REVIEW

Veterinary treatment and rehabilitation of indigenous wildlife

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Veterinary surgeons in general practice are frequently presented with injured or orphaned animals by wildlife rescue centres, members of the public or police officers. Following treatment, many of these animals are released to the wild. Despite the large numbers of wildlife casualties rehabilitated in this way there are few published data detailing species, numbers treated, quality of care provided and outcome following release. There is also ongoing debate regarding the welfare and conservation benefits of such human intervention. This article reviews the available published evidence on wildlife rehabilitation and offers recommendations on future policy.

INTRODUCTION – THE REHABILITATION OF WILDLIFE CASUALTIES

The International Wildlife Rehabilitation Council (IWRC) defines wildlife rehabilitation as; the treatment and temporary care of injured, diseased, and displaced indigenous animals, and the subsequent release of healthy animals to appropriate habitats in the wild (Miller 2012). The process of rehabilitation varies according to the species involved and injuries sustained. A deer entangled in a wire fence without other injury may be released to the wild immediately (Green 2003), whilst an orphaned otter requires specialist care for over a year before release (Simpson & King 2003). People involved in the rehabilitation process have a range of abilities and skills, varying from enthusiastic lay people with little training working with limited facilities, through to qualified professionals working in veterinary hospital standard premises (Kirkwood 2003).

RATIONALE FOR TREATMENT AND REHABILITATION OF WILDLIFE CASUALTIES

Most people become involved in wildlife rehabilitation to provide care for individual casualty animals until released or euthanased (Dubois 2003, Guy et al. 2013). The need to avoid causing unnecessary suffering to animals brought into captivity through an inappropriate attempt to extend their natural life must, however, be balanced against such well-meaning altruism (Best & Mullineaux 2003, Kirkwood 2003). Several authors have debated the ethics and welfare of treating wildlife species (Cooper 1989, Kirkwood & Sainsbury 1996, Kirkwood 2003, Cooper & Cooper 2006) with all concluding that the welfare of the individual casualty should be the overriding consideration. Unfortunately, the views of stakeholders (veterinary surgeons, rehabilitators and conservationists) can be at odds when subjects such as the preservation of life and prevention of unnecessary suffering (e.g. by performing euthanasia) are involved (Dubois 2003).

One justification for the treatment of wildlife casualties is an attempt to counter the negative actions of man on species demographics and individual animal welfare. This moral and ethical responsibility is most powerfully illustrated in large man-made catastrophes such as oil spills that impact upon large numbers of seabirds (Wernham et al. 1977, Mazet et al. 2005) and marine mammals (Baker et al. 1981). The same principles of “redressing the balance” can be applied to other man-made problems; 40% of European hedgehogs (Erinaceus europaeus) treated by wildlife rescue centres in the United Kingdom (UK) and the Netherlands arise from road traffic collisions (RTC), garden and pet injuries, poisoning, and disturbance of local environments (Reeve & Huijer 1999).

In countries with unique indigenous species, care of individual animals plays a part in conservation, for example in endangered bird species in New Zealand (NZ) (Mullineaux 2006). Rehabilitation of Australian species including wombat (Vombatus ursinus) (Saran et al. 2011), koala (Phascolarctos cinereus) and common brush-tail possum (Trichosurus vulpecula) (Tribe et al. 2005) has successfully contributed to conservation of these species. Under such circumstances provision of expert care is important but it is nonetheless essential that the individual animal’s welfare is not superseded by conservation aims (Kirkwood & Sainsbury 1996, Cooper & Cooper 2006). In the UK, it is unlikely that veterinary surgeons will be presented with individual animals that pose a conservation risk. Admissions data for wildlife centres and...
veterinary practices can, however, help highlight environmental problem areas, such as polluted water courses or busy roads, allowing mitigation policies to be put in place (Ramsden 2003).

