SUBMITTED VERSION

"This is the pre-peer reviewed version of the following article:

Mehregan Ebrahimi, Esmaeil Ebrahimie and C. Michael Bull
Minimizing the cost of translocation failure with decision-tree models that predict species' behavioral response in translocation sites
Conservation Biology, 2015; 29(4):1208-1216

© 2015 Society for Conservation Biology

which has been published in final form at http://dx.doi.org/10.1111/cobi.12479

This article may be used for non-commercial purposes in accordance with Wiley Terms and Conditions for Self-Archiving."

PERMISSIONS

http://olabout.wiley.com/WileyCDA/Section/id-820227.html

The submitted version of an article is the author's version that has not been peer-reviewed, nor had any value added to it by Wiley (such as formatting or copy editing).

The submitted version may be placed on:

- the author's personal website
- the author's company/institutional repository or archive
- not for profit subject-based preprint servers or repositories

Self-archiving of the submitted version is **not subject** to an embargo period. The submitted version may be self-archived immediately on acceptance of the article. The version posted must acknowledge acceptance for publication and, following the final publication, include the following notice on the first page:

"This is the pre-peer reviewed version of the following article: [FULL CITE], which has been published in final form at [Link to final article using the DOI]. This article may be used for non-commercial purposes in accordance with Wiley Terms and Conditions for Self-Archiving."

The version posted may not be updated or replaced with the accepted version (except as provided below) or the final published version (the Version of Record).

There is no obligation upon authors to remove preprints posted to not for profit preprint servers prior to submission.

24th March 2016

http://hdl.handle.net/2440/90029

Minimising the cost of translocation failure by using decision tree models to predict species behavioural response in translocation sites.

Journal:	*Conservation Biology*
Manuscript ID:	14-550
Wiley - Manuscript type:	Contributed Paper
Date Submitted by the Author:	09-Jul-2014
Complete List of Authors:	Ebrahimi, Mehregan; Flinders University, School of Biological Sciences; Shiraz University, Department of Biology Ebrahimi, Esmaeil; Adelaide university, School of Animal and Veterinary Science / School of Molecular and Biomedical Science Bull, Michael; Flinders University, School of Biological Sciences
Keywords:	Decision tree, Translocation, Behaviour, Prediction, Conservation management
Abstract:	Translocation is a powerful tool in conservation management, but the high number of failures of many translocation attempts is one reason why translocation is often not recommended as a first solution. In many conservation management issues more attention is now paid to animal behaviour. Considering how behaviours change during the translocation process may be a key to translocation success. In this paper we used data from five simulated translocation experiments on an endangered Australian skink to derive decision tree models. These experiments considered the short term responses when lizards were released under alternative sets of conditions. We used four different decision tree algorithms (decision tree, decision tree parallel, decision stump and random forest) with four different criteria (gain ratio, information gain, gini index and accuracy) to investigate how environmental and behavioural parameters that were measured in the five experiments, and their changes, might affect the success of a translocation. We assumed that any behavioural change that increased the chance of dispersal away from a release site would reduce the success of the translocation. The trees became more complex when we included all behavioural parameters as attributes, but these trees gave us more detailed understanding about why and how dispersal occurred. Decision tree models based only on parameters related to the release conditions were easier to follow and might be used by conservation managers to make decisions about the translocation process in different circumstances.

Title: Minimising the cost of translocation failure by using decision tree models to predict species behavioural response in translocation sites.

Running title: Predicting species behaviour by decision tree models

Keywords: Decision tree, Translocation, Behaviour, Prediction, Conservation management,

Word count: 5376

Mehregan Ebrahimi[1, 2], Esmaeil Ebrahimie[3, 4] and C. Michael Bull[1]

[1] School of Biological Sciences, Flinders University, Adelaide, South Australia 5001, Australia.

[2] Department of Biology, Shiraz University, Shiraz, Fars Province, 71454, Iran.

[3]Institute of Biotechnology, Shiraz University, Shiraz, Fars Province, 71946, Iran.

[4] School of Molecular and Biomedical Science, The University of Adelaide, Adelaide, South Australia 5005, Australia

Correspondence: Mehregan Ebrahimi: School of Biological Sciences, Flinders University, Adelaide, South Australia 5001, Australia.
mehregan.ebrahimi@flinders.edu.au
Ph: +61 8 8201 5352
Fax: + 61 8 8201 3015
Mobile: +61 4 1209 8448

Abstract

Translocation is a powerful tool in conservation management, but the high number of failures of many translocation attempts is one reason why translocation is often not recommended as a first solution. In many conservation management issues more attention is now paid to animal behaviour. Considering how behaviours change during the translocation process may be a key to translocation success. In this paper we used data from five simulated translocation experiments on an endangered Australian skink to derive decision tree models. These experiments considered the short term responses when lizards were released under alternative sets of conditions. We used four different decision tree algorithms (decision tree, decision tree parallel, decision stump and random forest) with four different criteria (gain ratio, information gain, gini index and accuracy) to investigate how environmental and behavioural parameters that were measured in the five experiments, and their changes, might affect the success of a translocation. We assumed that any behavioural change that increased the chance of dispersal away from a release site would reduce the success of the translocation. The trees became more complex when we included all behavioural parameters as attributes, but these trees gave us more detailed understanding about why and how dispersal occurred. Decision tree models based only on parameters related to the release conditions were easier to follow and might be used by conservation managers to make decisions about the translocation process in different circumstances.

