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2   species behavioural response in translocation sites.

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Abstract

24 The high number of failures is one reason why translocation is often not recommended.

25 Considering how behaviour changes during translocations may improve translocation

26 success. We used data from five simulated translocations, considering the short term

27 responses of an endangered Australian skink when released under alternative conditions, to

28 derive decision tree models. We used four different decision tree algorithms (decision tree,

29 decision tree parallel, decision stump and random forest) with four different criteria (gain

30 ratio, information gain, gini index and accuracy) to investigate how environmental and

31 behavioural parameters might affect the success of a translocation. We assumed that

32 behavioural changes that increased dispersal away from a release site would reduce

33 translocation success. The trees became more complex when we included all behavioural

34 parameters as attributes, but these trees gave us more detailed understanding about why and

35 how dispersal occurred. Decision trees based on parameters related to release conditions were

36 easier to follow and might be used by conservation managers to make translocation decisions

37 in different circumstances.

Introduction

39 Translocation is a potentially powerful tool in conservation management of endangered

40 species, but relatively few translocations have been confirmed as successful (Kleiman 1989;

41 Dodd & Seigel 1991; Fischer & Lindenmayer 2000; Carter et al. 2010; Sullivan et al. 2014).

42 Conservation managers are faced with many environmental uncertainties (Regan et al. 2005).

43 They often need to make fast, appropriate decisions to protect a threatened species or habitat,

44 with confidence that the option they choose has some probability of success. There are

45 guidelines for translocations (IUCN 2013), but more specific understanding of the response

46 of each species to the decisions taken are needed.

47   Models can be used to compare the likely success of alternative strategies in the selection of

48   translocation sites (Gilioli et al. 2008; Dade et al. 2014) and when to translocate (McDonald-

49   Madden et al. 2011). Decision trees are one form of modelling to compare the outcomes of

50   different decisions. Their algorithms help to identify which factors most strongly affect a

51   target end-point, and provide a basis for decisions to most efficiently reach that end-point.

52   Decision trees have been used in conservation biology to suggest monitoring programs

53   following environmental perturbations (Veltman et al. 2014), to classify vegetation age

54   classes for management recommendations (Delalieux et al. 2012), to determine whether to

55   release rehabilitated mammals (Guy et al. 2013), to assess extinction risk (Davidson et al.

56   2009), to assess impacts of livestock grazing on native vegetation (Lunt et al. 2007), to

57   determine when to intervene when infections threaten gorilla populations (Cranfield et al.

58   2006), and to decide amongst alternative intervention strategies in populations at critically

59   low densities (VanderWerf et al. 2006). Informal decision trees are probably used in most

60   translocations, in that managers consider how, when and where to translocate among a

61   number of options. Rout et al. (2013) included formal decision tree analyses for decisions of

62   whether to translocate species threatened by climate change.

63   Conservation focused decision trees rarely include behavioural responses. One probable

64   cause of translocation failure is that translocated individuals disperse away from release sites

65   (Stenseth & Lidicker 1992; Rittenhouse et al. 2007). They disperse because of unfamiliarity

66   with a new habitat (Tuberville et al. 2005; Ebrahimi & Bull 2013) handling and release stress

67   (Dickens et al. 2010), disrupted social structures and antagonistic social interactions among

68   conspecifics (Towns & Ferreira 2001; Skjelseth et al. 2007), and reduced resource

69   availability or quality (Bright & Morris 1994; Elliott et al. 2001). Each of these factors can

70   affect individual behaviours directly or indirectly to increase the chance of dispersal.

71   Behavioral ecologists advocate considering behaviour to reduce the risk of failure of specific

72   conservation management decisions (Gosling & Sutherland 2000; Festa-Bianchet &

73   Apollonio 2003). In our study we used behavioural parameters as indicators of the probability

74   that translocated animals would remain near their release site under alternative conditions,

75   and constructed translocation decision trees based on those behaviours.

76   Although decision trees in natural systems can be made with relatively few available data,

77   restrictions on time and budget to collect such data decrease the chance of accurate evaluation

78   (Goethals et al. 2006). There are few data from experimental or simulated translocations, and

79   a tendency (often related to the need for rapid intervention) to omit such research before an

80   actual translocation. When data are available, decision making models can predict how

81   different habitat factors, environmental conditions and species behaviours at the release site

82   can change the translocation outcome.