The reporting of wildlife diseases can be an important part of national disease surveillance affecting conservation, livestock diseases and zoonoses (Randall et al. 2012). The need to investigate and monitor wildlife for new and emerging infectious diseases of man and other species has been discussed on a Europe wide basis (Artois et al. 2001) and the requirement for coordinated monitoring of wildlife diseases in the UK has been acknowledged (Sainsbury et al. 2001). Much of the wildlife disease monitoring in the UK is carried out by the Animal Health Veterinary Laboratories Agency (AHVLA) Wildlife Disease Monitoring Program, which aims to detect reservoirs of potential zoonotic diseases, diseases of livestock, and new pathogens and environmental pollutants (Duff 2003). Opportunities exist for lay rehabilitators and veterinarians to contribute to such monitoring. Reports of diseases across Europe and the rest of the world are disseminated through organisations such as the Wildlife Disease Association (WDA), European Wildlife Disease Association (EWDA) and the World Organisation for Animal Health (OIE). The investigation of the cause of clinical illness in wildlife casualties may lead to the identification of novel pathogens not previously described in that species, such as those associated with enteric disease in European badger (Meles meles) cubs (Barlow et al. 2011, 2012) and causing Tyzzer’s disease in a rehabilitated European otter (Lutra lutra) (Simpson et al. 2008).

Internationally, there is strong public support for animal welfare, protection of wild populations, and protection of ecosystems, however, individuals may rank these differently (Dubois & Fraser 2013). Provision of professional veterinary services to members of the public finding sick or injured animals generates a “feel good factor” for those involved and a secondary public relation benefit to the veterinary practice (Kirkwood 2003, Cooper & Cooper 2006). There is also an educational benefit to those dealing with wildlife casualties, creating an environmental and conservation awareness (Wobeser 2007, Vogelnest 2008). Improving public awareness and education is cited a close second to provision of individual animal care by people involved in wildlife rehabilitation (Dubois 2003). Veterinary treatment of wildlife casualties may help to develop skills not normally used in general practice and improve these for future use when presented with endangered species (Sikarskie 1992, Wobeser 2007). At all times the welfare of the individual casualty must be the first priority and personal and professional development a secondary consideration (Cooper & Cooper 2006).

There is much ethical debate regarding the treatment of individual casualties with some authors regarding the only role of the veterinary surgeon as ending suffering through euthanasia (Loftin 1985), whilst others promote the benefits of treatment and rehabilitation (Kirkwood 2003). The potential negative ecological effects of rehabilitated animals on existing populations (Robinson 2002), especially where animals are translocated (Griffith et al. 1993, Wobeser 2007) are not often fully considered. There is also a credible argument that funds should not be diverted from habitat conservation (Sikarskie 1992, Wobeser 2007) and other “worthwhile goals” (Loftin 1985) to the care of casualties. There is, however, little evidence to suggest that those who fund wildlife rescue work would donate elsewhere if such work was to cease (Sikarskie 1992).

For the veterinary practitioner perhaps the greatest risks of dealing with wildlife casualties are related to health and safety of the practice work force. Many wildlife species will bite, kick or scratch, as well as being a potential source of zoonotic diseases (Best & Mullineaux 2003). The risk of disease transmission also extends to domestic species within the veterinary practice. Suitable standard operating procedures, training and risk assessments must be in place to mitigate these risks (Cooper 2003). Professional time, resources and materials diverted into wildlife care must be fully accounted (Sikarskie 1992).

### Regulatory Frameworks

There is an international appreciation of the need to treat wildlife casualties correctly and educate those involved in their care (Vogelnest 2008, Miller 2012), but the regulatory frameworks governing wildlife care vary greatly around the world. In Australia, NZ and North America, some statutory framework exists, but the extent to which standards and training are enforced varies between states within the same country. In South Africa, a need for centralization and enforced minimum standards has been recognized (Wimberger et al. 2010) but there is currently no formal regulation. Where licensing and standards exist there is often criticism from stakeholders that these are not stringent enough and relevant training is lacking (Sikarskie 1992, Dubois 2003). The best attempt to produce international standards and guidelines comes in the form of the IWRC, which offers training and publishes rehabilitation research in its journal.

