Rehabilitation as a conservation tool: a case study using the common wombat

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Wildlife rehabilitation seeks to return healthy animals back to their natural habitat with good survival prospects, and hence contribute to the persistence of their populations. However, the effectiveness of rehabilitation remains largely undocumented, and its utility as a conservation tool is unclear. In this paper, we document the rehabilitation success of a large, herbivorous marsupial, the common wombat (*Vombatus ursinus*), and use the findings as a case study to evaluate the contribution that rehabilitation can make to wildlife conservation. Using a database of 54 orphaned wombats monitored for up to eight years, we found that 81.5% of young survived to release and, of those, 77.3% were alive in the wild by the end of the study. Survival during rehabilitation was greater for larger, older animals, but influenced also by problems during care, reaction to human contact following weaning and, in particular, the responses of individuals to treatment. No factors associated with rescue condition, rehabilitation or release affected survival of animals once returned to the wild, suggesting that wombats were not disadvantaged by their progression through rehabilitation. We provide brief recommendations to improve rehabilitation success for wombats. We conclude that rehabilitation is an under-recognized but potentially valuable conservation tool, and suggest that it is timely to consider its contribution to wildlife management more generally.

Key words: Wombat, *Vombatus ursinus,* marsupial, rehabilitation, release, conservation tool, radio-tracking, survival

INTRODUCTION

ONE of the most widely used but poorly documented practices in animal conservation is that of rehabilitation. Wildlife rehabilitation initially requires the rescue and then captive maintenance of sick or injured animals, and has the ultimate objective of returning individuals to the wild after they have recovered (Vogelnest 2008). Rehabilitation is often viewed simply as an emergency response to catastrophic events such as strandings of cetaceans, near-shore oil spills or wildfires that impact on animal survival or welfare (Estes 1998; Goldsworthy *et al*. 2000; Altwegg *et al*. 2008). The swift actions needed in such situations are usually directed by government agencies and implemented by wildlife scientists, veterinarians and other conservation professionals. However, rehabilitation is also carried out on a more day-to-day basis for wild animals that have become displaced, injured or orphaned by human activities, domestic pets, exotic predators or other agencies (Shine and Koenig 2001; Tribe *et al*. 2005). In these situations rescue and rehabilitation actions are driven usually by concerned individuals or volunteer organizations. Their efforts may be extensive, but the overall effects of such "private" rehabilitation attempts on individual welfare and population persistence remain poorly known.

On the one hand, rehabilitation is seen by many practitioners as an important tool to help conserve biodiversity (Pettett and Yates 2005) and provide opportunities for the broader community to learn about native fauna (Smith 1995). There is emerging evidence that rescued and rehabilitated animals can bolster declining populations (e.g., Mee and Snyder 2007); for highly threatened species even small numbers of additional individuals can be crucial in achieving population recovery (Miller and Mullette 1985). In this respect, rehabilitation may be seen as an important practice that slows population loss and thus, ultimately, species loss (Dickman *et al*. 2007). The numbers of rehabilitated individuals returned to the field may be very large. In New South Wales (NSW), Australia, over 38 different organizations carry out wildlife rescue and rehabilitation. Records kept by the NSW Wildlife Information, Rescue and Education Service (WIRES), the largest of these organizations, indicate that some 75 000 native animals are rescued and rehabilitated each year (WIRES 2010). Such efforts clearly require the expenditure of much time and many resources by volunteer workers.

On the other hand, rehabilitation is sometimes seen as a "feel good" measure that contributes little to population persistence or the conservation of threatened species. Rehabilitation success should not be defined solely by the effective treatment of disease or trauma, but should also include the long-term survival of released and resident individuals (Lunney *et al.* 2004). However, post-release monitoring is seldom carried out; review of the few published studies suggests that survival after release varies greatly both within and between species (Ellis *et al*. 1990; Priddel and Wheeler 1994; Pietsch 1995; Carrick *et al*. 1996; Reeve 1998; Fajardo *et al*. 2000; Goldsworthy *et al*. 2000; Lander *et*

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al. 2002; Cooper *et al*. 2009). In addition to this, it is seldom clear whether populations are affected by losses of the individuals that are rescued, or by their return after rehabilitation. For example, populations may be unaffected if they lose individuals that are part of the "doomed surplus" (Banks 1999) or if compensatory reproduction occurs swiftly to replace the losses (Kirkpatrick and Turner 1991).

