1 **Adaptive space use by baboons (*Papio ursinus*) in**

2 **response to management interventions in a human-**

3 **changed landscape**

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5 **Running title: Adaptive space use by baboons**

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ABSTRACT

Growing human populations are increasingly competing with wildlife for limited resources and this can result in chronic human-wildlife conflict. In the Cape Peninsula, South Africa, chacma baboons (*Papio ursinus*) are habitual raiders of urban and rural areas, foraging on a variety of human-derived foods. Raiding behaviour is considered a threat to human health and safety, may result in damage to property, and has adverse welfare and conservation impacts on baboons. To mitigate this conflict, Cape Town municipality employs field rangers with paintball markers that "herd" baboons away from the urban edge. While this strategy is successful in reducing the time baboons spend in urban spaces, baboons still raid successfully. Here, we use direct observation and GPS data to investigate how one troop uses the peri-urban space and exploits human derived foods in urban areas and farm lands. We contrast this behaviour with the individual management strategies adopted by field rangers which we assessed in individual interviews. We find that baboons utilise space (i) where inter-individual variation in field ranger management strategy is highest, (ii) that is close to refuges in forested habitat, and (iii) that is close to the urban edge. Overall, this suggests adaptive space use by the baboons, whereby they minimise distances to refuges and potential food rewards, whilst exploiting uncertainty in risk variability that arises due to inter-individual differences in ranger management strategy. Together these results highlight the need for ranger consensus to reinforce management efficiency when dealing with a highly adaptive primate.

Keywords: primates, raiding, risk variability, home range, trade-off, human-wildlife conflict

1. INTRODUCTION

With the growth of the human population, transition zones between small protected natural areas and human landscapes are eroding (Woodroffe & Ginsberg, 1998). This often results in more frequent human-wildlife interactions (Creachbaum, Johnson, & Schmidt, 1998; Gurung, Smith, McDougal, Karki, & Barlow, 2008; Seiler, 2005) which can have negative consequences for both people and wildlife and manifest in chronic Human Wildlife Conflict (HWC) (Marker, Mills, & Macdonald, 2003; Nijman & Nekaris, 2010; Redpath et al., 2013; Takahata, Nielsen, Takii, & Izumiyama, 2014). Raiding behaviour – where animals venture into human-changed landscapes to exploit high energy food resources – is one of the most frequent drivers of HWC, and its occurrence is dependent upon the relative costs and benefits associated with raiding (Beamish & O'Riain, 2014; Fourie et al., 2015; Palmeira, Craivshaw, Haddad, Ferraz, & Verdad, 2008; C. E. Webber, Sereivathana, Maltby, & Lee, 2011). Where the benefits of acquiring resources in human-changed landscapes outweigh potential costs, wildlife populations alter their home range to increase their spatial overlap with human dominated landscapes to exploit these new food sources (Barnagaud, Devictor, Jiguet, & Archaux, 2011; Sih, 2013).

Among raiding species, primates are exceptionally difficult to manage because of their diverse modes of locomotion, dexterity and problem solving (Naughton Treves, 1998; Nijman & Nekaris, 2010). For instance, deterrents have to be regularly inter-changed because of rapid habituation (Catherine M. Hill & Wallace, 2012) and standard fences do not act as barriers because of climbing abilities (Hoffman & O'Riain, 2010). Some of the most high-profile and severe cases of HWC involving

3

93   primates occur with baboons (*Papio spp.*) which are viewed as pests throughout the

94   African continent (A. D. Webber & Hill, 2014). Indeed, crop-raiding baboons may

95   damage up to 2774 m^2 of crops per raiding event (Naughton Treves, 1998), and

96   human resources may comprise as much as 58% of their diet in some Southern

97   African populations (Strum, 2010). As such, baboons and their raiding behaviour

98   often lead to severe losses for local economies.

99

100   In the Cape Peninsula, South Africa, the lack of a buffer area between the Table

101   Mountain National Park (TMNP) and the city of Cape Town results in high levels of

102   spatial overlap between people and baboons (Hoffman & O'Riain, 2012a). A lack of

103   by-laws to enable the efficient policing of resident behaviour and properties adjacent

104   to TMNP translates into baboons exploiting urban areas to access waste bins,

105   fruiting trees, residential houses, shops and even people carrying food (Hoffman &

106   O'Riain, 2012b). As a result, the Cape Peninsula baboon population is gaining

107   international notoriety as a major pest species.