In Ireland, a licence is required to keep an injured animal in captivity, but no such restrictions exist in the UK. Wildlife in the UK is protected under animal welfare legislation (Animal Welfare Act 2006) and some species-specific legislation (Protection of Badgers Act (1992), Deer Act (1991)). These Acts prohibit “taking” wild animals and ensure their general welfare in captivity. The Wildlife and Countryside Act (1981) restricts the keeping of certain species in captivity and the release of others back into the wild. Wildlife also comes under the Veterinary Surgeons Act (1966), limiting the treatment of all animals to registered veterinary surgeons. There is no central database of those people involved in wildlife rehabilitation and their qualifications, or the numbers of animal in wildlife centres and those eventually released. Informal self-regulation of wildlife rehabilitation has come from the various Wildlife Trusts such as the Badger Trust, Bat Conservation Trust, British Hedgehog Preservation Society and British Trust for Ornithology (BTO), although the main focus for these groups has remained conservation rather than the treatment of individual animals. Later, rehabilitators from these groups have formed the British Wildlife Rehabilitation Council (BWRC), which produces guidelines for rehabilitation and has collected data on treatment and release rates (Best 1999, Kirkwood 2003).

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ADMISSIONS TO WILDLIFE RESCUE CENTRES

There are approximately 80 UK wildlife rescue centres (Mullineaux & Kidner 2011) dealing with an estimated 30 to 40,000 animals per annum (Molony et al. 2007), although true figures of admissions have been suggested to be double this (Grogan & Kelly 2013). Information relating to admissions to these centres is limited to surveys carried out by the BWRC in the late 1990s (Best 1999, Kirkwood 2003). From 16,000 admissions 67·1% were birds, 32·5% mammals, with small numbers of reptiles and amphibians (Kirkwood 2003). Four common species accounted for over 40% of admissions; hedgehogs, feral pigeons (Columbidae), blackbirds (Turdus merula) and collared doves (Streptopelia decaocto). Hedgehogs accounted for 16% of all admissions and 54% of mammals (Kirkwood 2003).

Juvenile animals feature heavily in admissions to wildlife centres. In the BWRC survey, 50% of birds and 54% of mammal admissions were of immature animals (Kirkwood 2003). Thirty-two percent of birds and 27% of mammals had no injuries and were considered to be “orphans” (Kirkwood 2003). In other UK surveys 65% of polecats (Mustela putorius) admissions (Kelly et al. 2010) and 68% of woodpigeon (Columba palumbus) admissions (Kelly et al. 2011) were juveniles. Similar patterns are seen elsewhere in the world; records from a South African rescue centre showed 43% of admissions to be juveniles (Wimberger & Downs 2010), as were 32-2% of raptor casualties (Molina-López et al. 2011) and 53-2% of little owl (Athene noctua) casualties (Molina-López & Darwich 2011) in Spain.

Traumatic injuries are a common reason for casualty admissions, representing approximately 39% of all admissions and 30% of mammal casualties in the UK (Kirkwood 2003). Trauma may occur alone or be secondary to debilitation as a result of disease. Traumatic injuries were responsible for the death of 39% of bats (Chiroptera) in a German study (Mühldorfer et al. 2011). In hedgehogs, 40% of admissions arose predominantly from trauma (Reeve & Huijer 1999). Trauma due to RTC is a primary reason for morbidity and mortality in mammals. High rates of hedgehog mortality were found on Polish roads, especially in urban areas (Orlowski & Nowak 2004). RTC also accounted for 37% of adult badger casualties admitted to wildlife hospitals in the UK (Mullineaux & Kidner 2011) and was the most common reason for presentation of koala in Australia (Griffith et al. 2013). Naturally occurring trauma such as conspecific (“territorial”) wounding in badgers may also be a reason for admission whereby 58% of all badger casualties had this lesion (Mullineaux & Kidner 2011).