If rehabilitation is to be successful, two important steps need to be taken (Tribe *et al*. 2005). The first is to evaluate whether a rescued animal may be ultimately suitable for release (Hall 2005). This is because, although injuries or sickness may be easily treated, substantial resources are often needed to restore individuals to health (Kleiman 1989), and survival post-release may be compromised if the period in captivity is prolonged. The evaluation process should thus involve assessment of the nature of any injuries, age at admission, and the likely duration of care (Ellis *et al*. 1990; Pietsch 1995; Carrick *et al*. 1996). The second step is to monitor animals post-release to document their survival and ensure integration of rehabilitated individuals back into the population.

In this study, we investigate factors contributing to rehabilitation success in a large (~25 kg) herbivorous marsupial, the common wombat (*Vombatus ursinus*). This species is a grazer, with the bulk of the diet comprising grass (Evans *et al*. 2006). Highest densities (1.5 – 1.9 animals / ha) occur usually in agricultural areas (Skerratt *et al*. 2004), where animals can be persecuted owing to the damage that they cause to pastures and to infrastructure such as fences, tracks and dam walls (Borchard and Wright 2010). Although not listed formally as a threatened species, the common wombat has disappeared from many parts of its former range due to habitat change, and populations are exposed increasingly to losses from dogs, diseases such as sarcoptic mange, and collisions with motor vehicles (McIlroy 1973; Bryant and Reiss, 2008). As a result, individuals are regularly brought into care and raised for release (Mui 2003; Farrugia 2005). This makes the common wombat a useful case study subject to evaluate the contribution that rehabilitation can make to wildlife conservation. Based on our findings, we also propose recommendations to improve the rehabilitation process.

METHODS

Study area

Individuals used in this study were rescued by the Wingecarribee WIRES branch in the Southern Highlands of New South Wales, and released onto a private property (20.2 ha) at Wingello in the same area (34°42'S, 150°17'E, 680 m above sea level). The property contains open forest and is bordered by plantations of pine (*Pinus radiata*) to the south and state forest to the east. We used seven release pens within the property during the final stages of rehabilitation and for the release of individuals. The pens are located near several small creeks that allowed wombats access to their preferred riparian habitat.

Rescue, rehabilitation and release

We studied 54 young wombats, or joeys, all rescued between 2000 and 2007. Few adults were presented for care, and we do not consider their rehabilitation results here. Using the guidelines of George *et al*. (1995), animals were given a rank assessment upon presentation and any deemed not viable for rehabilitation were euthanazed (Table 1).

Joeys were aged according to the criteria of Triggs (1996) and Jackson (2003), and then fed "Wombaroo wombat milk replacer" (Wombaroo Food Products, Adelaide, South Australia), using formulas specific to the wombat's estimated age. On reaching weaning size, animals were fed grass, low-protein pellets (YSfeeds, Young, New South Wales) and first-cut lucerne hay.

Animals that survived rehabilitation were generally considered ready for release from about 12–13 kg or when displaying evident escape or dispersal behaviour (Triggs 1996).

Table 1. Scores for initial rescue condition of young wombats (joeys), based on severity of injury. 1 = most severe, 5 = least severe. Animals judged to be in condition 1 are euthanazed as not viable for rehabilitation. Adapted from George *et al.* (1995).

Score	Initial assessment
1	Blow to abdomen, with ruptured internal organs; compound fractures; other evidence of severe injuries.
2	Serious head injury (e.g., resulting from bite wounds from fox or dog).
3	Weak, dehydrated or suffering from prolonged stress (e.g., resulting from being in the pouch of the dead mother for 1-2 days, or being extracted from the pouch and cared for by an inexperienced person).
4	Superficial lacerations, abrasions and bruises (e.g., resulting from joey being thrown out of pouch, subjected to bird attack, or involved in a minor collision inside pouch).
5	Mother killed by injuries to the head or thorax, but no injury to joey.

Following the NSW Rehabilitation of Protected Fauna Policy (*National Parks and Wildlife Act 1974*), the release site contained much habitat suitable for wombats. Release of individuals at the exact location of the original rescue was not practical as animals were often picked up at unspecified places along the side of a road. Animals were released with supplemental food provided *ad libitum* for the first few weeks post-release.