83   In this paper we derived decision tree algorithms from the data of five simulated translocation

84   experiments on an endangered Australian skink, the pygmy bluetongue lizard (*Tiliqua*

85   *adelaidensis*) (Ebrahimi & Bull 2012, 2013, 2014, 2015). Our response variables were

86   behavioural parameters that we judged might affect whether a lizard would disperse in the

87   short period immediately after translocation release. We anticipated these models would

88   predict dispersal under different sets of conditions at the release site, and could be used to

89   develop specific procedures to reduce the risk of early post release dispersal. We considered

90   in the models how behavioural parameters might influence conservation management (Caro

91   1998; Caro 1999; Wallace 2000; Shier 2006; Caro 2007).

92   Endangered pygmy bluetongue lizards occur in a few isolated fragments of native grassland

93   in a small part of the Mid North region of South Australia (Milne 1999). They occupy, and

94   rarely move from abandoned spider burrows, using the burrow entrances to bask and to

95   ambush passing invertebrate prey (Milne et al. 2003a). They readily accept artificial burrows

96 (Milne & Bull 2000; Milne et al. 2003b).Climate modelling suggests translocations will be

97 required if the species is to persist (Fordham et al. 2012).

98 **Methods**

99 We previously reported data from ten trials over five experimental studies during spring and

100 summer of 2009-2010 and 2010-2011 (Ebrahimi & Bull 2012, 2013, 2014, 2015). They were

101 conducted to identify how different conditions influenced whether lizards dispersed from

102 simulated translocation sites. Trials were conducted in four 15 m diameter circular cages in

103 the grounds of Monarto Zoo, South Australia (35° 06' S, 139° 09' E) with 1 m high

104 galvanised iron walls and bird wire roofs. Each cage contained three areas, a 4 m diameter

105 central area, with 41 artificial burrows, as the experimental release site, a 5 m wide matrix of

106 unsuitable habitat with no burrows, and a ring, 0.5 m wide, with burrows, around the inside

107 cage perimeter that trapped lizards that dispersed from the central area. Four surveillance

108 cameras recorded lizard activity in the central area over four days during each experimental

109 trial (Ebrahimi & Bull 2012). Eight male and eight female adult pygmy bluetongue lizards

110 were captured from two populations near Burra, South Australia (33° 42' S, 138° 56' E) in

111 September 2009 and four, randomly chosen, were released into the central area of each cage

112 for each trial. Our data set came from the first four days of each trial in five experiments.

113 Each experiment involved replicate trials with manipulation of a single environmental factor

114 within the central release area. The experimental treatments in each experiment became the

115 independent variables that, in the decision tree, were called regular attributes. The parameters

116 defining these treatments were: 1) Confinement time: we initially confined lizards to the

117 central area in two cages for one day and two other cages for five days, then observed

118 behaviour after the confining walls were removed (Ebrahimi & Bull 2013). 2) Supplementary

119 food: we fed three mealworms to each lizard every day in two cages while we did not feed

120 lizards in two other cages (Ebrahimi & Bull 2012). 3) Vegetation density: in two cages we

5

121   provided lizards with high vegetation density and in two other cages we removed all

122   vegetation to ground level (Ebrahimi & Bull 2015). 4) Soil disturbance: in two cages we

123   ploughed the soil in a 2 m wide area of the matrix immediately around the central area, and

124   we left two cages with no soil disturbance (Ebrahimi & Bull 2015). 5) Conspecific models:

125   we added 18 conspecific models close to burrow entrances in two cages and left two cages

126   without models (Ebrahimi & Bull 2014). In addition, because replicate trials in each

127   experiment were conducted at different times within the lizard's natural activity season, we

128   included the month when we released lizards into the cages as a sixth attribute. For analyses

129   we included ten experimental trials conducted in October (two), November (three), December

130   (two), and January (three).

131   We then used five behavioural parameters that we recorded in each experiment, as dependent

132   variables that we called target (label) attributes. Previously we suggested that each of these

133   behaviours may indicate whether translocated lizards will remain close to their release area.