108

109   Baboons in the Cape Peninsula became protected in 1998, supported by a program

110   aiming to mitigate baboon raiding (Beamish & O'Riain, 2014). Today, around 60 field

111   rangers are employed to manage 10 baboon troops away from urban spaces. At

112   first, rangers were permitted only to shout and chase the baboons to herd them away

113   from urban spaces, but in 2012, rangers were allowed to use paintball marker guns

114   as an active deterrent (Cape Nature, 2012), increasing the efficiency of rangers

115   (Richardson, 2012). In addition to the activities of the municipality, some crop

116   farmers have developed their own management strategies and hire private rangers

117   to keep baboons away from their property. Whilst these activities do reduce the time

118 baboons spend in the urban space and consequently the frequency of raiding events

119 (van Doorn, 2009), baboon-human conflict is still prevalent, and in July 2014 (the

120 time of this study) 331 baboon raiding events were observed by field rangers and

121 147 phone calls were received from the public reporting the presence of a raiding

122 baboon(s) in residential areas (Richardson, 2014).

123

124 The purpose of this study is to provide an independent assessment of current

125 management strategies. In doing so, we explore the potential trade-offs that baboons

126 make between foraging returns and risk of human-baboon conflict in their patterns of

127 habitat use. To do this, we first use direct observation and GPS data to track baboon

128 space use, categorising areas used by the baboons according to the level of

129 anthropogenic activities (both vineyards and dense residential areas occur within

130 their home range). We then relate baboon space use to the management strategies

131 adopted by field rangers tasked with managing the troop, assessed via individual

132 interviews. Given that the baboons are continuing to raid the urban space despite

133 ranger activities, we tested the extent to which baboons (1) use habitats to maximise

134 foraging rewards, and/or (2) balance their foraging rewards with risk of ranger

135 encounter. The former would indicate poor efficacy of the ranger management

136 strategy, whilst the latter may inform management on how to improve current

137 practices and so reduce human-baboon conflicts.

138

139 **2. MATERIALS AND METHODS**

140

141   ***2.1. Study site and subjects***

142 We studied a single troop, the 'Constantia troop' that comprised 10 adult males, 20

143 adult females, 3 sub adult males, and approximately 30 juveniles of both sexes. The

144 troop ranged in a varied landscape (S -34.0349, E 18.4156; Fig. 1) that included two

145 wine farms (Farm A and B), commercial and residential buildings, a restaurant, and

146 commercial pine and eucalyptus plantations, all of which the baboons are known to

147 access and/or raid (Richardson, 2012). The entire western part of their home range

148 was bordered by TMNP which includes indigenous fynbos vegetation that extends

149 over a mountain and down to the Atlantic Ocean. We studied the troop from mid-

150 April to mid-July 2014, which is after the harvest of the grapes, when the vineyards

151 are no longer providing rich energetic food. Baboons tend to urban raid more in

152 these months (van Doorn, O'Riain, & Swedell, 2010).

153

154 To reduce the frequency and impact of baboon raiding, field rangers actively move

155 baboons out of high-risk raiding areas using shouts and whistles, movements, and

156 paintball guns (Cape Nature, 2012). Two alternating teams of five field rangers

157 managed the baboons on a daily basis from approximately 7am to 5pm, with each

158 team working four days on, four days off. Ranger teams were comprised of

159 employees from two different organisations: (i) the City of Cape Town's service

160 provider (Human Wildlife Solutions) whose primary goal is to protect residential

161 properties and (ii) the employees of Farm B whose goal is to protect the vineyards.

162 One ranger team would be comprised of individuals from both organisations working

163 together over the whole area.

164

165 *2.2. Baboon troop ranging*

166 The baboons were habituated to close (≤ 10m) human observation and could thus

167 be followed on foot by one or two observers. Baboons were observed daily in

168 accordance with the guidelines for the treatment of animals in behavioural research

169 and teaching (Animal Behaviour, 2012, 83: 301-309). The troop was followed for 17

170 ± 0.8 (mean ± standard error) days per month and their position was recorded every

171 30 minutes using a handheld GPS device (eTrex 10, Garmin Ltd, Olathe, Kansas,

172 USA) with the observer positioned at the middle of the troop (Hoffman & O'Riain,

173 2010). This resulted in 51 days of observations, and 13 ± 5 (mean ± standard error)

174 GPS fixes per day (total GPS fixes = 685). We estimated troop home range by fixed

175 kernel densities using an ad hoc method for selecting the smoothing parameter

176 (Worton, 1989) with the package "adehabitat", function "getvolumeUD" (Calenge,

177 2006) in R.