Micro-chipping and radio-tracking

Prior to release, we micro-chipped all wombats by subcutaneous insertion of PIT tags above the left shoulder. This allowed us to confirm the identity of any individuals that were subsequently returned to care or encountered during observations. Following previous studies (McIlroy 1976; Johnson 1991; Buchan and Goldney; 1998, Evans 1998), we also tracked 20 wombats using radio-collars equipped with 2-stage transmitters and trailing whip antennae. The collars, from Biotelemetry Tracking (St Agnes, South Australia), were fitted with a break-away mechanism that had been found suitable in earlier studies of wombats (Mui 2003; Farrugia 2005), and had no evident adverse effects on normal behaviour or well-being. Animals were located visually both day and night using a 3-element Yagi antenna and receiver. This allowed us to make general observations of behaviour and, on occasion, checks of body weight and health. Wombats not fitted with collars were identified by distinct physical marks or micro-chip readings and observed opportunistically, allowing long-term monitoring of all released individuals.

Data collection

To evaluate the factors influencing rehabilitation and post-release success, we collected information on each wombat throughout its care and following release. The initial factors were the immeditate rescue circumstance and each animal's overall condition; these included the joey's estimated age, sex, body weight, and rescue condition score (Table 1). We then explored rehabilitation aspects, ranking the degree of treatment required (Table 2), the individual's response to treatment (ranked subjectively as "good", "average" or "poor" depending on the speed of recovery during care), whether there were problems that affected recovery during care ("yes" or "no"), whether the joey was raised as a pair, the response to human contact following weaning (as a reflection of the extent of human imprinting — "aggressive", "indifferent", "friendly" or "scared"), and growth rate during care. Animals surviving rehabilitation were monitored following their release. We evaluated factors documented during this phase for their influence on post-release survival; these included body condition at release, age, weight, response to human contact following release, and the most recent body condition score in the wild. To assess body condition, we adapted the muscle mass scores of D. Alpers and A. Horsup (Table 3), following their successful application in several recent studies (Woolnough *et al*. 1997; McGill 2003; Mui 2003).

We also included aspects of release circumstances to assess whether greater success was associated with a specific release situation. These factors included time spent in rehabilitation, the season of release, whether pairs were released together and whether an individual utilized the available support food. We recorded any mortalities during rehabilitation and following release to determine if there were practices, either during or following care, that could be changed to help prevent or limit these deaths.

Table 2. Scale of treatment required upon initial rescue of young wombats (joeys), once admitted into care. 1 = most intensive, 6 = least intensive.

Score	Treatment
1	Mange present, intensive care needed to control sarcoptic mites and associated infections.
2	Serious infection present, intensive course of antibiotics required.
3	Minor infection present, antibiotics required (usually short-term, topical application).
4	Joey intact but dehydrated, requires provision of subcutaneous fluids.
5	Joey with superficial injuries that need minor treatment (e.g., flushing with saline solution).
6	Joey intact but cold, needs warming, placement in pouch.

Table 3. Body condition scores based on muscle mass of young wombats (joeys). Adapted from scale developed by D. Alpers and A. Horsup (see text for details).

Score	Description	Condition
1	Ribs visible.	Emaciated
2	Ribs covered, easily felt but not sticking out; vertebrae sharp, sides can be felt, obvious laterally; easy to clasp around pelvis; sunken rump.	Poor
3	Intermediate.	Moderate
4	Pelvis well covered.	Good
5	Overall body well covered, thriving.	Excellent

We evaluated post-release success of rehabilitated wombats via survivorship, both following the critical post-release period (from practical experience, considered to be 42 days following release) and when the study was completed after eight years.

Data analysis

In general, our analyses compared factors within the rehabilitation and release categories with whether individuals survived these stages or not. We further compared post-release aspects of care for individuals that survived rehabilitation. Chi-squared and one-factor ANOVAs were used for all comparisons. Significance was set initially at 0.05 but, for multiple comparisons, sequential Bonferroni adjustment was used to reduce the chance of committing type-1 errors (Quinn and Keough 2002). In further analyses, we used multiple logistic regression to determine the relative importance of different factors on survival within the rehabilitation and release categories. After inspection of the raw data, we pooled results for the two sexes to increase sample sizes. Variables were discarded if they were highly correlated ($r \geq 0.80$) with one or more others, and then entered into the model if they had moderate individual influence on wombat survival ($p \leq 0.25$). The Hosmer-Lemeshow test was used to assess the overall fit of the model and Wald statistics to test the significance of model coefficients (Quinn and Keough 2002), with 0.1 used as the α-level for variable retention. Chi-squared and ANOVA tests were computed using JMP (SAS Institute, North Carolina, USA) and logistic regressions using SPSS 15.0 (SPSS 2006). The statistical comparisons used here are exploratory in the sense that no *a priori* hypotheses could be identified to test; we used them primarily to uncover patterns in the overall data set. Means are given ± SD.