Introduction

Decision tree algorithms have been used widely in health science (Omiotek et al. 2013), engineering (Evans et al. 2013) and environmental sciences (Pal & Mather 2003). The results from these algorithms help to quickly identify which factor or factors most strongly affect a target end-point, and provide a basis for decision making to most efficiently reach that end-point. One of the main problems for many conservation managers is that they are faced with many uncertainties in the environment where they work (Regan et al. 2005) and they need to make appropriate decisions as soon as possible to protect a threatened species or habitat. Some organisations such as the IUCN provide a general frame work and decision guidelines for specific management processes, such as translocations (IUCN 2013), but more detailed understanding of the response of each species to the decisions taken are still very important.

Assisted colonisation or translocation is a potentially powerful tool in conservation management, but is accompanied by some controversy. Relatively few previous translocations have been confirmed to be successful (Dodd & Seigel 1991; Fischer & Lindenmayer 2000; Kleiman 1989) with one probable cause of failure being the tendency of translocated individuals to disperse away from release sites (Rittenhouse et al. 2007; Stenseth & Lidicker 1992). Reasons for dispersal after translocation include unfamiliarity with a new habitat (Ebrahimi & Bull 2013b; Tuberville et al. 2005) handling and release stress (Dickens et al. 2010), disrupted social structures and antagonistic social interactions among conspecifics (Skjelseth et al. 2007; Towns & Ferreira 2001), and reduced resource availability or quality (Bright & Morris 1994; Elliott et al. 2001). Each of these factors can affect individual behaviours directly or indirectly to increase the chance of dispersal. Behavioral ecologists advocate including behaviour in considerations of conservation management, to reduce the risk of failure of specific conservation management decisions (Festa-Bianchet & Apollonio 2003; Gosling & Sutherland 2000).

Although decision trees in natural systems can be made with relatively few available data, restrictions on time, budget and labour to collect such data decrease the chance of an accurate evaluation (Goethals et al. 2006). In the case of translocations, the lack of data from experimental or simulated translocations, and a tendency not to do such research before the actual translocation takes place, decrease the precision of any model and its predictions about the responses of translocated species. When such data are available, decision making models can help to boost our understanding of how different habitat factors, environmental conditions and species behaviours at the translocation release site can change the outcome of the translocation. Decision trees are important algorithms for management approaches in many situations, and should be helpful in conservation management programs.

In this paper we derived different decision tree algorithms from the data of five simulated translocation experiments on an endangered Australian skink, the pygmy bluetongue lizard (*Tiliqua adelaidensis*) (Ebrahimi & Bull 2012, 2013a, b, 2014). Our response variables were behavioural parameters that we judged to be relevant to understanding whether or not a lizard was likely to disperse in the short period immediately after release at the translocation site. We had two aims. First, we anticipated these models would provide understanding of how, when and why dispersal happens under different sets of conditions at the release site. In that case we could use the models to plan specific procedures and sets of conditions at the release site to reduce the risk of early post release dispersal. Second, we used the models to provide broader support for the view that behavioural parameters are important for conservation management issues such as translocation (Caro 1999, 2007; Caro 1998; Shier 2006; Wallace 2000).

The pygmy bluetongue lizard is an endangered species that inhabits a few isolated fragments of native grassland in a small part of the Mid North region of South Australia (Milne 1999). The lizards occupy abandoned spider burrows, and resident lizards rarely move more than a metre from their burrows, using the burrow entrances to bask and to ambush passing invertebrate prey (Milne et al. 2003a). Lizards in natural populations readily accept artificial burrows (Milne & Bull 2000; Milne et al. 2003b), but climate modelling has suggested that translocations will be required to maintain the species into the future (Fordham et al. 2012). A specific aim of this study was to prepare for that translocation program.

Methods

The data we used have already been reported from a series of ten trials over five experimental studies during the austral spring and summer of 2009-2010 and 2010-2011 (Ebrahimi & Bull 2012, 2013a, b, 2014). Those experiments were conducted to identify how different conditions influenced the tendency of pygmy bluetongue lizards to disperse from simulated translocation sites. Details of the methods have already been reported.