178

179 **_2.3. Habitat type_**

180 Based on researcher knowledge of the site and images from Google Earth

181 (accessed 06/06/2014), we categorized the study region into one of five major

182 habitat types (fynbos, trees, meadows, vineyards and urban areas). We created an

183 index of anthropogenic activities for each habitat ranging from 0 for areas with no

184 human activity during the study period, to 4 for areas with daily human activities

185 based on personal observations. Fynbos habitat is comprised of natural vegetation,

186 vehicle access is restricted and walkers are infrequent (score 0); tree habitat

187 comprises alien pine and eucalyptus plantations where vehicle access is restricted

188 and walkers sometimes pass through to the areas of the TMNP (score 1); meadow

189 habitat comprised open areas dominated by exotic grasses and a variety of annuals

190 including wheat and barley under maintenance by farm workers (score 2); vineyard

191 habitat consisted of planted vines, which had been harvested but kept under

192 maintenance by farm workers (score 3); urban habitat included residential and

193 commercial property with people using the space daily (score 4). We classified all

194 habitats within the baboon home range, and additionally for a radius of half of the

195 mean distance covered by the troop in one day (which is akin to an outward and

196 return path from the sleeping sites). We compared habitat composition within and

197 outside of the home range using a Chi squared test.

198

199   ### 2.4. Management strategies

200 We assessed ranger 'strategy' as rangers' likelihood of herding baboons from a

201 specific area. Each field ranger's strategy (n=11) was assessed in an interview with

202 GF and CK. Interviews were anonymous and conducted with the consent of both

203 employers and the field rangers. Field rangers were provided with a map of the study

204 area (Fig. S1) and asked to colour in areas where, in their opinion, the baboons were

205 allowed to be: at any time (green; score 2), allowed some of the time (orange; score

206 1), or never allowed (red; score 0). Rangers were tasked to colour the map

207 according of their plan of action (chase or leave) in the different scenarios regardless

208 of their motivation. This provided us with 11 different maps representing individual

209 field ranger management strategies, and a composite map created by summing cell

210 scores across all field rangers. Low scores indicate that a baboon would be highly

211 likely to be chased or herded away from a given area, whilst high scores (maximum

212 22 in the composite map), indicated no conflict with the baboon rangers and

213 baboons would not be chased or herded. In addition, to assess the level of

214 agreement (A) across the field rangers, we calculated the Simpson's diversity index

8

215　(Simpson, 1949) to express the probability of two field rangers selected by random

216　giving the same score for a specific cell:

217

$$A = \frac{\sum_0^2 n_i(n_i - 1)}{N(N - 1)}$$

218　Where A is computed for each cell, N is the total number of field rangers, and n_i is

219　the number of field rangers scoring a given cell with the score i (0, 1 or 2; chased all

220　of the time, sometimes or never).

221

222　***2.5. Spatial and statistical analyses***

223　We divided the study area into 150 x 150m grid cells (total = 22500 m^2 cells). This

224　grid-cell size was larger than the average spread of baboon troops within the Cape

225　Peninsula (Hoffman & O'Riain, 2012a) and elsewhere in South Africa (Henzi, Byrne,

226　& Whiten, 1992). We then created raster layers quantifying every grid cell's Euclidian

227　distance to all habitat types (see above) using the "Spatial Analyst" toolbox of

228　ArcGIS 9.3 (Environmental Systems Research Institute, Redlands, California). Each

229　grid cell was also assigned an intensity of baboon use scaled between 0 and 100,

230　where 100 represents the core area of the home range, based upon the utilities for

231　home-range size estimation (see 2.2 above).

232

233　To investigate whether any key landscape or habitat details predicted field ranger

234　strategy, we used partial Mantel tests to test for a correlation between two matrices'

235　grid cell scores (R environment, package "vegan", Spearman correlation, 10 000

236　permutations), whilst controlling for the spatial effect (details of spatial

237　autocorrelation are provided in Fig. S2). Specifically we tested whether the collective

ranger strategy (derived from the composite map, details above) was correlated with (i) habitat type, (ii) distance to specific raiding opportunities (i.e. measured as the distance to urban space, or vineyards) or (iii) distance to key baboon refuges (measured as the distance to trees).