RESULTS

Overall survival

Of the 54 wombats included in this study, 44 (81.5%) survived to release; of those, all but two survived beyond the critical period of 42 days. Following this period, 34 wombats survived in the wild to the end of the study. Overall, 63% of wombats taken in for care survived through rehabilitation and post-release and could therefore be considered successfully rehabilitated. At release, wombats ranged from an estimated 566–1 078 days old (mean 805.7 ± 129.5 days). Release weights were 12–19.2 kg (mean 14.8 ± 1.7 kg). Of those individuals that survived, length of stay in rehabilitation lasted 316–868 days (mean 607.6 ± 139.7 days). Of the animals that made it to release, those surviving by the conclusion of the study had been in the wild from 44 days for recently-released individuals to 2 518 days for animals released in earlier years.

Factors affecting survival during rehabilitation

The initial factors that caused joeys to be brought in for care had no influence on their survival in rehabilitation. While rescue condition reflected the degree of injury an individual had experienced, the actual extent of impairment had no impact on the joey surviving the rehabilitation phase of treatment ($\chi^2_3 = 1.66$, $p = 0.761$). This was also the case for the initial level of treatment required once a joey had been presented for rehabilitation ($\chi^2_5 = 3.061$, $p = 0.691$).

Sex played no role in survival ($\chi^2_1 = 0.59$, $p = 0.444$), but age was influential. Survival was greater if joeys were older ($F_{1,52} = 4.95$, $p = 0.030$, Fig. 1a) and heavier ($F_{1,52} = 4.06$, $p = 0.047$, Fig. 1b) at the time of rescue. Not surprisingly, the response of individual joeys to treatment and care had a strong effect on survival ($\chi^2_2 = 13.05$, $p = 0.002$) (Fig. 2a), as did problems they faced during treatment after rescue ($\chi^2_1 = 14.93$, $p < 0.001$) (Fig. 2b). In general, animals that responded poorly to treatment or experienced problems during care had a lower likelihood of survival. The responses of wombats to human contact following weaning also affected rehabilitation success ($\chi^2_3 = 9.61$, $p = 0.022$). The less human-imprinted, the more likely an individual was to survive to release (Fig. 2c). Raising wombats in pairs made no difference to rehabilitation survival ($\chi^2_1 = 1.53$, $p = 0.216$), nor did the daily rate of growth ($F_{1,52} = 0.97$, $p = 0.328$).

Logistic regression confirmed the importance of animals' rescue weight ($\beta = 0.957$, Wald = 3.12, $p = 0.077$) and response to treatment during rehabilitation ($\beta = 3.919$, Wald = 4.26, $p = 0.039$) on survival, but failed to include response to human contact post-weaning and problems affecting recovery during weaning. The Hosmer-Lemeshow statistic was not significant ($\hat{C} = 8.812$, $p = 0.358$), thus providing no evidence for lack of model fit.

Post-release survival

No rehabilitation factors influenced the post-release survival of wombats. Release age ($F_{1,42} = 0.0003$, $p = 0.987$), weight ($F_{1,42} = 0.215$, $p = 0.645$) and condition ($\chi^2_3 = 3.71$, $p = 0.295$) had no influence on survival following release. The number of days spent in care also had no impact on post-release survival ($F_{1,42} = 0.48$, $p = 0.492$), and nor did the season when animals were released ($\chi^2_3 = 1.72$, $p = 0.642$).