Briefly we used four 15 m diameter circular cages in a line, about 5 m apart in the grounds of Monarto Zoo, South Australia (35° 06' S, 139° 09' E) with 1 m high galvanised iron walls and bird wire roofs. Each cage was divided into three areas, a 4 m diameter central area, containing burrows, as the experimental release site, a 5 m wide matrix of unsuitable habitat with no burrows, and a ring, 0.5 m wide, with burrows, around the inside cage perimeter that trapped any lizards that dispersed from the central area. We hammered 41 artificial burrows for lizards (Milne et al. 2003a) into the central area and 30 around the perimeter area as previously described (Ebrahimi & Bull 2012). Four surveillance cameras were used to record lizard activity in the central area over, usually, four days during each experimental trial (Ebrahimi & Bull 2012). Eight male and eight female pygmy bluetongue lizards were captured from two populations near Burra, South Australia (33° 42' S, 138° 56' E) in September 2009 and four, randomly chosen, were released into the central area of each cage for each trial. Because of permit restrictions for this endangered species, the same lizards were used in each trial. Details of the lizard biology and husbandry have been provided previously (Ebrahimi & Bull 2012, 2013b).

We used data from the first four days of each trial in the five experiments to make our data set. In the experiments we manipulated environmental conditions within the central release area. The experimental treatments that we changed in each experiment became the independent variables that, in the decision tree, were called regular attributes. The parameters defining these treatments are listed below. Each of the five experiments involved replicate trials with manipulation of a single factor. 1) Confinement time: we initially confined lizards to the central area of the cage, in two cages for one day and two other cages for five days, then observed behaviour after the confining walls were removed (Ebrahimi & Bull 2013b). 2) Supplementary food: we fed three mealworms to each lizard every day in two cages while we did not feed lizards in two other cages (Ebrahimi & Bull 2012). 3) Vegetation density: in two cages we provided lizards with high vegetation density and in two other cages we removed all vegetation to ground level (Ebrahimi & Bull 2013a). 4) Soil disturbance: in two cages we ploughed the soil in a 2 m wide area of the matrix immediately around the central area, and we left two cages with no soil disturbance (Ebrahimi & Bull 2013a). 5) Conspecific models: we added 18 conspecific models close to burrow entrances in two cages and left two cages without models (Ebrahimi & Bull 2014). In addition, because each of these experiments was conducted as replicate trials conducted at different times within the natural activity season for this lizard, we included the month when we released lizards into the cages as the sixth attribute. For these analyses we included ten experimental trials conducted in October (two), November (three), December (two), and January (three).

We then used five behavioural parameters that we recorded in each experiment, as dependent variables that we called target (label) attributes. In our previous reports we have suggested how each of these behaviours may be indicative of how likely it is that translocated lizards will remain close to the release area. In the current analyses each behavioural parameter had one of two possible states. Each lizard was recorded either as showing the behaviour at least once on a day, or not showing the behaviour on that day. The recorded behaviours were; 1) Basking: recorded if the lizard had partially emerged and was sitting at the entrance of its burrow. 2) Movements around burrows: when a lizard fully emerged from its burrow, moved about, to bask fully emerged, to ambush passing prey, or to defecate, and then retreated to the same burrow. 3) Burrow changes: when lizards moved from their burrows to choose another burrow within the central release area. 4) Dispersal: when a lizard moved across the habitat matrix to a burrow in the perimeter region. In terms of the translocation simulation, these moves represented dispersal events away from the release site. Note that within their cages, lizards could not move beyond the perimeter area, and often moved back to the central area. Thus a lizard could disperse on more than one day. 5) Fights: when two lizards approached each other on the ground surface, they always showed some agonistic interaction, which we defined as fights.

The number of cases represented in the decision trees was derived from 16 lizards in each of four days in each of ten trials, making 640 cases. There were five cases when dispersed lizards did not return to the filmed central area, and where no data were available for an entire day.

To develop decision trees for our analysis we imported the data set into RapidMiner software (Rapid-I 2013). We had five target attributes (the five behavioural parameters) and produced two different types of final data sets for each target attribute. For the first type, we selected one of the behavioural parameters as a target attribute for each data set, excluding the other behavioural parameters, to produce five-data sets, one data set for each behavioural parameter. Those five data sets each included six regular attributes (confinement time through to time of release) and one target attribute (one of the behavioural parameters). We considered that models produced from these first five data sets would be useful for developing management strategies for the conditions of release in future translocations. For the second type of data set, we chose again one behavioural parameter as the target attribute, but included the other four behavioural parameters as additional regular attributes. Therefore we had another five data sets (one for each behavioural parameter) that had one target attribute (the chosen behavioural parameter) and 10 regular attributes (six representing the experimental conditions, confinement time through to time of release, plus the four remaining behavioural parameters). Data sets of this second type allowed interpretation of how the other behavioural parameters could also influence the target behavioural attribute. We used these ten data sets to produce, and select the most appropriate decision tree models as described in Appendix S1.

Results

Decision trees

We produced 1760 trees, or 176 trees for each of the ten target attributes. Most (1600) did not have roots or leaves, and were excluded because they had no results we could use. From the remaining 160 trees, we selected ten with the highest accuracy (highest CCI score, as defined in Appendix S1), that described different target attributes from each of the two types of data sets (Table 1). The presence or absence of conspecific model lizards during the trials had no role in any of the preferred decision tree models.