To test what factors predicted baboon space use (i.e. grid cell use) we used a spatial Simultaneous Auto Regressive lag model (SAR lag). This model based on a classical linear model control for spatial autocorrelation by building a spatial weight matrix based on nearest neighbours (R environment, package "spdep"). We adopted this approach because subsampling was impractical due to the degree of spatial autocorrelation (Fig. S2). In all models, we applied a logit transformation to the intensity of baboon cell use, our response variable given as a percentage, to normalise model residuals. We entered a combination of: overall field ranger strategy (summed scores), field ranger agreement (Simpson's diversity index), distances to fynbos, trees, vineyards, and residential areas space (in meters) as fixed effects, where they were correlated with a coefficient less than 0.5 (Table S1). We then used Akaike Information Criteria (AIC) to select the best fitting model. All analyses were conducted in R (R version 3.1.1, R Core Team (2015). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.).

3. RESULTS

3.1. Baboon troop ranging and habitat type

261 The mean (μ) ± standard deviation (sd) troop day path length was 2261 ± 657m and

262 home range (Kernel density, 95%) was 1.97 km^2 (Fig. 1). The home range

263 comprised 16.4% of fynbos, 17.8% of trees, 11.6% of meadows, 50.5% of vineyards,

264 and 3.0% of urban areas (Fig. 1). The habitat composition within the troops home

265 range was significantly different to that in the surrounding region which comprised

266 36.6% of fynbos, 13.5% of trees, 6.4% of meadows, 29.9% of vineyards, and 12.9%

267 of urban areas (Chi squared test: X^2=756611.7, df = 5, p<0.001).

268

3.2. Management strategies

270 Individual field ranger strategies scores for urban space were low indicating that

271 baboons are generally prohibited from entering this habitat (μ ± sd = 0.5 ± 0.8, Fig. 2

272 and Fig. 3), while scores for fynbos were high (μ ± sd = 20.9 ± 2.3, Fig. 2 and Fig. 3)

273 suggesting the baboons are generally permitted. This meant that the sum of field

274 ranger scores was strongly correlated with habitat type (scored according to level of

275 anthropogenic influence) when controlling for spatial autocorrelation (Partial Mantel

276 test: R=0.698, p<0.001, Fig. 2 and Fig. 3, Table S2).

277

278 Ranger agreement scores were from 27.3% to 100%, with more than half of all grid

279 cells showing low level of agreement, i.e. less than 50% agreement among rangers.

280 For these cells with a low agreement scores, 75% of these occurred within vineyard

281 habitats, with almost all the remaining low agreement cells (24%) occurring within a

282 300m range of a vineyard cell (Fig. 2 and Fig. 3). Overall, we found that the level of

283 field ranger agreement was most strongly correlated with the distance of cells from

284 vineyards; the further the distance from the vineyards, the more the rangers agreed

285 on a strategy (Partial Mantel test: R=0.401, p<0.001, Fig. 2 and Fig. 3, Table S2).

286

3.3. Baboon space use

288 Of all models considered (Table S3), intensity of baboon space use was best

289 predicted by distance from urban space (SAR: Estimate: 0.0003; Standard Error:

290 0.000; $Z = 1.988$, $P = 0.047$; Table S4, Fig. 4 a), distance from trees (Estimate: -

291 0.0018; Standard Error: 0.000; $Z = 5.738$, $P < 0.001$; Table S4, Fig. 4 b), and by the

292 level of field rangers' agreement (SAR: Estimate: -1.4187; Standard Error: 0.269; $Z =$

293 -5.290, $P < 0.001$; Table S3, Fig. 4 c). All candidate models and details of the

294 selected model predictions are provided in Table S3 and Fig. S3.

295 ## 4. DISCUSSION

296

297 Our results show that baboons in this study utilised space near to trees and far from

298 the urban edge. We expect that this space use reflects the importance of refuges

299 (trees) and the risk of negative interaction with field rangers that baboons are likely

300 to experience in human-modified landscapes. Perhaps most importantly, our findings

301 also show that baboons intensively use spaces where rangers show a low

302 agreement score, suggesting that baboons are sensitive to, and exploit risk

303 variability that arises due to inter-individual differences in ranger management

304 strategies.

305

306 To prevent Human Wildlife Conflict (HWC) and urban raids, the City of Cape Town

307 employs baboon field rangers who are responsible for minimizing the time that

308 troops spend in urban areas (Hoffman & O'Riain, 2012a; van Doorn et al., 2010).

