succeeded, although there is little documentation of the translocations, and the causes of failure are unknown (Tomich 1986). Several colonies of *Molossus molossus tropidorhynchus* were recently discovered in the Florida Keys and may have resulted from a translocation from Cuba for insect control in 1929. However, the species has excellent colonising ability and may have established naturally (Frank 1997). In 2003, an attempt was made to passively translocate an entire colony of ~30 000 grey-headed flying foxes *Pteropus poliocephalus* from the Melbourne Botanical Gardens to a nearby site to prevent damage to the garden's plants. The bats were subjected to recorded loud noises in an attempt to encourage them to leave their campsite. Supplementary food provision, decoy animals and playback calls, a captive colony, and habitat improvement were then used to encourage them to roost at their receptor site. Although the project successfully removed the bats from the gardens they did not roost at the selected receptor site. Their new campsite is being managed to protect the colony (DSE 2003, 2004). In Scotland, a colony of pipistrelles (*Pipistrellus* spp.) was used as a source for 2 translocations of ~100 bats, each to a different site within 50 km of the original roost. It was estimated that in each case all bats had returned home within a week of release (S. Swift pers. comm.). In New Zealand, the Department of Conservation (DOC) has attempted 2 translocations of lesser short-tailed bats *Mystacina tuberculata* to establish populations on predator-free islands. In the first of these, 50 lesser short-tailed bats were translocated approximately 40 km to Ulva Island. Several bats were fitted with radio transmitters but their signals were lost within hours of release. Subsequent acoustic surveys did not record any bat passes (B. Lloyd unpubl. data). It is believed the bats dispersed off the island (B. Lloyd unpubl. data), although they may have died soon after release. In their second translocation attempt the DOC released 20 captive-bred lesser short-tailed bats on

Kapiti Island, approximately 40 km from their source population. In this attempt, release methods were modified to minimise the likelihood of death or dispersal following release: bats were juveniles to reduce the chance of them imprinting on their source location; they were kept in captivity for 2 mo at their release site to allow recovery from the stress of handling and transfer, and to increase fidelity to the site; and they were provided with supplementary roosts and food after release to remove pressure to find resources in an unfamiliar environment (Ruffell & Parsons 2009, this Theme Section, L. Adams et al. unpubl. data). At least 45% of bats remained on the island and survived for 8 mo after release. However, all bats captured 8 mo after release had damaged, infected ears, and 2 were balding (Ruffell & Parsons 2009). These problems were treated with antibiotics and anti-parasite treatments. However, bats were taken into captivity permanently when the ear damage recurred. A team of veterinarians working with DOC was unable to diagnose the source of the damage.

Finally, a number of experiments have tested the homing ability of bats by releasing them outside their home ranges; these can be viewed as non-conservation translocations. While these studies have not monitored the release site to determine if any bats remained and survived to establish populations, they have shown that a large proportion of bats frequently disperse from their release site. For example, in 32 homing experiments where bats were considered to have been released outside their home ranges, a median of 13.9% of bats (interquartile range 0 to 33.3%) were relocated at their original roost (Davis 1966, Gunier & Elder 1971, Guilbert et al. 2007). This figure reflects a lower limit of the number of bats that homed and is likely to be conservative, given the difficulty of relocating bats at their original roost (Davis 1966). The majority of these data were derived from Davis (1966) and are biased towards New World microchiroptera.

PROBLEMS RELEVANT TO THE TRANSLOCATION OF BATS

Dispersal from the release site

Bats are capable of flying long distances, and some species are known to home (Davis 1966). Dispersal from the release site has been demonstrated or suggested as the cause of failure of 3 of the 5 translocations of bats known to us, and homing experiments that release bats outside their home ranges have shown that they often disperse from their release site (see previous section). As such, dispersal is likely to be a problem when attempting to translocate bats.