TRAUMATIC INJURIES TO BADGERS

A distinctive feature of badgers is the long bone fractures, including the head, coracoid, clavicle and internal soft tissue injuries (Cousins et al. 2012). These injuries are usually caused by RTC (Moline-López & Darwich 2011). Badgers are also susceptible to cat trauma and this accounted for the primary reason for admission of 28·7% of bat casualties in a study in Italy (Ancillotto et al. 2013) and around half of the traumatic deaths of bats found in Germany (Mühldorfer et al. 2011).

Many authors have observed a distinct seasonality to casualty admissions, typically related to breeding season (Kelly & Bland 2006, Molina-López & Darwich 2011, Molina-López et al. 2011, Mullineaux & Kidner 2011, Ancillotto et al. 2013, Griffith et al. 2013). Seasonal trends may allow for planning of resources within wildlife centres and veterinary facilities. A skewed sex distribution of certain injuries in some species is also noted (Mullineaux & Kidner 2011, Ancillotto et al. 2013).

Key to ensuring the welfare of individual wildlife casualties is a proven process that enables the rapid euthanasia of animals that are considered unlikely to be able to be released back to the wild, this process is referred to as “triage” (Best & Mullineaux 2003, Molony et al. 2007, Vogelnest 2008). In medical terms, “triage” is usually used to differentiate between the most urgent and less medically concerning cases in an emergency room or at the site of an accident, in order to provide first aid and emergency care with priority where it is most needed. The limiting factors of medical triage are time and resources. There are wildlife situations where true “triage” is required, for example in a mass cetacean strand (Baker et al. 2000, Barnett & Robinson 2003, Gales et al. 2008), bush fire (Vogelnest 2008) or an oil spill event (Mazet et al. 2005).

Where individual wildlife casualties are involved triage decisions are made based upon the condition of the individual animal and its suitability for eventual release. Authors agree that wildlife casualties should be released in a state of physical and psychological fitness that enables them to survive in the wild equally as well as other free-living members of their species (Best & Mullineaux 2003, Molony et al. 2007). Illness and injury are generally considered to be more important factors than body mass in making
a clinical decision to continue with treatment (Molony et al. 2007). All the factors that contribute to an eventual successful outcome for a casualty need to be considered in the triage decision and not all these factors are veterinary considerations. The success of treatment and rehabilitation of wildlife casualties depends upon the facilities, suitably trained personnel, veterinary services, adequate funding and availability of release sites (Best & Mullineaux 2003, Wobeser 2007).

Triage decisions should be made quickly, ideally within 48 hours of admission (Kelly et al. 2011) in order to prevent unnecessary suffering of casualties in captivity. Figures for casualty survival beyond 48 hours following admission, either as a result of death or euthanasia, are around 60% (Kirkwood 2003, Molony et al. 2007). Ideally a veterinary examination should be part of the triage process for all casualties (Best & Mullineaux 2003, Vogelnest 2008). In large wildlife hospitals, where casualties arrive at all times of day and night, and there is a good relationship with a local veterinary practice, initial triage may be through the use of written schemes of practice allowing trained non-veterinary staff to make triage decisions and carry out humane euthanasia of casualties (Best & Mullineaux 2003). Suitable training is required in appropriate euthanasia techniques (Dubois 2003) and consideration must be given to relevant firearms and medicines legislation (Best & Mullineaux 2003).