134   Lizards in natural populations use their burrows as refuges and ambush sites to catch passing

135   prey. We considered lizards were settled and unlikely to disperse if they regularly basked at

136   their burrow entrance or only moved short distances from it, but less settled and more likely

137   to disperse if they more frequently changed burrows, were involved in fights or moved out of

138   the release area. In other studies, with other species, specific indicator behaviours will need to

139   be identified.

140   In our analyses each behavioural parameter had one of two possible states. Each lizard either

141   showed or did not show the behaviour at least once on each day. The recorded behaviours

142   were; 1) Basking: recorded if the lizard had partially emerged and was sitting at the entrance

143   of its burrow. 2) Movements around burrows: when a lizard fully emerged from its burrow,

144   moved about, to bask fully emerged, to ambush passing prey, or to defecate, and then

145   retreated to the same burrow. 3) Burrow changes: when a lizard moved from its burrows to

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146   choose another burrow within the central area. 4) Dispersal: when a lizard moved across the

147   habitat matrix to a burrow in the perimeter region. Within the cages, lizards could not move

148   beyond the perimeter area, and often moved back to the central area. Thus lizards could

149   disperse on more than one day. 5) Fights: when two lizards approached each other on the

150   ground surface, they always showed some agonistic interaction, which we defined as fights.

151   There were 640 cases in each decision tree, derived from 16 lizards in each of four days in

152   each of ten trials. However, in five cases dispersed lizards did not return to the filmed central

153   area, and no behavioural data were available for an entire day.

154   To develop decision trees we imported the data set into RapidMiner software (Rapid-I 2013).

155   We had five target attributes (the five behavioural parameters) and produced two different

156   data sets for each target attribute. First we selected one behavioural parameter as the target

157   attribute, excluding all other behavioural parameters. This produced five-data sets, one for

158   each behavioural parameter. Those data sets each included six regular attributes (confinement

159   time through to time of release) and one target attribute (one of the behavioural parameters).

160   We considered that models derived from these data sets would be useful for developing

161   management strategies for the conditions of release in future translocations. Second, we

162   chose again one behavioural parameter as the target attribute, but included the other four

163   behavioural parameters as additional regular attributes. This produced another five data sets

164   (one for each behavioural parameter) that had one target attribute (the chosen behavioural

165   parameter) and 10 regular attributes (six representing the experimental conditions,

166   confinement time through to time of release, plus the four remaining behavioural parameters).

167   These data sets allowed interpretation of the influence of other behavioural parameters on the

168   target behavioural attributes. We used all ten data sets to produce, and select the most

169   appropriate decision tree models as described in Appendix S1.

170 **Results**

171 *Decision trees*

172 We produced 1760 trees, 176 trees for each of the ten target attributes. Most (1600) had no

173 roots or leaves, and were excluded because they had no results we could use. From the

174 remaining 160 trees, we selected ten with the highest accuracy (highest CCI score, as defined

175 in Appendix S1), that described different target attributes from each of the two types of data

176 sets (Table 1). The presence or absence of conspecific model lizards during the trials had no

177 role in any of the preferred decision tree models.

178 *Single behaviour data sets and decision trees*

179 No trees had roots and leaves for the target attribute behaviour of fights when other

180 behaviours were excluded. Thus only four decision trees were selected for these data sets.

181 Basking behaviour produced a decision tree with three branches (Fig 1A). Vegetation density

182 was the first node. More lizards basked in low vegetation density. In high vegetation density

183 the next branching node was soil disturbance in the matrix. More lizards basked with

184 undisturbed soil in the matrix. The final node was time of release. With high vegetation

185 density and disturbed soil in the matrix, more lizards basked when they were released in

186 October, November and January but less lizards basked when released in December (Fig 1A).

187 Movements around burrows produced a six branch tree, with three nodes representing

188 different components of time of release (Fig 1B). Soil disturbance in the matrix was the first

189 node, with soil disturbance reducing cases of movement. Density of vegetation formed the

190 next node. Where soil was undisturbed, high vegetation density decreased the number of

191 cases of movement. Time of release formed the next three nodes, and confinement time, the

192 last node. There were fewer cases of movement in low vegetation density in January than the

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193   other months, and in those other months more cases of movement in October. That October

194   movement was reduced more by one day than by five days of preliminary confinement to the

195   release site.