309 Our data suggest that the City's objectives are being met, with the proximity of cells

310 to the urban edge showing an overall negative relationship with intensity of baboon

311 cell use. However, baboons frequently use spaces where rangers disagree on how

312 to manage them (whether to herd them away, or not; Fig 4c) and are often found at a

313 distance of 400-600m from the urban edge (Fig. 4 a) consistent with a trade-off

314 between risks and rewards available in the urban environment (G. Cowlishaw, 1997;

315 Fraser & Huntingford, 1986; Lima & Dill, 1990). Although it is difficult to tease apart

316 effects of habitat and rangers' disagreement (because they are correlated), our

317 models suggest that rangers' disagreement, rather than distance to certain habitats

318 (e.g. the vineyards), explains more of the variance in baboon cell use (Table S4).

319

320 In line with our interpretation that baboons are mitigating risks, the most important

321 habitat factor determining baboon space use was the proximity to trees. We expect

322 that the importance of the tree habitat is two-fold. Among cells classified as trees in

323 baboons' home range, 42% were used as sleeping sites (n=3) by the troop. Sleeping

324 sites are among primary resources for baboons, giving protection against nocturnal

325 predation (Guy Cowlishaw, 1994) and influencing baboon ranging behaviour and

326 ultimately home range size (Hamilton, 1982; Hoffman & O'Riain, 2012a). Even in the

327 absence of predators across the Cape Peninsula, sleeping sites remain an important

328 feature of baboon spatial ecology and they have been documented sleeping on cliffs,

329 in pine and eucalyptus plantations and even apartment buildings and factory roofs

330 (Hoffman & O'Riain, 2012a). The remaining 52% of tree habitat within the home

331 range were not used as sleeping sites but rather as cover and refugia when being

332 chased by rangers (GF and CK personal observation). Recent theoretical models

333 support these empirical data (Taylor, Ryan, Brashares, & Johnson, 2016), predicting

334   that buffer zones between refuges and raiding areas can limit raiding behaviour in

335   baboons in the absence of apex predators.

336

337   Threat avoidance via refuge use represents a principal survival strategy and its

338   importance in HWC has been highlighted in several species such as bears

339   (Takahata et al., 2014), tigers (Gurung et al., 2008) and langurs, macaques and

340   chimpanzees (Naughton Treves, 1998; Nijman & Nekaris, 2010). Thus, in line with

341   the findings of Hoffman and O'Riain (2012a), our results suggest that the removal of

342   large exotic trees in close proximity to either vineyards or urban areas would greatly

343   reduce the intensity of cell use in these areas and ultimately the frequency of raids in

344   nearby residential and commercial areas. However, such management actions

345   would necessitate extra care since habitat engineering can play an important

346   functional role (Foley et al., 2005; Ramesh, Kalle, & Downs, 2016; Vitousek,

347   Mooney, Lubchenco, & Melillo, 1997). Moreover, it is certainly possible that if we

348   were to conduct this study during a different time of year (e.g., before the harvest of

349   the vineyards), baboon space use and management strategies would likely be

350   different, thus potentially shifting the location of conflict and refuge locations.

351

352   Crop or livestock guarding is common and often seen as one of the most effective

353   ways to reduce raiding for a wide diversity of species (Catherine M. Hill & Wallace,

354   2012; Hsiao, Ross, Hill, & Wallace, 2013; Ogada, Woodroffe, Oguge, & Frank, 2003;

355   Sitati & Walpole, 2006). However, the baboons appear to be sensitive to risk

356   variability that arises due to inter-individual differences in ranger management

357   strategy. This poses an additional, overlooked dimension to our understanding of

358   how wildlife evaluate and adjust their response to human disturbance (Sol, Lapiedra,

14

359 & González-Lagos, 2013). It also highlights the adaptability and cognitive skills of

360 baboons (C. M. Hill, 2000; Naughton Treves, 1998), and supports findings of other

361 studies in which baboons are observed to assess risk before raiding (C. M. Hill,

362 2000; Warren, 2009). Being a group-living species with complex social interactions

363 (King, Clark, & Cowlishaw, 2011; King, Douglas, Huchard, Isaac, & Cowlishaw,

364 2008), the sampling of intraspecific public information is a common feature of the

365 daily life of baboons and may explain their apparent ability to integrate field rangers'

366 activity and adapt their own strategies in accordance with this information (Dall,

367 Giraldeau, Olsson, McNamara, & Stephens, 2005). Such behaviour reinforces their

368 adaptability, enabling them to mitigate risks associated with raiding behaviours and

369 make the most of the high energetic resources available in the urban areas (Snell-

370 Rood, 2013). As such, management strategies based on guarding should make their

371 spatial strategy clear especially when working with species with high cognitive skills

372 or complex social systems such as other raiding primates, e.g. as chimpanzees or

373 macaques (Krief et al., 2014; Yeo & Neo, 2010), or elephants (Sitati & Walpole,

374 2006; C. E. Webber et al., 2011).