**VETERINARY CARE**

Review of the extensive published literature of wild animal diseases is beyond the scope of this article. However, the conditions presented to veterinary surgeons originate from areas of human–wildlife interactions around houses, gardens and roads and are consequently biased towards trauma rather than disease with only 9% of “casualties” presented for “natural causes” including disease (Kirkwood 2003). The prognosis for this category is poor and most are euthanased at first examination. Diseased adult animals are often older individuals at the end of their natural life and typically emaciated (Mullineaux 2003, Griffith et al. 2013). Disease conditions are more commonly treated in juvenile casualties, for example hedgehogs with parasitic skin and lung disease (Bexton & Robinson 2003).

Specific disease in some species may become a significant rehabilitation issue, both as clinical cases and because of a need to screen some animals before release. Examples include tuberculosis in badgers (Mullineaux & Kidner 2011) and chlamydiosis in koalas (Griffith et al. 2013).

Veterinary first aid provision during triage follows the same basic principles as domestic species. Where treatment is carried out it is essential that the long-term future of the casualty animal is continually considered where release remains the ultimate aim. Some specific knowledge of the ecology, biology and specific problems encountered by the various species is necessary; reference to the available literature together with a good working relationship with naturalists and rehabilitators (Miller 2012) is essential to this process.

After initial assessment and treatment animals are usually moved to a rehabilitation facility for further treatment and eventual release. Pre-release fitness assessment is an important and often overlooked part of the rehabilitation process and should include a veterinary examination (Vogelnest 2008), all too often veterinary intervention is limited to the early part of the rehabilitation process.

**VETERINARY RESOURCES**

Published information, in particular peer-reviewed literature, relating specifically to veterinary care and treatment of wildlife casualties is limited. The amount of available literature is dependent upon the value placed on wildlife, either as a commercial resource (e.g. in Southern Africa) or through being unique to a specific country (e.g. in Australia, New Zealand) or considered of international importance (e.g. Giant pandas (Ailuropoda melanoleuca) and tigers (Panthera tigris spp.)]. In the UK, several textbooks describing the care of British wildlife to a general audience have been available for many years (Cooper & Eley 1979, Stocker 2005). More recently literature aimed specifically at veterinary surgeons in practice, rather than rehabilitators, has been produced (Mullineaux et al. 2003). Online resources are available to veterinary surgeons and several articles have been published in veterinary journals aimed specifically at the first opinion practitioner dealing with wild birds (Cousquer 2005a), including raptors (Chitty 2006a,b, Couper & Bexton 2012) and swans (Routh 2000, Cracknell 2004), and mammals, including badgers (Lewis 1997a,b,c, Cousquer 2005b, Mullineaux 2012), bats (Mullineaux & Brash 2009, Bexton & Couper 2010), deer (Benato & Bexton 2011) and hedgehogs (Robinson & Routh 1999).

Veterinary nurses are often responsible for the care of wildlife both in veterinary practices and as employees of wildlife centres. Published information specifically aimed at veterinary nurses (Gosden 2004, Meredith et al. 2008, Varga et al. 2012) is a useful addition to available literature.

**REHABILITATION CARE**

The possibility for disease transfer to and from wildlife casualties to domestic animals and the environmental conditions in most veterinary facilities (bio-containment risks) make them unsuitable for anything other than short-term care. Casualties should be moved to a more suitable rehabilitation facility as soon as they are clinically stable. The availability of facilities, suitably trained personnel and funding are limiting factors in rehabilitation (Best & Mullineaux 2003, Dubois 2003, Wobeser 2007). Standards of care and facilities vary enormously, especially when regulatory standards are lacking.

A good working relationship between lay rehabilitators and vets is an essential part of a successful rehabilitation programme (Miller 2012) and this can sometimes be difficult when emotive subjects such as euthanasia must be discussed. Most wildlife care
and rehabilitation is provided by lay people rather than veterinary surgeons and this may create emotional and philosophical, as well as veterinary, problems (Sikarskie 1992).