Single behaviour data sets and decision trees

There were no trees with root and leaves for the target attribute behaviour of fights when other behaviours were excluded. Thus only four decision trees were selected for these data sets.

Basking behaviour produced a decision tree with three branches (Fig 1A). Vegetation density was the first node, with more lizards basking in low vegetation density. In the high vegetation density the next branching node was soil disturbance in the matrix area. More lizards basked with undisturbed soil in the matrix. The final node was time of release. With high vegetation density and disturbed soil in the matrix, more lizards basked when they were released in October, November and January but less lizards basked when released in December (Fig 1A).

For movements around burrows there was a six branch tree, with three of the nodes representing different components of the time of release (Fig 1B). Soil disturbance in the matrix was the first node of the tree, with soil disturbance reducing cases of movement. Density of vegetation formed the next node. Where soil was undisturbed, high vegetation density decreased the number of cases of movement. Time of release formed the next three nodes, and confinement time, the last node. There were fewer cases of movement in low vegetation density in January than the other months, and in those other months more cases of movement in October. That October movement could be reduced more by one day than by five days of preliminary confinement to the release site.

For burrow changes there was a three branch tree (Fig 1C). Supplementary food was the first node with less lizards changing their burrows when supplementary food was presented. Time of release formed the next two nodes. Without supplementary food, there were fewer cases of lizards changing their burrows in January than other months, and in those other months more lizards changed burrows in October.

Dispersal produced a decision tree with four branches (Fig 1D). Soil disturbance in the matrix, the first node of the tree, reduced the number of cases of dispersal (to 2%). Density of vegetation formed the second node. When soil was undisturbed, high vegetation density decreased the number of cases of where lizards dispersed (to 5%). Time of release and confinement time were the last two nodes. In areas with low vegetation density there were fewer cases of dispersal in November and December (4% of cases) than the other months, and in those other months (January and October) the number of cases of dispersal was reduced more by confining lizards for one day than five days.

All behavioural parameters data sets and decision trees

The best decision tree for basking behaviour had 14 branches, is not discussed here but is included as Appendix S2.

The decision tree for movements around burrows had four branches (Fig 2A). Burrow change was the first node, with more cases of moving around burrows among the lizards that also changed their burrows. Time of release was the second, fighting the third and vegetation density the fourth branching node. For lizards that did not change burrows, there were fewer cases of movement in January than other months, and in those other months lizards that were not involved in fights showed fewer cases of movement (20%) than those that did fight. Among the fighters, there were no cases of lizards moving around their burrows in high vegetation density, but movement in 50% of cases in low vegetation density.

Burrow changes produced a decision tree with four branches (Fig 2B). As in Fig 5, the strongest relationship was between burrow changes and movements around burrows, but each of the branches from that first node had different secondary nodes. In cases of no movements, fighting was the second node. Lizards that did not fight (the majority of cases as expected with no movements around the burrow) mostly did not change burrows. In the few (11) cases when lizards did fight (while basking at the burrow entrance) the majority (64%) changed burrows. On the other branch, in cases where the lizards made movements around the burrow, basking behaviour was the second node. Lizards that basked were more likely to change burrows. If not basking, lizards were less likely to change burrows in cases with supplementary food was. Although this tree was complicated, indicating the degree of complexity that these trees can generate, the major determining factor in whether or not a lizard changed burrows was whether or not it moved around its initial burrow. The majority of leaves at the end of the branches for cases of no movements, were for no change of burrow. Most leaves at the end of the branch for cases of movements, were for a change of burrow.

For fighting the best decision tree had four branches (Fig 2C). Dispersal was the first node. Cases of lizards fighting were uncommon among lizards that did not disperse. Time of release formed the second and last nodes and supplementary food the third node. Among dispersal cases, there were fewer cases of fighting in October and January than other months. In those other months lizards with supplementary food showed fewer cases of fighting, and in those did not have food there were more cases of fighting in November than December.

For dispersal four decision tree models with the same CCI value of 87% were produced. Three were selected, each with three branches (Fig 3). The fourth, with considerably more branches is shown in Appendix S3. The three alternative selected decision trees show primary nodes of vegetation density, soil disturbance and supplementary food. In each of those models there was no dispersal in 97%, 99% and 93% of cases with high vegetation density, disturbance of soil matrix and provision of supplementary food, respectively.

Discussion

Management implications: Single behaviour data sets and decision trees

In the initial stages of a translocation program, managers need to provide conditions that will enhance survival and encourage released individuals to stay close to the release site. Dispersing individuals risk moving away from preferred habitats or from mating opportunities. For pygmy bluetongue lizards, behaviours that should be associated with successful translocation include basking at the burrow entrance (to allow thermoregulation and prey capture), reduced movements around the burrow (reducing exposure to predation), reduced burrow changes (again reducing predation and reducing the chance of attempting to move but not finding a new burrow), and reduced dispersal away from the release area. Our decision tree models in which only single behavioural attributes were included gave indications of the sets of ecological conditions that might promote all of those success inducing behaviours. Managers would also want to reduce the incidence of fights among the released individuals, to minimise the stress among the released lizards, although no specific decision tree models provided advice on that when other behaviours were excluded from the data set.