375

376 One potential cause for inter-individual differences in ranger management strategies

377 may be because rangers are working for two different organisations – local farms,

378 and the municipality of Cape Town. Each has a different primary objective: to keep

379 the baboons away from the vineyard, or to keep the baboons from entering the urban

380 edge, respectively. However, we found that the majority of cells across the study site

381 had low agreement scores, and this is greater than would be expected by simple

382 disagreement between the six (municipality) versus four (farm) employees. Similar

383 results have been found in other studies where, even if a community or specific

384 group share the same objectives, perceptions and reactions can differ. For example,

385 farmer reaction towards crop raiding by primates in Sri Lanka (Nijman & Nekaris,

386 2010), and citizen preference for bear zoning management in Japan, consistently

387 differed (Kubo & Shoji, 2014).

388

389 Overall, our results suggest that baboon troops in Cape Town balance the foraging

390 rewards gained from raiding against the risk of field ranger (or other human) conflict.

391 This suggests that current management strategies do impact baboons' behaviour

392 and successfully prevent them from frequenting urban spaces. However, baboons

393 also appear sensitive to risk variability that arises due to inter-individual differences

394 in ranger management strategies, and thus, for management to be more effective, a

395 consensus is needed on actions taken with respect to baboon movement close to

396 the urban edge. Forested areas close to raiding spots should also be considered

397 carefully, since these offer refuges that are likely to decrease the efficiency of field

398 rangers' activity. Showing similarities with other studied systems, such as the

399 importance of refuges (Nijman & Nekaris, 2010; Takahata et al., 2014) or risk

400 assessment by wildlife (C. M. Hill, 2000; Warren, 2009), we believe our

401 recommendations could be considered in the development of better management

402 strategies throughout the Cape Peninsula or for raiding species more generally, in

403 comparable cases where refuges around raiding spots and/or a management

404 strategy based on guarding exist. Our findings suggest that effective management

405 strategies will be those that increase the attractiveness of natural resources,

406 decrease the attractiveness of human modified areas, and increase the costs in

407 terms of energy or risks associated with these areas (Kaplan, O'Riain, Eeden, &