196   Burrow changes produced a three branch tree (Fig 1C). Supplementary food was the first

197   node with less lizards changing their burrows when supplementary food was presented. Time

198   of release formed the next two nodes. Without supplementary food, there were fewer cases of

199   lizards changing their burrows in January than other months, and in those other months more

200   lizards changed burrows in October.

201   Dispersal produced a decision tree with four branches (Fig 1D). Soil disturbance in the

202   matrix, the first node of the tree, reduced the number of cases of dispersal (to 2%). Density of

203   vegetation formed the second node. When soil was undisturbed, high vegetation density

204   decreased the number of cases when lizards dispersed (to 5%). Time of release and

205   confinement time were the last two nodes. In areas with low vegetation density there were

206   fewer cases of dispersal in November and December (4% of cases) than the other months,

207   and in those other months (January and October) the number of cases of dispersal was

208   reduced more by confining lizards for one day than five days.

209   *All behavioural parameters data sets and decision trees*

210   The best decision tree for basking behaviour had 14 branches. This was too complex for

211   simple interpretation and is not discussed here, but is included as Appendix S2.

212   The decision tree for movements around burrows had four branches (Fig 2A). Burrow change

213   was the first node, with more cases of moving around burrows among the lizards that also

214   changed their burrows. Time of release was the second, fighting the third and vegetation

215   density the fourth branching node. For lizards that did not change burrows, there were fewer

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216   cases of movement in January than other months, and in those other months lizards that did

217   not fight showed fewer cases of movement (20%) than those that did fight. Among the

218   fighters, there were no cases of lizards moving around their burrows in high vegetation

219   density, but movement in 50% of cases in low vegetation density.

220   Burrow changes produced a decision tree with four branches (Fig 2B). As in Fig 5, the

221   strongest relationship was between burrow changes and movements around burrows, but each

222   of the branches from that first node had different secondary nodes. In cases of no movements,

223   fighting was the second node. Lizards that did not fight (the majority of cases as expected

224   with no movements around the burrow) mostly did not change burrows. In the few (11) cases

225   when lizards did fight (while basking at the burrow entrance) the majority (64%) changed

226   burrows. On the other branch, where the lizards moved around their burrows, basking

227   behaviour was the second node. Lizards that basked were more likely to change burrows. If

228   not basking, lizards were less likely to change burrows in cases with supplementary food.

229   Although this tree was complicated, indicating the degree of complexity that these trees can

230   generate, the major factor determining whether or not a lizard changed burrows was whether

231   or not it moved around its initial burrow. The majority of leaves at the end of the branches for

232   cases of no movements, were for no change of burrow. Most leaves at the end of the branch

233   for cases of movements, were for a change of burrow.

234   For fighting the best decision tree had four branches (Fig 2C). Dispersal was the first node.

235   Cases of lizards fighting were uncommon among lizards that did not disperse. Time of

236   release formed the second and last nodes and supplementary food the third node. Among

237   dispersal cases, there were fewer cases of fighting in October and January than other months.

238   In those other months lizards with supplementary food showed fewer cases of fighting, and in

239   those did not have food there were more cases of fighting in November than December.

240 For dispersal, four decision tree models with the same CCI value of 87% were produced.

241 Three were selected, each with three branches (Fig 3). The fourth, with considerably more

242 branches is shown in Appendix S3. The three alternative selected decision trees showed

243 primary nodes of vegetation density, soil disturbance and supplementary food. In each of

244 those models there was no dispersal in 97%, 99% and 93% of cases with high vegetation

245 density, disturbance of soil matrix and provision of supplementary food, respectively.

246 **Discussion**

247 This study represents the initial planning stage of a translocation program for this endangered

248 lizard. We do not yet know how important it is to consider behaviour of this or of any other

249 species in a real translocation program. Sullivan et al. (2014) reviewed translocations of

250 herpetofauna and considered that low success could be partly explained by behavioural

251 responses, and specifically increased movement and dispersal, of the translocated individuals.

252 Our results suggest that behaviour and attempting to modify it by adjusting release conditions

253 may be improve the success of translocations.