The most consistent factor influencing these behaviours in our trials was soil disturbance in the matrix around the release site. Essentially this is equivalent to a soft release in that soil disturbance made the matrix more inhospitable, making it more likely that lizards will stay in translocation sites. Milne (1999) showed that pygmy bluetongue lizards in natural habitats avoid natural burrows in ploughed areas and Souter (2003) showed lizard will not occupy artificial burrows in ploughed areas immediately next to population sites.

Vegetation density had opposite effects on different behaviours in our decision tree models. Low vegetation density encouraged basking (positive for translocations), supporting observations of Pettigrew and Bull (2012). But low vegetation also encouraged movements around burrows and dispersal (negative for translocations), as previously reported (Ebrahimi & Bull 2013a).

The effect of time of release was consistent across the decision tree models, with release in October leading to more movements, more burrow changes, and more dispersal (negative for translocations) than in other later months. Mating occurs in October and early November (Fenner & Bull 2009; Milne et al. 2003b) and lizards must move about in this spring breeding season to locate mating partners. Confirming this, pitfall trap captures of adult lizards moving around on the surface in wild populations occur predominantly in the spring (Schofield et al.

2012). This natural tendency for lizards to move around more in spring months suggests that other months would be better times for translocation release.

Providing supplementary food had a major influence on one behavioural attribute, changing burrows. Lizards with extra food were less likely to abandon an occupied burrow. However, in the single behaviour decision trees, supplementary food formed a node for only one behaviour, time of initial confinement only appeared as a terminal branch, and presence or absence of conspecific models was never a node. Although individual experiments suggested each of these three habitat manipulations significantly influenced whether lizards remained close to a release site (Ebrahimi & Bull 2012, 2013b, 2014) the decision tree modelling showed they were less important factors for the behaviours we documented.

Reducing dispersal from the release site is one primary goal in the early stages of translocations. For pygmy bluetongue lizards our best decision tree (Fig 4) showed that managers could maintain soil disturbance around the release site, keep vegetation dense, and time releases to occur in late spring and early summer (November and December) in order to decrease the risk of dispersal in the early stage of translocation. Although soil disturbance around the release site may have a short term benefit in reducing local dispersal, there may be longer term adverse impacts in preventing the spread of reproductive recruits from a successfully established translocation site. Our trees, based on short term behavioural changes, need to be balanced against longer term considerations. Nevertheless, selective soil disturbance practices could be used to reduce population spread in undesired directions.

Behaviour and conservation: All behavioural parameters data sets and decision trees

The decision tree models that included all behavioural attributes provide clues about relevant combinations of behaviour that may influence translocation success. The trees showed clear positive associations between movements around burrows and burrow changes. Lizards that emerged to move around their burrows more often were also more likely to move away and change their burrows. Lizards that were involved in fights were more likely to disperse. These and other relationships from the decision trees reflect the connections and interactions among the different types of behaviour that are related to successful settlement of released lizards. Of equal relevance for conservation managers is to document those behaviours that are not tightly linked, and thus may be less indicative of translocation success. In our decision trees there were few connections between basking behaviour and movements around the burrow or dispersal, indicating that not all behaviours that we thought may be important are interconnected in influencing establishment success.

Overview

The main result of this study was to demonstrate how decision trees that model aspects of animal behaviour open new doors for the study of conservation management. They provide conservationists with the opportunity to predict the behaviours of translocated species, under different sets of circumstances, immediately after release, and provide indications of the relative importance among a range of possible conservation measures. Caro (2007) suggested that the interdisciplinary interface between behavioural ecology and conservation biology answers many problems in conservation. Simple examples include feeding condor chicks with condor-head-shaped puppets to ensure those chicks were less attracted to the humans than to conspecifics after release (Wallace 2000), and translocations of black-tailed prairie dogs as whole family, behaviourally integrated units (Shier 2006). A problem is identifying how species behaviour changes after release at translocation sites, and determining which sorts of behaviours have negative impacts on the translocation success. Decision tree models add dimensions to these studies by predicting which combined set of conditions can alter behaviour, which have the most influence, and which behavioural combinations work synergistically. Managers could use the models to suggest interventions to reduce behaviours with negative impact. In addition decision tree models could decrease the cost and time needed to find how and why species dispersed. Developing those models before actual translocation release might improve success. Regan et al. (2005) commented that conservationists must make decisions under severe uncertainty and decision models give possible responses to at least some of those uncertainties.