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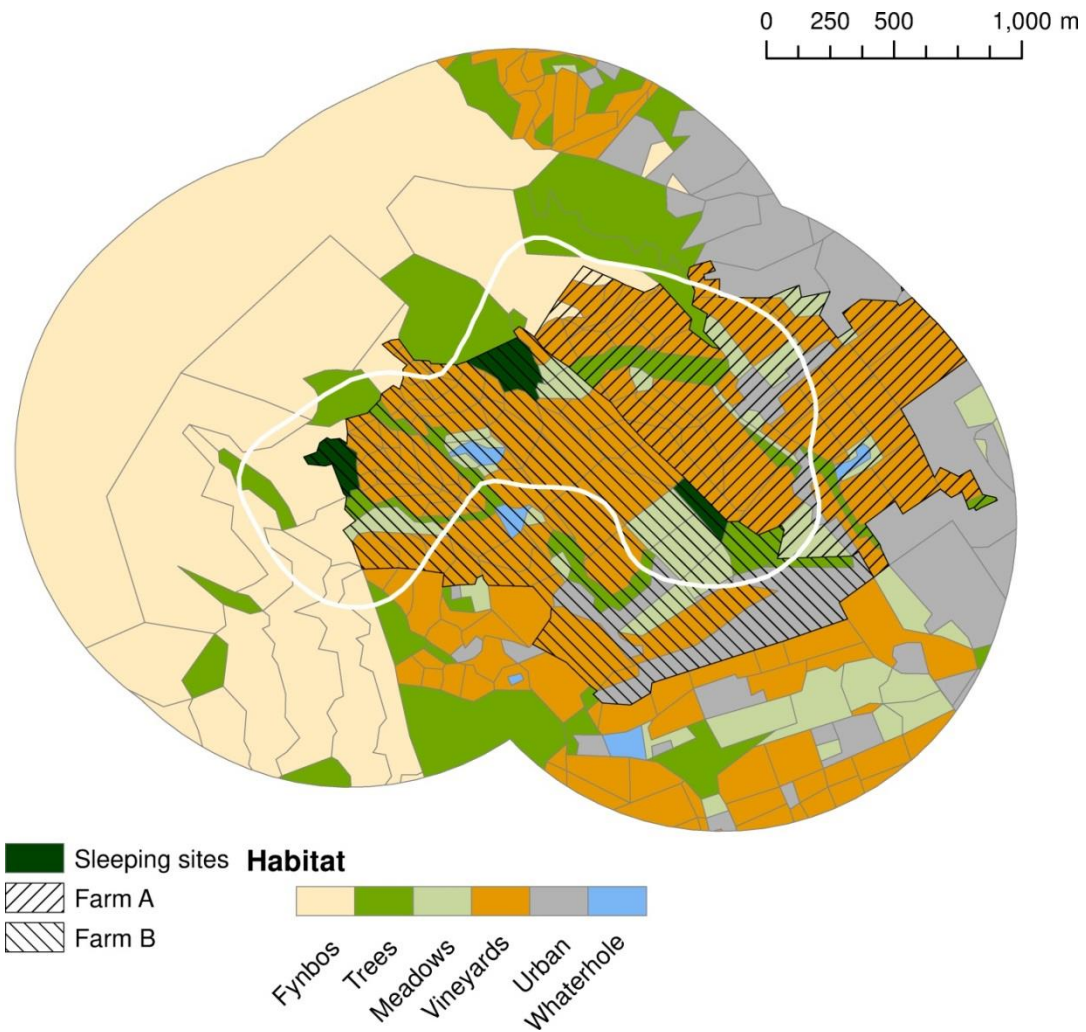
Fig. 1: Study area (-34.0349, 18.4156) showing the baboon troop home range (solid white line) estimated by a 95% kernel density, major habitat types, and location of baboon sleeping areas used over the study period.
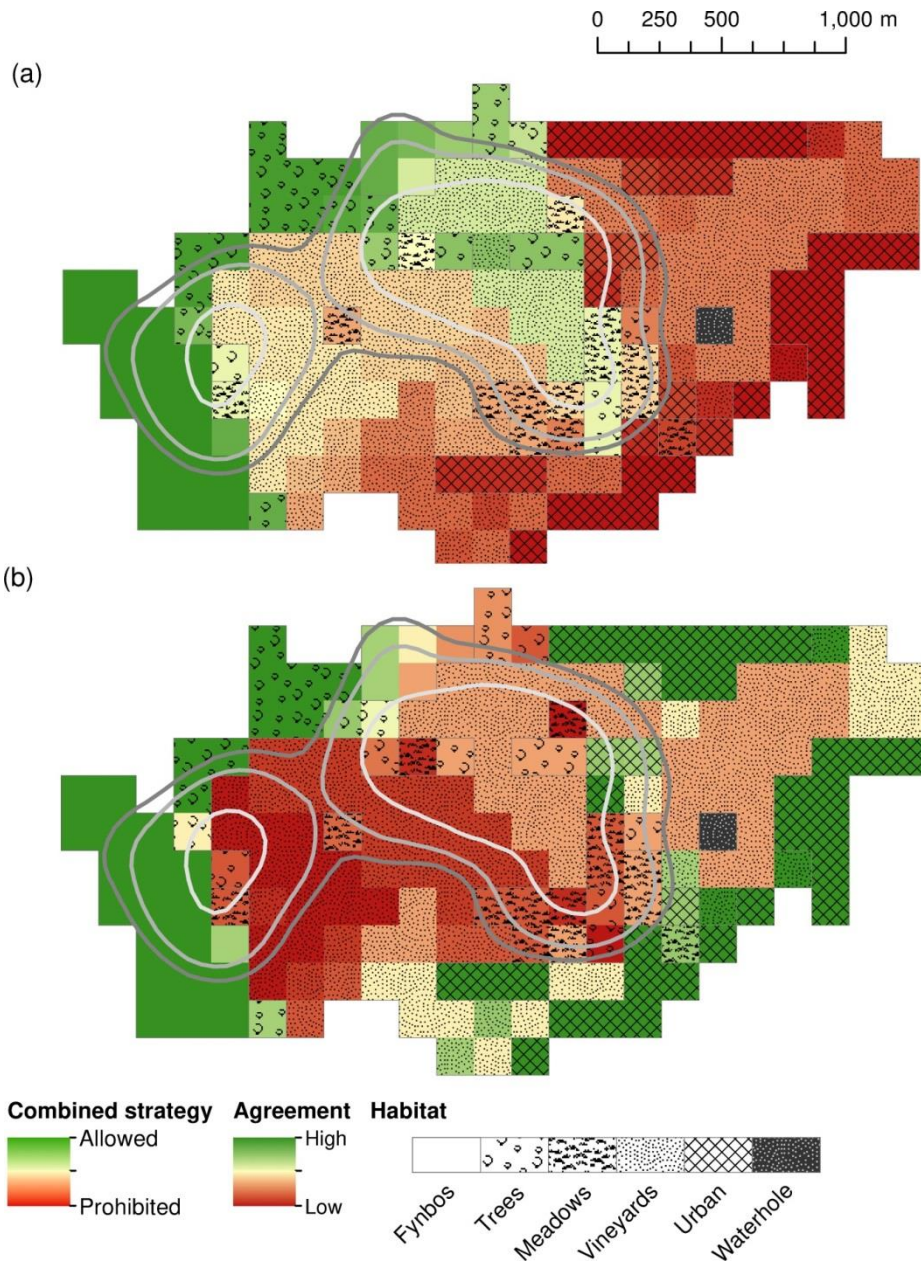
Fig. 2: Management strategies and baboon space use. A map of study area divided up into 150m x 150m grid cells. Baboon home range, defined by kernel densities are represented by the contour lines from light to dark grey that represent 70%, 90% 95% contours respectively in both (a) and (b). (a) Overall field ranger strategy with cells coloured according to whether baboons were 'allowed' or 'prohibited' based on field ranger interviews. (b) Overall ranger agreement across the 11 individuals interviewed, with cells coloured according to the level of field ranger agreement; from 'low agreement' to 'full agreement'.