254 *Management implications: Single behaviour data sets and decision trees*

255 The initial stages of a translocation should provide conditions that will enhance survival and

256 encourage released individuals to stay close to the release site. Dispersing individuals risk

257 moving away from preferred habitats and mating opportunities. For pygmy bluetongue

258 lizards, behaviours associated with successful translocation probably include basking at the

259 burrow entrance (to allow thermoregulation and prey capture), reduced movements around

260 the burrow (reducing exposure to predation), reduced burrow changes (again reducing

261 predation and reducing the risk of not finding a new burrow), and reduced dispersal away

262 from the release area. Our decision tree models in which only single behavioural attributes

263 were included indicated the sets of ecological conditions that might promote each of those

264 behaviours. Reduced incidence of fights among released individuals, should also minimise

265 their stress, although no specific decision tree models provided advice on that, when other

266 behaviours were excluded from the data set.

267 The most consistent factor influencing these behaviours in our trials was soil disturbance in

268 the matrix around the release site. This is equivalent to a soft release because soil disturbance

269 made the matrix inhospitable, making lizards more likely to stay in translocation sites. Milne

270 (1999) showed that pygmy bluetongue lizards in natural habitats avoid natural burrows in

271 ploughed areas and Souter (2003) showed lizard will not occupy artificial burrows in

272 ploughed areas immediately next to population sites.

273 Vegetation density had opposite effects on different behaviours in our decision tree models.

274 Low vegetation density encouraged basking (positive for translocations), supporting

275 observations of Pettigrew and Bull (2012). But low vegetation density also encouraged

276 movements around burrows and dispersal (negative for translocations), as previously reported

277 (Ebrahimi & Bull 2015).

278 The effect of time of release was consistent across the decision tree models. Release in

279 October lead to more movements, more burrow changes, and more dispersal (negative for

280 translocations) than in other later months. Mating occurs in October and early November

281 (Milne et al. 2003b; Fenner & Bull 2009) and lizards must move about in this period to locate

282 mating partners. Confirming this, pitfall trap captures of adult lizards in wild populations

283 moving on the surface occur predominantly in the spring (Schofield et al. 2012). This natural

284 tendency for lizards to move around more in spring months suggests that other months would

285 be better times for translocation release.

286 Providing supplementary food had a major influence on one behavioural attribute, changing

287 burrows. Lizards with extra food were less likely to abandon an occupied burrow. However,

288   in the single behaviour decision trees, supplementary food formed a node for only one

289   behaviour, time of initial confinement only appeared as a terminal branch, and presence or

290   absence of conspecific models was never a node. Although individual experiments suggested

291   each of these three habitat manipulations significantly influenced whether lizards remained

292   close to a release site (Ebrahimi & Bull 2012, 2013, 2014) the decision tree modelling

293   showed they were less important factors for the behaviours we documented.

294   Reducing dispersal from the release site is one primary goal in the early stages of

295   translocations. For pygmy bluetongue lizards our best decision tree (Fig 3) showed that

296   maintaining soil disturbance around the release site, keeping vegetation dense, and releasing

297   lizards in late spring and early summer (November and December) would decrease the risk of

298   dispersal in the early stage of translocation. Although soil disturbance around the release site

299   may have a short term benefit in reducing local dispersal, there may be longer term adverse

300   impacts in preventing the spread of reproductive recruits from a successfully established

301   translocation site. Our trees, based on short term behavioural changes, need to be balanced

302   against longer term considerations. Nevertheless, selective soil disturbance practices could

303   reduce population spread in undesired directions.

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

305   The decision tree models that included all behavioural attributes provided clues about

306   relevant combinations of behaviour that may influence translocation success. The trees

307   showed clear positive associations between movements around burrows and burrow changes.

308   Lizards that emerged to move around their burrows more often were also more likely to move

309   away and change their burrows. Lizards that were involved in fights were more likely to

310   disperse. These and other relationships from the decision trees reflect the connections and

311   interactions among different types of behaviour related to successful settlement of released

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312   lizards. Of equal relevance for conservation is documenting behaviours that are not tightly

313   linked, and thus less indicative of translocation success. In our decision trees there were few

314   connections between basking behaviour and movements around the burrow or dispersal,

315   indicating that not all behaviours that we thought may be important are interconnected in

316   influencing establishment success.