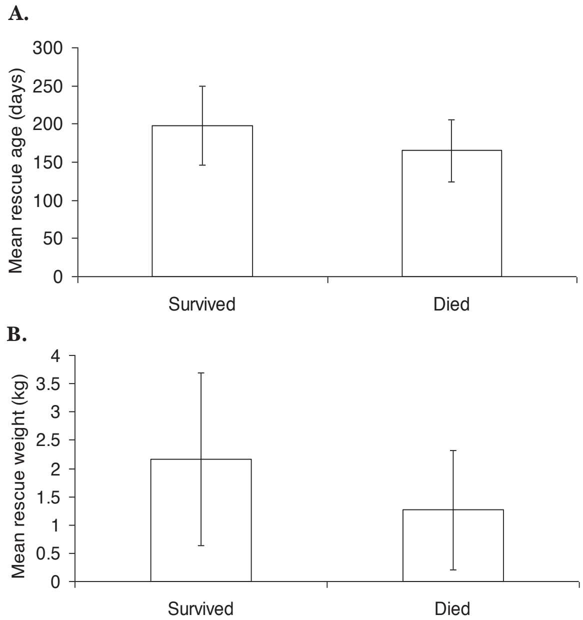

Fig. 1. Survival of young wombats (joeys) during rehabilitation in relation to a) estimated rescue age in days, and b) rescue weight in kilograms. Means are shown ± SD, n = 54.

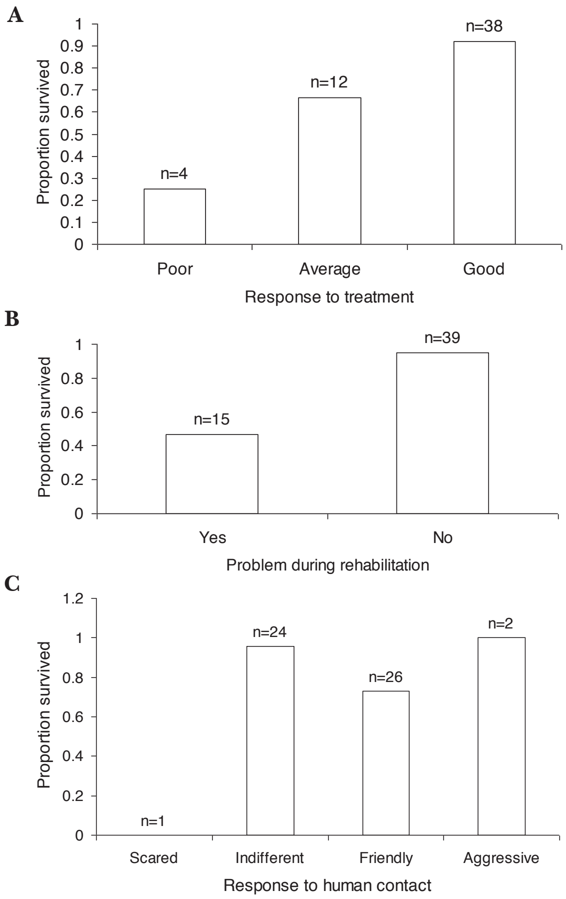

Fig. 2. Survival of young wombats (joeys) during rehabilitation in relation to a) their response to care, b) problems experienced during care, and c) their response to human contact from weaning until release. Proportions are shown for each of the response classes, n = 54 in a) and b); n = 53 in c).

Additionally, release condition had no influence on most recent condition score ($\chi^2_6 = 11.04$, $p = 0.087$). Survival was not affected by whether animals used the support feed provided as a supplement for their natural grazing foods ($\chi^2_1 = 0.57$, $p = 0.452$).

There was no relationship between the post-release survival of wombats released individually or as animals raised in pairs while in rehabilitation ($\chi^2_1 = 0.05$, $p = 0.817$). The responses of wombats to human contact following release also had no effect on survival ($\chi^2_2 = 2.54$, $p = 0.282$). We were unable to construct any multiple logistic regression models with factors influencing post-release survival, even after forcing variables into analyses. This failure to construct models was consistent with the lack of any significant results in the univariate tests.

Post-release care

Seven wombats were returned to care at various times following their release for reasons including being hurt by other wombats or dogs, injuries of unknown causes, and infections or serious loss of condition. Four of these individuals were returned to the wild, while the others were euthanazed or died during in-care recovery. Without return into care we also temporarily treated five individuals for varying degrees of mange, with full recovery seen following the completion of treatment.

Rehabilitation and post-release mortality

Causes of death of wombats during rehabilitation included prolapse (organ not recorded) (n = 1), coccidiosis (n = 1), bacterial infections (n = 3), unidentified problems with organ failure (n = 2), and unknown causes (n = 3). Of the two wombats that did not survive the critical post-release period, one was found dead of unknown causes, and the other died after a dog attack. Identified causes of death in the other eight wombats following the critical period included dog attack (n = 2), wombat attack (n = 2), burrow collapse (n = 1) and sarcoptic mange (n = 2); the cause of the death of the remaining animal is unknown.