Not all endangered species will be as easy to work with as the pygmy bluetongue lizard. This small species (snout-to-vent length average 95 mm) can be easily confined within experimental enclosures. Their very small normal activity range means they can be observed almost continuously in and around their burrows, to derive the behavioural parameters we used in this analysis. For larger, more mobile species it may be harder to generate equivalent behavioural data from multiple replicate cases. Nevertheless the benefits derived from the decision tree models suggest it is worth exploring ways of quantifying critical behaviours in a range of alternative conditions as background for translocation projects across a wider range of animal species.

Acknowledgments

The Australian Research Council, Holsworth Wildlife Research Endowment, Sir Mark Mitchell Research Foundation, Zoos SA, the SA Department of the Environment and Natural Resources, the Field Naturalists Society of SA, the SA Museum, the Northern and Yorke NRM Board and the SA Murray-Darling NRM Board all supported this research. The Ministry of Sciences, Research and Technology of Iran sponsored the PhD studies of Mehregan Ebrahimi. The study was conducted according to the guidelines of the Flinders University Animal Welfare Committee (approval no.E206) and was conducted under DEWNR Permit (G25011).

Supporting Information

Additional supporting information are available online which include construction of the decision trees (Appendix S1), the decision tree for basking behaviour when all behaviour parameters were included (Appendix S2) and additional decision tree for dispersal (Appendix S3). The authors are solely responsible for the content and functionality of these materials. Queries (other than absence of the material) should be directed to the corresponding author.

Literature Cited

Bright, P. W., and P. A. Morris. 1994. Animal translocation for conservation: performance of dormice in relation to release methods, origin and season. Journal of Applied Ecology **31**:699-709.

Caro, T. 1999. The behaviour–conservation interface. Trends in Ecology & Evolution **14**:366-369.

Caro, T. 2007. Behavior and conservation: a bridge too far? Trends in Ecology & Evolution **22**:394-400.

Caro, T. M. 1998. Behavioral ecology and conservation biology. Oxford University Press.

Dickens, M. J., D. J. Delehanty, and R. L. M. 2010. Stress: An inevitable component of animal translocation. Biological Conservation **143**:1329-1341.

Dodd, C. K., and R. A. Seigel. 1991. Relocation, repatriation, and translocation of amphibians and reptiles: are they conservation strategies that work? Herpetologica **47**:336-351.

Ebrahimi, M., and C. M. Bull. 2012. Food supplementation reduces post-release dispersal during simulated translocation of the Endangered pygmy bluetongue lizard *Tiliqua adelaidensis*. Endangered Species Research **18**:169-178.

Ebrahimi, M., and C. M. Bull. 2013a. Behavioural changes in an endangered grassland lizard resulting from simulated agricultural activities. Journal of Arid Environments, Under review.

Ebrahimi, M., and C. M. Bull. 2013b. Determining the success of varying short-term confinement time during simulated translocations of the endangered pygmy bluetongue lizard (*Tiliqua adelaidensis*). Amphibia-Reptilia **34**:31-39.

Ebrahimi, M., and C. M. Bull. 2014. Visual conspecific cues will not help in pygmy bluetongue lizard translocations. Applied Animal Behaviour Science **151**:102-109.

Elliott, G. P., D. V. Merton, and P. W. Jansen. 2001. Intensive management of a critically endangered species: the kakapo. Biological Conservation **99**:121-133.

Evans, L., N. Lohse, and M. Summers. 2013. A fuzzy-decision-tree approach for manufacturing technology selection exploiting experience-based information. Expert Systems with Applications **40**:6412-6426.

Fenner, A. L., and C. M. Bull. 2009. *Tiliqua adelaidensis* (pygmy bluetongue lizard) mating behaviour. Herpetological Review **40**:91-92.

Festa-Bianchet, M., and M. Apollonio 2003. Animal Behavior and Wildlife Conservation. Island Press, Washington, USA.

Fischer, J., and D. B. Lindenmayer. 2000. An assessment of the published results of animal relocations. Biological Conservation **96**:1-11.

Fordham, D. A., M. J. Watts, S. Delean, B. W. Brook, L. M. B. Heard, and C. M. Bull. 2012. Managed relocation as an adaptation strategy for mitigating climate change threats to the persistence of an endangered lizard. Global Change Biology **18**:2743-2755.

Goethals, P., A. Dedecker, W. Gabriëls, and N. De Pauw. 2006. Development and application of predictive river ecosystem models based on classification trees and artificial neural networks. Page 532 in F. Recknagel, editor. Ecological Informatics: Understanding ecology by biologically-inspired computation. Springer, Germany.

Gosling, L. M., and W. J. Sutherland 2000. Behaviour and Conservation. Cambridge University Press, Cambridge

IUCN 2013. IUCN Guidelines for reintroductions and other conservation translocation. Prepared by the IUCN/SSC Re-introduction Specialist Group. IUCN.

Kleiman, D. G. 1989. Reintroduction of captive mammals for conservation. Bioscience **39**:152-152.

Milne, T. 1999. Conservation and ecology of the endangered pygmy bluetongue lizard (*Tiliqua adelaidensis*). Page 314. School of Biological Sciences. Flinders University.