317   *Overview*

318   The main result of this study was to demonstrate how decision trees that model aspects of

319   animal behaviour open new doors for the study of conservation management. They provide

320   conservationists with the opportunity to predict the behaviours of translocated species, under

321   different circumstances, immediately after release, and provide indications of the relative

322   importance among a range of possible conservation measures. Caro (2007) suggested an

323   interdisciplinary interface between behavioural ecology and conservation biology answers

324   many problems in conservation. Simple examples include feeding condor chicks with condor-

325   head-shaped puppets to reduce subsequent attraction to humans by those chicks after release

326   (Wallace 2000), and translocations of black-tailed prairie dogs as whole family,

327   behaviourally integrated units (Shier 2006). A problem is identifying how behaviour changes

328   after release at translocation sites, and determining which sorts of behaviours have negative

329   impacts on translocation success. Decision tree models add dimensions to these studies by

330   predicting which combined set of conditions can alter behaviour, which have the most

331   influence, and which behavioural combinations work synergistically. Managers could use the

332   models to suggest interventions to reduce behaviours with negative impact. Decision tree

333   models could decrease the cost and time needed to find how and why species dispersed.

334   Developing those models before actual translocation release might improve success.

335   Conservationists must make decisions under severe uncertainty (Regan et al. (2005), and

336   decision tree models provide possible responses to at least some of those uncertainties.

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337   Not all endangered species will be as easy to work with as the pygmy bluetongue lizard. This

338   small species (snout-to-vent length average 95 mm) can be easily confined within

339   experimental enclosures. Their very small normal activity range means they can be observed

340   almost continuously in and around their burrows, to derive the behavioural parameters we

341   used in this analysis. For larger, more mobile species it may be harder to generate equivalent

342   behavioural data from multiple replicate cases. Nevertheless the benefits derived from the

343   decision tree models suggest it is worth exploring ways of quantifying critical behaviours in a

344   range of alternative conditions as background for translocation projects across a wider range

345   of animal species.

346   **Supporting Information**

347   Supporting information available online includes construction of the decision trees (Appendix

348   S1), the decision tree for basking behaviour when all behaviour parameters were included

349   (Appendix S2) and additional decision trees for dispersal (Appendix S3). The authors are

350   solely responsible for the content and functionality of these materials. Queries should be

351   directed to the corresponding author.

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480   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 (%)
	Basking	1A	Rule	Random forest	Gini index	3	4	82.2
Single behaviour	Movements around burrows	1B	unweighted data	Random forest	Accuracy	6	7	61.0
	Burrow changes	1C	SVM	Random forest	Gini index	3	4	67.0
	Dispersal	1D	Info Gain	Random forest	Accuracy	4	5	87.0
All behavioural parameters	Movements around burrows	2A	Rule	Random forest	Gini index	4	5	64.0
	Burrow changes	2B	unweighted data	Random forest	Gini index	4	5	73.0
	Fight	2C	Rule	Random forest	Info gain	4	5	93.0
	Dispersal	3A 3B 3C	unweighted data SVM Rule	Random forest Parallel based Random forest	Accuracy	3	4	87.0

481   * Name of data set is according their attribute weighting algorithms
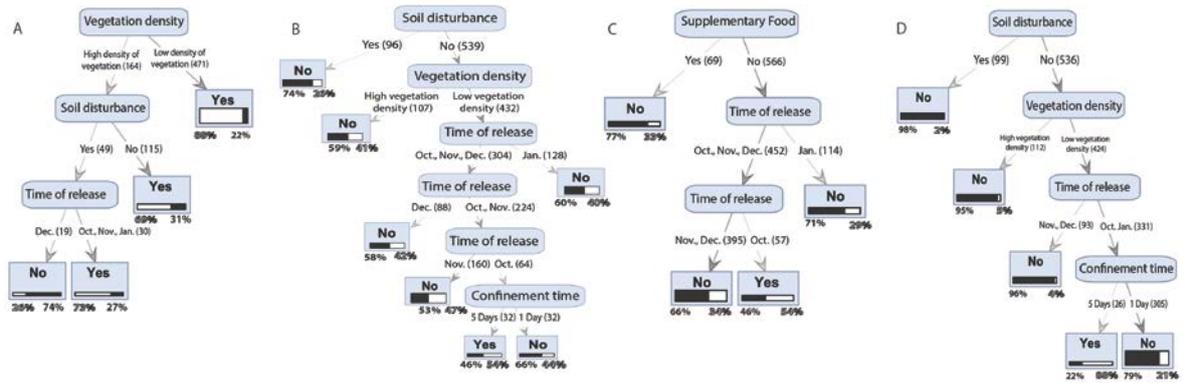
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492 Fig 1. The Random forest based decision trees for (A) basking behaviour; (B) movements