DISCUSSION

Upon rescue, all 54 wombats included in this study were deemed suitable for rehabilitation, and most (81.5%) survived to release. Post-release survivorship, at 77.3%, was similar to that found in other studies that have investigated post-release survivorship of wombats (83%, 85.7%) (Mui 2003; Farrugia 2005). Overall survival of individuals from rescue to post-release achieved 63%, and compares favourably with survival rates of young in wild populations (Triggs 1996). Based solely on these results, the current efforts and practices employed by wildlife rehabilitators appear to contribute successfully to wombat rehabilitation, and thus make this process an intensive but potentially viable strategy for management by individuals and volunteer organizations.

Rehabilitation results for other marsupials are mixed. Several studies of koalas (*Phascolarctos cinereus*) suggest that individuals generally fare well after being returned to the natural environment (Ellis *et al*. 1990; Starr 1990; Carrick *et al*. 1996), with annual survival rates of rehabilitated and free-living uninjured animals differing little (58% and 67%, respectively) (Lunney *et al*. 2004). In contrast, rehabilitated common brushtail possums (*Trichosurus vulpecula*) and common ringtail possums (*Pseudocheirus peregrinus*) exhibit very low survival after release, with no animals persisting more than a few months (Pietsch 1995; Augee *et al*. 1996). One explanation for the relatively high post-release survival of koalas and wombats is that they are not as susceptible to predation from introduced carnivores as are smaller marsupials. Indeed, the introduced red fox (*Vulpes vulpes*) and feral house cat (*Felis catus*) were significant sources of mortality for possums in the studies of both Pietsch (1995) and Augee *et al*. (1996), and are the key causes of failure of many programmes that seek to translocate threatened marsupials for conservation purposes (Short *et al*. 1992; Serena 1995; Finlayson *et al*. 2010). However, other explanations cannot be discounted. Different species respond in very different ways to time spent in captivity (Molony *et al*. 2006; Jule *et al*. 2008), as well as to conditions in the captive environment (Biggins *et al*. 1999; Field *et al*. 2007) and at the release site (Goossens *et al*. 2005). We discuss some of the factors influencing wombats in more detail below.

Rehabilitation success

Surprisingly, the initial rescue condition of a joey considered suitable for care had no influence on its survival during rehabilitation. The severity of injuries sustained played no role in survival, nor did the extent of treatment required for these injuries. This, in combination with the fact that individuals responded differently to treatment, provides support for the idea that there is individual variation in the ability to cope with the transition to care, and that survival may be based largely on an individual's capacity to deal with captive conditions. Assuming that individuals are viable for rehabilitation at the point of entry into care, most should therefore have the potential for successful release back into the wild, regardless of their rescue condition.

Both age and weight at rescue influenced survival, with weight emerging as a significant factor in both univariate and multivariate analyses. Although these factors are clearly correlated, as animals gain weight with growth, their effect on survival is not surprising. Older joeys have spent more time developing in their mother's pouch and have less growth to complete independent of their mother in the more stressful captive environment (Taylor and Rose 1987). Older joeys also receive higher grade milk when rescued than younger ones and need to make fewer transitions from one milk type to another. Not only this, they are likely to be more immuno-competent than young joeys and should therefore be better able to withstand challenges from pathogens and disease (Bryant and Reiss 2008).

Young wombats are often recommended to be raised in pairs (non-sibling; twins are a rarity) to minimize human imprinting (Myers 2006) and create a bond between them rather than between the rehabilitator and the individual joey. However, in terms of rehabilitation and post-release survival, we found no support for this recommendation. The response of wombats to human contact following weaning appears instead to be an important influence on rehabilitation survival. Level of success was highest for individuals that were aggressive or indifferent to humans compared with those that were friendly or scared, although only one individual was placed in the latter category. Restricting human contact as soon as possible after weaning should help to limit familiarity and habituation, thereby reducing human attachment and associated negative behaviours (Beringer *et al*. 2004; Hall 2005).

As the success of wombats in rehabilitation appears to come down largely to each individual's ability to deal with the transition into and through rehabilitation, it is difficult to predict at the time of rescue those that will thrive and those that will succumb. Studies of increasing numbers of animal taxa currently are uncovering large and consistent differences in behaviour between individuals (e.g., Réale *et al*. 2007; Biro and Stamps 2008); such "personality" differences contribute importantly to differences in individual fitness, but can make sampling and prediction difficult (Biro and Dingemanse 2009). In wombats, evaluation of physiological stress may help to predict individuals that are most at risk. In future research, it might be profitable to test whether individual stress levels are associated with survival by assaying them for stress hormones such as free corticosteroids early in the rehabilitation process.