Homing or dispersal following translocation may be reduced by the release techniques used. For example, strongly philopatric seabirds can be translocated successfully by releasing only juveniles, which acts to minimise the level of imprinting on the source location (Gummer 2003). Similarly, homing experiments that have displaced juvenile and adult bats have shown that juveniles return home less frequently, although this may reflect weaker flight or higher mortality (Davis 1966). A period of captivity at the release site may also reduce levels of dispersal by allowing recovery from the stress of relocation and encouraging imprinting on the release site (Armstrong & Mclean 1995). Finally, the provision of supplementary resources following release can reduce the stress of finding resources in an unfamiliar environment (Armstrong & Mclean 1995) and may provide incentive to stay near the release site.

The New Zealand DOC utilised these 3 release techniques in its translocation of lesser short-tailed bats to Kapiti Island to reduce the likelihood of the bats leaving the release site (see previous section). Of the 20 bats released, a minimum of 9 were still on the island 8 mo after release, when monitoring ceased. Although the translocation ultimately failed, results demonstrate that at least 1 species of bat can be kept at its release site following translocation. Which of the release techniques (if any) contributed to the bats remaining at the release site was not determined.

Size of the founder group

For any taxon, a translocation is less likely to succeed if a small number of founders are released (Griffith et al. 1989, Wolf et al. 1998). This is because small populations face a greater risk of extinction due to environmental, demographic and genetic stochasticity (Gilpin 1991). A meta-analysis comparing the outcome of translocations with the number of founders released indicated that the probability of success reaches an asymptote at around 40 ind. for mammals and 100 ind. for birds (Griffith et al. 1989). However, the ideal number of founders to release is likely to vary amongst species.

Many bat species live in colonies that are larger than the typical size of founder groups used for translocations. Cave-, mine- and building-roosting species can aggregate in colonies of thousands to millions of individuals (Kunz 1982). Tree-roosting species typically roost with tens or hundreds of conspecifics, with individuals switching amongst a pool of nearby trees, such that the colony is spread over a number of trees and is larger than the number of individuals in each tree (Kerth & König 1999, O'Donnell 2000, Willis & Brigham

2004, Popa-Lisseanu et al. 2008). Such coloniality can improve individual fitness by facilitating thermo-regulation, information transfer, predator avoidance and altruistic behaviour (Kunz 1982, Wilkinson 1988, Speakman et al. 1995, Kerth & König 1999). Below a threshold colony size there are probably negative effects on individuals (Humphrey 1975, Racey & Entwistle 2003), and a founder group below the threshold would have a reduced chance of establishing a viable population. Although the precise level of this threshold is not known, for some species of bat translocation may not be a practicable management option because the release of a sufficiently large founder group would have an excessive impact on the source population or involve excessive financial costs for capture and transfer.

Habitat quality at the release site

Habitat quality is a major predictor of translocation success (Griffith et al. 1989). For bats, roosts are the major component of habitat quality in conjunction with foraging grounds (Fenton 1997). However, most species use a range of roost types (Humphrey 1975) and are very selective of the characteristics of their roosts (Sedgeley 2001, Chruszcz & Barclay 2002), and some species may avoid roosts containing other species of bat (Humphrey 1975). Tree-roosting species typically rotate amongst a pool of many roosts (Lewis 1995). Furthermore, these roosts are often uncommon features of the landscape, typically being in caves or cavities in very large trees (Kunz 1982). Correlations between bat diversity and roost diversity, and range expansions in response to the creation of man-made roosts, suggest that roosts limit bat populations in some landscapes (Humphrey 1975). As such, finding release sites with high-quality, unoccupied roosting habitat may be difficult. This problem may be compounded by the fact that factors affecting roost selection are poorly understood for many species of bat.

Supplementary resource provision has been used during translocations of other taxa where natural resources at the release site may be insufficient. For example, a translocated population of stitchbird *Notiomystis cincta* has survived with the aid of supplementary food provision on an island lacking in natural nectar sources (Armstrong & Ewen 2001). Supplementary roost provision could be particularly useful to enable the translocation of bats to areas lacking in suitable unoccupied roosts. Many species of bat readily colonise artificial roosts (McComb & Noble 1981, Kerth & Reckardt 2003, Kunz & Reynolds 2003), and roost-box provision has been used to provide habitat for bats where other roosts are lacking (Brittingham & Williams

2000, Flaquer et al. 2006). In the DOC's second translocation of lesser short-tailed bats, the release site contained little of the old-growth forest in which the species is normally found, but was chosen because it was free of introduced pest mammals. The aviary in which bats were kept prior to release was left open following release, and was used frequently throughout the 8 mo that aviary use was monitored (Ruffell & Parsons 2009). As the translocation was ultimately unsuccessful, whether or not the aviary provided a suitable substitute for natural roosts is unknown. The ability to successfully translocate bats to areas lacking in natural roosts by providing supplementary roosts will depend on the species being translocated and the ability of managers to produce a supplementary roost whose characteristics match those of natural roosts.