**RELEASES FROM WILDLIFE RESCUE CENTRES**

There are limited data relating to release rates from wildlife centres. BWRC figures suggested 42% of all admissions were eventually released (Kirkwood 2003). The RSPCA estimated an overall 40% release rate from its centres (Grogan & Kelly 2013). A detailed study of RSPCA admission records for eight common species suggested an overall release rate of 39% (Molony et al. 2007). Similar release rates were found in casualties from Australian wildlife centres (Vogelnest 2008).

BWRC figures for mammals suggested an overall release rate of 31% (Kirkwood 2003). Release rates for the mammalian species, across all ages, considered in the review of RSPCA data were; badgers 32%, foxes (Vulpes vulpes) 43%, hedgehogs 53% and Pipistrellus spp. bats 29% (Molony et al. 2007). Other studies found that 36% of adult badgers (Mullineaux & Kidner 2011) and 43% of adult polecats (Kelly et al. 2010) survived to release.

Release rates are overall higher for birds than mammals, across all ages. Forty-seven percent of birds in the BWRC surveys survived to release (Kirkwood 2003). Release rates were slightly lower for the avian species included in the RSPCA survey; blackbirds 37%, house sparrows (Passer domesticus) 33%, starlings (Sturnus vulgaris) 36%, tawny owls (Strix aluco) 45% (Molony et al. 2007). Other studies found only 14% of adult woodpigeons (Kelly et al. 2011) and 24% of sparrowhawks (Accipiter nisus) were released after treatment (Kelly & Bland 2006).

Release rates are generally higher in juveniles compared to adult casualties, reflecting the lack of injury in “orphan” animals. For example, 89% of juvenile polecats (Kelly et al. 2010), 31% of juvenile woodpigeons (Kelly et al. 2011), 65% of mallard (Anas platyrhynchos) ducklings (Drake & Fraser 2008) and 81.5% of juvenile wombats (Saran et al. 2011) survived to release.

**EVALUATING A SUCCESSFUL OUTCOME**

The first issue in evaluating the success of rehabilitation is to define “success”, which may be viewed differently by the various people involved in the process (Dubois 2003). Success may be judged in terms of “preventing unnecessary suffering” whereby a high level of euthanasia could be considered successful (Loftin 1985). For most people a "successful" process is defined by the beneficial and release of the animal back into the wild as close as possible to its capture site (Llewellyn 2003). The time of year can influence the success of releases (Tribe et al. 2005) and juvenile animals should be released when food is plentiful and territorial behaviour reduced; special consideration must be given to the release of migratory species (Llewellyn 2003). Selection of release site areas is critical to the release process (Tribe et al. 2005).

Release is an underestimated component of the rehabilitation process with the potential for high losses (Vogelnest 2008). Animals need to re-integrate into the wild for the release to be considered truly successful (Grogan & Kelly 2003) and this includes normal behaviour and future breeding. Release also has potentially negative ecological, genetic and disease effects on existing populations (Cunningham 1996, Robinson 2002, Vogelnest 2008), especially when animals are translocated (Griffith et al. 1993, Wobeser 2007). An Australian survey of rehabilitation and release practices found most centres conducted limited or no pre-release veterinary screening, animals exhibiting stereotypic behaviours were often released, and only 40% of centres had criteria for evaluating the success of releases, with just 58% of centres carrying out short-term post-release monitoring (Guy et al. 2013). The author’s knowledge of rehabilitation practices in the UK suggests the situation is no better.

**METHODS OF POST-RELEASE MONITORING**

Post-release monitoring is essential to assess the true success of the release process. Such monitoring may simply involve direct observation with recognition of individual animals achieved by marking with rings, tags, fur clips, coloured dyes or tattoos (Llewellyn 2003, Guy et al. 2013). Movement sensitive cameras assist this process and allow for monitoring at night. Permanent marking of animals generally requires a licence through an appropriate agency (e.g. Natural England). Radio frequency identification (RFID) transponders or passive integrated transponders (PIT tags) placed as subcutaneous chips or ear tags can be used to identify animals moving through readers fitted to feeding tubes or shelter openings (Rigby et al. 2012). Proximity loggers can be used to measure contacts between individual animals in a group (Ji et al. 2005). However, these methods are time consuming and animals are “lost” once they disperse from the release site.