Post-release success

The fact that none of the tested rehabilitation factors influenced post-release survival is a positive finding, as all individuals that survive to the time of release appear to be in no way disadvantaged by their specific progression during rehabilitation. Providing that joeys make it through rehabilitation and are released as healthy individuals, they should all have a similar chance of surviving in the wild.

Release age, weight and body condition had no effect on post-release survival. This is also encouraging, as it suggests that individuals can be released as soon as they reach the appropriate dispersal age or size. As animals of varied body condition survived, this perhaps reflects variation that would naturally be seen in wild populations and therefore it is not essential that all hand-reared juvenile wombats be in peak body condition before release. Additionally, as pair-release had no impact on survival, individuals should be released as soon as they are ready and without waiting for the other pair member.

The lack of effect of release season on survival may reflect aseasonality in wombat breeding; pouch young have been found in wild wombats year round, and consequently there is no specific dispersal time (Triggs 1996; Jackson 2003). While supplemental feeding also played no significant role in survival, "soft release" may simulate the natural dispersal process that occurs when wild young move gradually from their mothers' home ranges (McIlroy 1976; Taylor 1993; Triggs 1996; Hall 2005). Thus, it is possible that supplementary food was advantageous to those individuals that made use of it; however, this aspect of the release process merits further study.

Most fatalities post-release were linked to attacks by dogs and other wombats. Aggression and fighting between wombats occurs in wild populations (McIlroy 1976; Triggs 1996) and, as a result, can be expected to affect both hand-raised and wild parent-raised individuals. However, it is also possible that levels of aggression were elevated in the present study, as more than 54 individuals had been released into an area of just 20 hectares over eight years, and at the time of the study many of these remained on site. Density at Wingello was not assessed, but could be expected to be higher than in surrounding areas owing to the release programme and to the provision of supplemental food. Despite this, wombats have been reported to occur naturally at densities of 1.9 per hectare (Skerratt *et al*. 2004), while pairs are often maintained in captivity in enclosures of just 45-400 m^2 (Jackson 2003; Hogan and Tribe 2006). Dog attack, being both a cause of mortality and the need to bring wombats into care in the first place, is a potentially serious threatening process for this species. It is not clear whether rehabilitated wombats are at similar risk to their wild counterparts, but public education and increased enforcement of dog ownership laws have both been advocated to reduce the problem (Kleiman 1989; Nattrass 1992). Post-release monitoring is generally recognized as being a vital part of rehabilitation and reintroduction programmes (Chivers 1991; Fischer and Lindenmayer 2000), and this is affirmed by our results.

Implications: rehabilitation as a conservation tool

Wildlife rehabilitation takes place in many parts of the world, and results in large numbers of animals being restored to health and returned to their natural habitats each year. If survival rates are high, as they are for common wombats, rehabilitation may contribute significantly to the dynamics and persistence of wildlife populations. However, potential risks remain. For example, rehabilitation may introduce diseases into wild populations (Tidemann *et al*. 1992), although such possibilities should be minimized by effective veterinary screening before captive animals are released. There are also uncertainties. Most importantly, there is little documentation of the effects of individuals being returned to populations, both in terms of their contribution to population growth and their effects on existing population members. In addition, if individuals are not returned to their own populations because their provenance is uncertain, genetic problems may manifest, such as the appearance of deleterious traits or outbreeding depression (Hodder and Bullock 1997), or even the breakdown of population structure (Laikre *et al*. 2010). These questions may form priorities for future research.

In a review of animal relocation studies, Fischer and Lindenmayer (2000) recommended that the value of relocation could be enhanced by ensuring that this tool was appropriate for the conservation goals that had been set, by establishing generally accepted criteria for success, by better monitoring of the outcomes, by ensuring better financial accountability, and by publishing the results. Although Fischer and Lindenmayer (2000) did not deal with studies describing rehabilitation *per se*, we suggest that their recommendations could enhance the rigour of rehabilitation works too. Because wildlife rehabilitation is carried out by individuals and volunteer organizations and is subject to little review, it remains a low profile activity. Our results for just one species indicate that rehabilitation is a potentially valuable conservation tool, and suggest that it is timely to consider its contribution to wildlife management more generally.

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