Disease transmission

Translocation of a species also risks the translocation of any pathogens that the species hosts. If these pathogens are not already present at the release site they may infect any resident conspecifics, and if pathogens spill over into other species they can have large and unforeseeable effects on the biological community at the release site. Alternatively, pre-existing pathogens may become more prevalent if the translocated species becomes a vector for their transmission (Cunningham 1996). Assessing and removing disease risks should be part of the planning of any translocation (Cunningham 1996, IUCN 1998).

Bats are important reservoirs for infectious diseases (Calisher et al. 2006). Their immune systems may deal with disease in a manner different from other mammals (Calisher et al. 2006) and they can carry a number of diseases that can have dramatic effects on other wildlife, livestock and humans without showing signs of infection themselves (Constantine 2003, Calisher et al. 2006). To date, approximately 66 viruses have been isolated from bat tissue, the most serious of which include rabies, Hendra, Nipah and Australian bat lyssavirus (Calisher et al. 2006). The effects of these diseases on other taxa are unknown, and bats may carry many unknown diseases (Calisher et al. 2006).

The impact of moving diseased animals is further compounded by bats' ability to move great distances in a short period of time. As such, bats are a high-risk taxon in terms of transmitting new pathogens to the release site or acting as vectors for existing pathogens. Bats should only be translocated after the results of an in-depth risk assessment of the likelihood of disease transmission have been weighed up against the potential benefits of translocation, and the distances they are translocated should be as small as possible to reduce

the risk of the release community being naïve to any pathogens they carry (Cunningham 1996, IUCN 1998).

Anthropogenic effects on the founder population

The International Union for Conservation of Nature (IUCN) recommends that organisms should only be translocated to areas that will be protected for the foreseeable future (IUCN 1998). Therefore, it is highly unlikely that a threatened species would be translocated to areas with high levels of anthropogenic impact. Indeed, species such as the golden eagle *Aquila chrysaetos*, once driven to extinction in the Republic of Ireland, have been reintroduced after negative anthropogenic effects (habitat loss and exploitation by humans) have been reversed (O'Toole et al. 2002). However, because bats are capable of travelling long distances whilst foraging or migrating, the potential for them to move out of protected areas and be exposed to anthropogenic threats should be considered.

Bats often have a negative public image, and translocation could result in persecution. Bats are important reservoir hosts to a number of diseases capable of affecting both humans and domestic and wild animals (see previous section) and many are killed due to the perceived threat of disease transmission (Mayen 2003). The threat does indeed appear to be only perceived, as disease levels do not seem to drop following the removal of bats (Mayen 2003). Bats may also be persecuted because they are perceived as an economic threat. Fruit bats are known to forage in commercial orchards, and the economic damage caused by these bats is real. For example, in 1997 the damage caused by flying foxes to Australia's fruit industry was estimated at AUS\$21 million (Tidemann et al. 1997), and in the past orchardists have been known to kill many thousands of bats (Vardon & Tidemann 1995, Mickleburgh et al. 2002). Nowadays, conservationists and governments advocate non-destructive methods for the control of flying foxes, including roost management, protection of orchards (e.g. netting, replay of distress calls), and farm management (decoy trees, early removal of early and over-ripe fruit) (Mickleburgh et al. 1992).

Cave-roosting bats are also at risk from unintentionally harmful anthropogenic impacts because they are vulnerable to disturbance while roosting and because caves are attractive to humans for tourism and recreation purposes (Nowak 1999). For example, a colony of approximately 30 to 50 million Brazilian free-tailed bats *Tadarida brasiliensis* was reduced to just 30 000 due to vandalism and disturbance within their cave (Wilson 1997).