The “return” of rings, bands tags or tattoo number data to a central organisation (e.g. BTO) affords long-term marking of animals and birds. Easily visible rings such as Darvic rings permit longer-term individual live monitoring of larger birds such as swans (Grogan & Kelly 2013).

Several types of remote tracking are used to monitor animals post rehabilitation, and in ecological projects. Traditional radio tracking (radio telemetry) involves the use of very high frequency
(VHF) radio signals, which are picked up using a handheld receiver (Llewellyn 2003). Data produced tend to be spatially crude and temporally sparse (Cross et al. 2009). This type of tracking, although labour intensive, is inexpensive (Cross et al. 2009) and is the method most commonly employed for post-release monitoring of British wildlife (Grogan & Kelly 2013). Modern tracking systems transmit signals to tracking satellites or receive signals from satellites allowing the use of global positioning systems (GPS). These systems are initially costly but produce very detailed temporo-spatial data with minimal manpower costs (Cross et al. 2009, Thomas et al. 2011).

All tracking systems have to be attached to the animal in some way. In non-mammalian species they may be glued on to the skin (e.g. crocodiles) or feathers (e.g. larger birds) or even placed in more novel areas such as drilled into the horns of rhinoceroses (Lander et al. 2001). If glue is used then the transmitters/receivers may fall off or be shed in the next moult (Lander et al. 2001). A collar, harness or ear tag is commonly used in mammals (Kareesh 1999). Transmitters may be placed internally (e.g. cloaca, peritoneal cavity, subcutaneously) which reduces wear and tear, but requires appropriate licensing (Lander et al. 2001). All systems rely on battery power and this limits the number and frequency of data produced, and the lifespan of the tracking method (Fedak et al. 2002). Battery size also limits which species the systems can be used in effectively – the weight of the battery should typically be no more than 4% of the animal’s body weight (Walters 1998). Monitoring systems may have an effect upon the animal’s behaviour and activity (Vandenabeele et al. 2011), and in the worst situations may cause trauma (Trible et al. 2005, Michael et al. 2012). Radio or satellite receivers also need a power supply and this can be an issue in the field.

The cost of tracking systems is becoming cheaper allowing more ready access to rehabilitators. Battery size and lifespan are also improving, reducing weight and allowing monitoring for longer periods of time (Recio et al. 2011). Other developments include solar cells (Kareesh 1999) and acoustic tags for marine animals (Lander et al. 2001). The newest animal tracking technologies involve DNA sampling and analysis from hair plucks (e.g. from sleeping areas or on fences) and faecal samples to track free-ranging wild animals (Bryan et al. 2012). These systems have the advantage of being non-invasive, but are very time consuming and costly at present.

European hedgehogs are the UK mammal species seen most frequently by rescue centres (Reeve & Huijer 1999, Kirkwood 2003) and several authors have reported survival rates in rehabilitated juvenile hedgehogs. These vary from good; 82% survival at 6 weeks following release (Morris 1998), 77% survival at 6 weeks (Morris 1997), 75% survival at 5 weeks (Morris et al. 1993), to less successful rates; 33% survival at 6 weeks (Sainsbury et al. 1996), 25% survival at 8 weeks (Morris & Warrick 1994). Studies of other UK mammals showed poor survival rates in foxes (Robertson & Harris 1995a) and in polecats a 50% survival at 1 month (Kelly et al. 2010). In many cases, RTC and predation were significant causes of death (Robertson & Harris 1995a, Sainsbury et al. 1996, Kelly et al. 2010).