Milne, T., and C. M. Bull. 2000. Burrow choice by individuals of different sizes in the endangered pygmy blue tongue lizard *Tiliqua adelaidensis*. Biological Conservation **95**:295-301.

Milne, T., C. M. Bull, and M. N. Hutchinson. 2003a. Fitness of the endangered pygmy blue tongue lizard *Tiliqua adelaidensis* in artificial burrows. Journal of Herpetology **37**:762-765.

Milne, T., C. M. Bull, and M. N. Hutchinson. 2003b. Use of burrows by the endangered pygmy blue-tongue lizard, *Tiliqua adelaidensis* (Scincidae). Wildlife Research **30**:523-528.

Omiotek, Z., A. Burda, and W. Wojcik. 2013. The use of decision tree induction and artificial neural networks for automatic diagnosis of Hashimoto's disease. Expert Systems with Applications **40**:6684-6689.

Pal, M., and P. M. Mather. 2003. An assessment of the effectiveness of decision tree methods for land cover classification. Remote Sensing of Environment **86**:554-565.

Pettigrew, M., and C. M. Bull. 2012. The response of pygmy bluetongue lizards to simulated grazing in the field during three drought years. Wildlife Research **39**:540-545.

Rapid-I. 2013. Package com.rapidminer.operator.features.weighting. Rapidminer, Germany.

Regan, H. M., Y. Ben-Haim, B. Langford, W. G. Wilson, P. r. Lundberg, S. y. J. Andelman, and M. A. Burgman. 2005. Robust decision-making under severe uncertainty for conservation management. Ecological Applications **15**:1471-1477.

Rittenhouse, C. D., J. J. Millspaugh, M. W. Hubbard, and S. L. Sheriff. 2007. Movements of translocated and resident three-toed box turtles. Journal of Herpetology **41**:115-121.

Schofield, J. A., A. L. Fenner, K. Pelgrim, and C. M. Bull. 2012. Male-biased movement in pygmy bluetongue lizards: implications for conservation. Wildlife Research **39**:677-684.

Shier, D. M. 2006. Effect of family support on the success of translocated black-tailed prairie dogs. Conservation Biology **20**:1780-1790.

Skjelseth, S., T. H. Ringsby, J. Tufto, H. Jensen, and B. Sæther. 2007. Dispersal of introduced house sparrows *Passer domesticus*: an experiment. Proceedings of the Royal Society B: Biological Sciences **274**:1763-1771.

Souter, N. J. 2003. Habitat requirements and conservation of the endangered pygmy bluetongue lizard *Tiliqua adelaidensis*. PhD thesis. Page 377. School of Biological Sciences. Flinders University of South Australia.

Stenseth, N. C., and J. W. Z. Lidicker 1992. The study of dispersal: a conceptual guide. In animal dispersal: small mammals as a model. Chapman and Hall, Londen, UK.

Towns, D. R., and S. M. Ferreira. 2001. Conservation of New Zealand lizards (Lacertilia: Scincidae) by translocation of small populations. Biological Conservation **98**:211-222.

Tuberville, T. D., E. E. Clark, K. A. Buhlmann, and J. W. Gibbons. 2005. Translocation as a conservation tool: site fidelity and movement of repatriated gopher tortoises (*Gopherus polyphemus*). Animal Conservation **8**:349-358.

Wallace, M. P. 2000. Retaining natural behaviour in captivity for re-introduction programmes. Pages 300-314 in L. M. Gosling, editor. Behaviour and conservation. Cambridge University Press, Cambridge, United Kingdom.

Table 1. The properties of the ten decision tree models that were selected by the analysis.

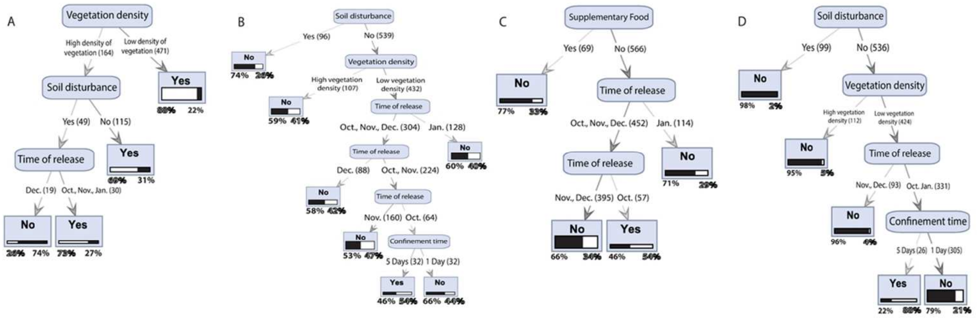
	Target attribute	Figure No.	Data set*	Decision tree algorithm	Criteria	No. branches	No. leaves	CCI (%)
Single behaviour	Basking	1	Rule	Random forest	Gini index	3	4	82.2
	Movements	2	unweighted data	Random forest	Accuracy	6	7	61.0
	Burrow changes	3	SVM	Random forest	Gini index	3	4	67.0
	Dispersal	4	Info Gain	Random forest	Accuracy	4	5	87.0
All behavioural parameters	Movements	5	Rule	Random forest	Gini index	4	5	64.0
	Burrow changes	6	unweighted data	Random forest	Gini index	4	5	73.0
	Dispersal	7A 7B 7C	unweighted data SVM Rule	Random forest Parallel based Random forest	Accuracy	3	4	87.0
	Fight	8	Rule	Random forest	Info gain	4	5	93.0