The bushmeat trade is increasingly being seen as a major threat to wildlife, with wildlife sanctuaries often

targeted. However, little published information exists regarding the threat to bats. Commerson's leaf-nosed bat *Hipposideros commersoni* has been taken as bushmeat in Madagascar either opportunistically (Garcia & Goodman 2003) or during a period of food shortage (Goodman 2006). Shively (1997) reported 2 species of fruit bat (*Eonycteris* spp. and *Acerodon leucotis*) being hunted by low-income farming households in the southwest of the Philippines. Fruit bats have also been exploited in the northern Marianas islands (Mickleburgh et al. 2002). The impact of hunting on the bats is often unsustainable (Francis et al. 1999, Garcia & Goodman 2003).

Many of the anthropogenic threats to founder populations can be overcome by simply moving animals into protected areas (IUCN 1998). However, such protected areas often attract humans wishing to exploit wildlife. Furthermore, bats, more than most other species, have the ability to roam widely. Therefore, prior to any translocation of bats the potential of the population to move outside the protected area and encounter humans must be taken into consideration. Redmond et al. (2006) list several strategies for minimising anthropogenic persecution of animals. These include: involvement of government and government policies, education of the public as well as private companies, protection and management of species, and research and monitoring. The effectiveness of these strategies varies significantly from region to region and species to species. Bat-specific strategies can include education on the low risk of disease transmission from bats (Wilson 1997), positive roles played by bats in the ecosystem (Proctor et al. 1996), and the use of mass media to counter the negative image of bats. Non bat-specific strategies used include identification of protein alternatives, improving agricultural infrastructure and the integration of conservation with social and economic development (Redmond et al. 2006).

Post-release monitoring

Post-release monitoring is an essential part of translocation (Ewen & Armstrong 2007). It enables active management that can prevent a translocation's failure, such as veterinary treatment, continued supplementary feeding, or the release of additional founders. Furthermore, monitoring provides feedback for future translocations so that methodology can be modified to maximise the likelihood of success (IUCN 1998).

Many mammals and birds, once released, can be observed and individually identified from a distance because of easily visible bands, tags, or other individually identifiable features (Knowlton et al. 1964, Powell

& Proulx 2003). Many species can be fitted with transmitters that provide a signal detectable over large distances and for long periods of time, allowing founders to be relocated reliably. In contrast, bats are difficult to locate and identify because of their cryptic habits, and most can only carry small transmitters that have a small detection range and short battery life. They are also highly mobile. As a result of these factors, the effort and cost required to effectively monitor founders following release will be much greater than for many other taxa. This is particularly true if bats are not relocated before transmitter failure, making the outcome of the translocation difficult to determine. For example, the DOC's first translocation of lesser short-tailed bats was monitored by fitting bats with radio-transmitters with a battery life of <28 d (B. Lloyd unpubl. data). Transmitter signals were lost within hours of release and were not subsequently detected. Later surveys with ultrasound detectors did not find evidence of bats. It is believed they dispersed from the release site (B. Lloyd unpubl. data), but the cause of failure remains unknown.

Supplementary resource provision may facilitate post-release monitoring by providing a reliable point of recapture. In the DOC's second translocation of lesser short-tailed bats the aviary in which they had been kept prior to release was left open as a roost and bats were provided with supplementary food within the aviary in the same manner as pre-release. Both the aviary and supplementary food were frequently used, and bats could be captured following release by harp-trapping in the vicinity of the aviary at night and by taking them from within the aviary during the day. This allowed a minimum number of bats that remained at the release site to be determined, the condition of those bats to be monitored, and veterinary intervention when bats were found to be diseased (Ruffell & Parsons 2009).

CONCLUSION

Translocation has been a valuable tool in the conservation of a wide range of taxa, and could be a similarly useful strategy for the conservation of bats. However, bats have been translocated only rarely and with limited success, and are biologically different from the taxa for which existing translocation guidelines have been developed. In addition to information available in existing literature and translocation guidelines, we suggest that managers should pay particular attention to the issues outlined in the present paper when determining if translocation is a feasible management option and when planning the translocation protocol to ensure that the likelihood of success is maximised.

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