The post-release survival of rehabilitated birds of prey, mostly juveniles, using leg band return data and radio-tracking was approximately 66% including tawny owls (Bennet & Routh 2000, Leighton et al. 2008, Griffiths et al. 2010), barn owls (Tyto alba) (Fajardo et al. 2000), western screech owls (Otus kennecottii) (Allbritten & Jackson 2002) and peregrine falcons (Falco peregrinus) (Sweeney et al. 1997). Limited longer-term survival rates (over 1 year) (Leighton et al. 2008) are comparable to wild populations (Francis & Saurola 2004). It has been suggested that 4 to 6 weeks is the critical point for survival of rehabilitated birds, after which mortality rates resemble those of wild birds (Martell et al. 1991, Fajado et al. 2000). Post-release survival of rehabilitated woodpigeons was comparable to wild birds (Kelly et al. 2011).

As well as release rates, post-release studies can help to establish factors in the rehabilitation process that influence release success. A period of time in captivity before release was shown to be beneficial in a group of hedgehogs translocated from Uist to the UK mainland (Molony et al. 2006). Excessive human contact may result in ‘imprinting’ especially in juvenile animals (Llewellyn 2003) and in all animals human contact reduces the success of rehabilitation. Human habituation specifically reduces an animal’s ability to deal with hazards and predators efficiently (Robertson & Harris 1995a, Ben-David et al. 2002, Trible et al. 2005, Jule et al. 2008) and in some species results in abnormal denning and foraging behaviour (Trible et al. 2005). Although animals need to be physically fit for release, unnecessary time in captivity is clearly disadvantageous (Trible et al. 2005). With the correct management, the behaviour of released animals is not dissimilar to their wild counterparts (Lander et al. 2002).

Physical fitness for release includes correct bodyweight for its size because most animals lose weight after release (Robertson & Harris 1995a, Morris et al. 2011, Kelly, Jule et al. 2010). Survival is generally higher for larger animals (Bunnell 2002, Trible et al. 2005). Optimum weights have been suggested for the release of hedgehogs (Morris & Warrick 1994). Provision of naturally occurring foods in captivity before release has encouraged post-release feeding and improved survival (Guy et al. 2013).

Pre-release flight training is an essential part of the rehabilitation process in birds and bats (Fajardo et al. 2000, Holz et al. 2006, Kelly et al. 2008, Serangeli et al. 2012). Flight training has been shown to be most successful when it attempts to mirror natural conditions. Post-release survival rates were improved in falconry-trained peregrine falcons and brown goshawks compared to those trained peregrine falcons and brown goshawks compared to those trained peregrine falcons and brown goshawks compared to those...
subjected to cage exercise (Holz et al. 2006). Owls released following training programs with live prey also showed higher survival values (Fajado et al. 2000). Pre-release flight training using large flight cages (Kelly et al. 2008) and training to negotiate small openings to avoid entrapment upon release (Kelly et al. 2012) are important for successful bat release.

Post-release studies contribute to decisions regarding when and how to release casualties. Releases are more successful when food is plentiful and territorial stressors are reduced (Fajado et al. 2000, Llewellyn 2003, Tribe et al. 2005). In some species, such as foxes (Robertson & Harris 1995b), soft release pens have been shown to improve post-release survival in captive reared animals. Conversely, survival of tawny owls (Griffiths et al. 2010) is not significantly negatively affected by adopting hard release techniques.

Conclusions
Wildlife rehabilitation fulfils a welfare, conservation and educational role, which varies around the world. The welfare of casualty and orphan animals would benefit from increased veterinary intervention especially in areas such as pre-release assessment. The true success of rehabilitation cannot be assessed without improved post-release monitoring. How animals survive, integrate and behave in the wild will determine the effectiveness of clinical triage, veterinary treatment and care received during rehabilitation. Such information can be used to educate veterinarians and wildlife rehabilitators, and ultimately benefit the welfare of the animals in their care.

Conflict of interest
None of the authors of this article has a financial or personal relationship with other people or organisations that could inappropriately influence or bias the content of the paper.

References