* Name of data set is according their attribute weighting algorithms

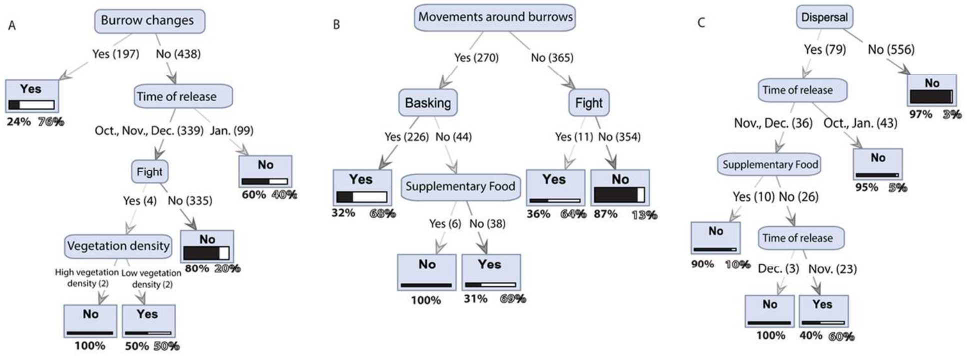
Fig 1. The Random forest based decision trees for (A) basking behaviour; (B) movements around burrows; (C) burrow changes and (D) dispersal, when other behavioural parameters were excluded. Bold Yes/No in gray box showed whether the behaviour did or did not happen. The numbers in brackets under the grey boxes represent the actual number of cases when lizards were exposed to each set of conditions for the attribute described in the box above. In the “leaves” at the end of each “branch” of the tree, the black and white bars with percentages represent the proportion of cases when lizards did (white) or did not (black) show the behaviour in the specified set of experimental conditions.

Fig 2. The Random forest based decision trees for (A) movements around burrows; (B) burrow changes and (C) fight, when other behavioural parameters were included. Explanatory symbols as in Fig 1.

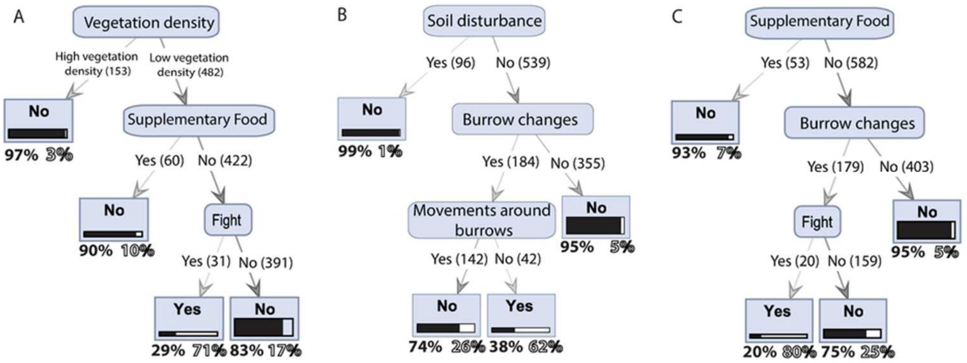
Figure 3. Three equally preferred models for dispersal when other behavioural parameters were included. A) The random forest based decision tree (unweighted data set); B) The parallel based decision tree (SVM data set); and C) The random forest based decision tree (rule data set). Explanatory symbols as in Fig 1.



The Random forest based decision trees for (A) basking behaviour; (B) movements around burrows; (C) burrow changes and (D) dispersal, when other behavioural parameters were excluded. Bold Yes/No in gray box showed whether the behaviour did or did not happen. The numbers in brackets under the grey boxes represent the actual number of cases when lizards were exposed to each set of conditions for the attribute described in the box above. In the "leaves" at the end of each "branch" of the tree, the black and white bars with percentages represent the proportion of cases when lizards did (white) or did not (black) show the behaviour in the specified set of experimental conditions.
102x36mm (300 x 300 DPI)



The Random forest based decision trees for (A) movements around burrows; (B) burrow changes and (C) fight, when other behavioural parameters were included. Explanatory symbols as in Fig 1.
112x42mm (300 x 300 DPI)



Three equally preferred models for dispersal when other behavioural parameters were included. A) The random forest based decision tree (unweighted data set); B) The parallel based decision tree (SVM data set); and C) The random forest based decision tree (rule data set). Explanatory symbols as in Fig 1.
81x32mm (300 x 300 DPI)