493 around burrows; (C) burrow changes and (D) dispersal, when other behavioural parameters

494 were excluded. Bold Yes/No in gray box showed whether the behaviour did or did not

495 happen. The numbers in brackets under the grey boxes represent the actual number of cases

496 when lizards were exposed to each set of conditions for the attribute described in the box

497 above. In the "leaves" at the end of each "branch" of the tree, the black and white bars with

498 percentages represent the proportion of cases when lizards did (white) or did not (black) show

499 the behaviour in the specified set of experimental conditions.
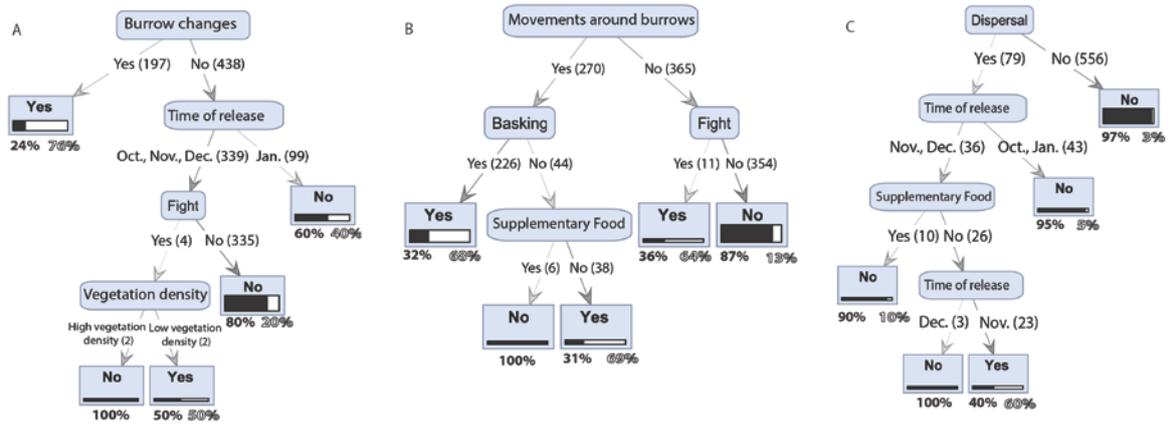
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Fig 2. The Random forest based decision trees for (A) movements around burrows; (B)

burrow changes and (C) fight, when other behavioural parameters were included.

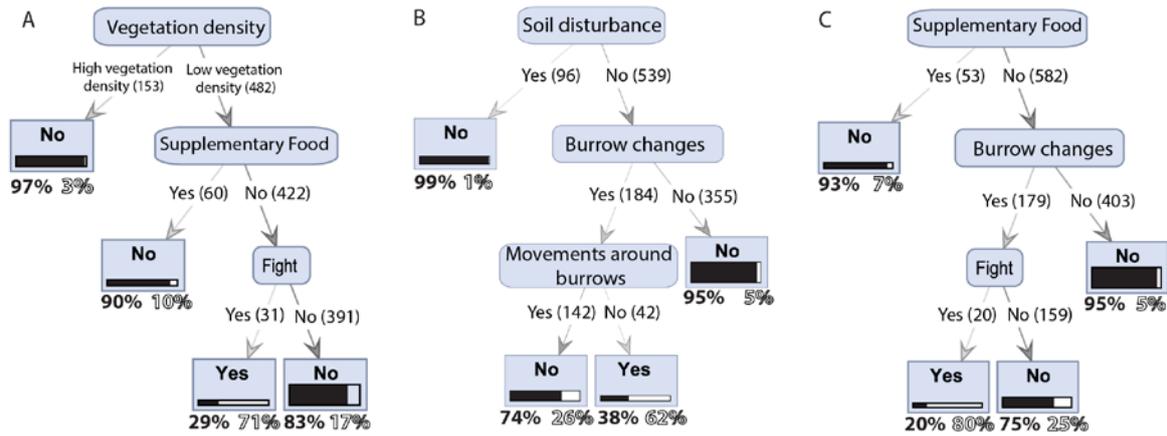Explanatory symbols as in Fig 1.

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Fig 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.