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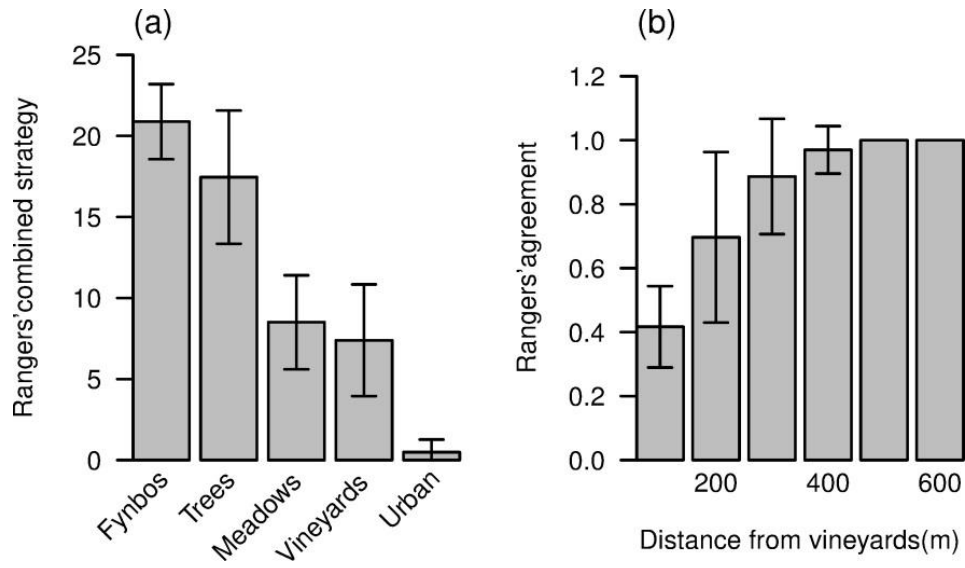
573

574 **Fig. 3**: Field ranger's combined strategy according to habitat type and distance to

575 vineyards. (a) The mean ± standard error sum of baboons ranger overall strategy

576 scores (0 = prohibited; 22=always allowed) for grid cells within each of the five major

577 habitat types. (b) The mean ± standard error of agreement in field ranger scores

578 (Simpson's diversity Index) for grid cells as a function of the distance from vineyard

579 habitat. Cell scores for agreement in ranger scores are significantly positively

580 correlated with the distance from vineyards (Partial Mantel test, R=0.401, p<0.001).

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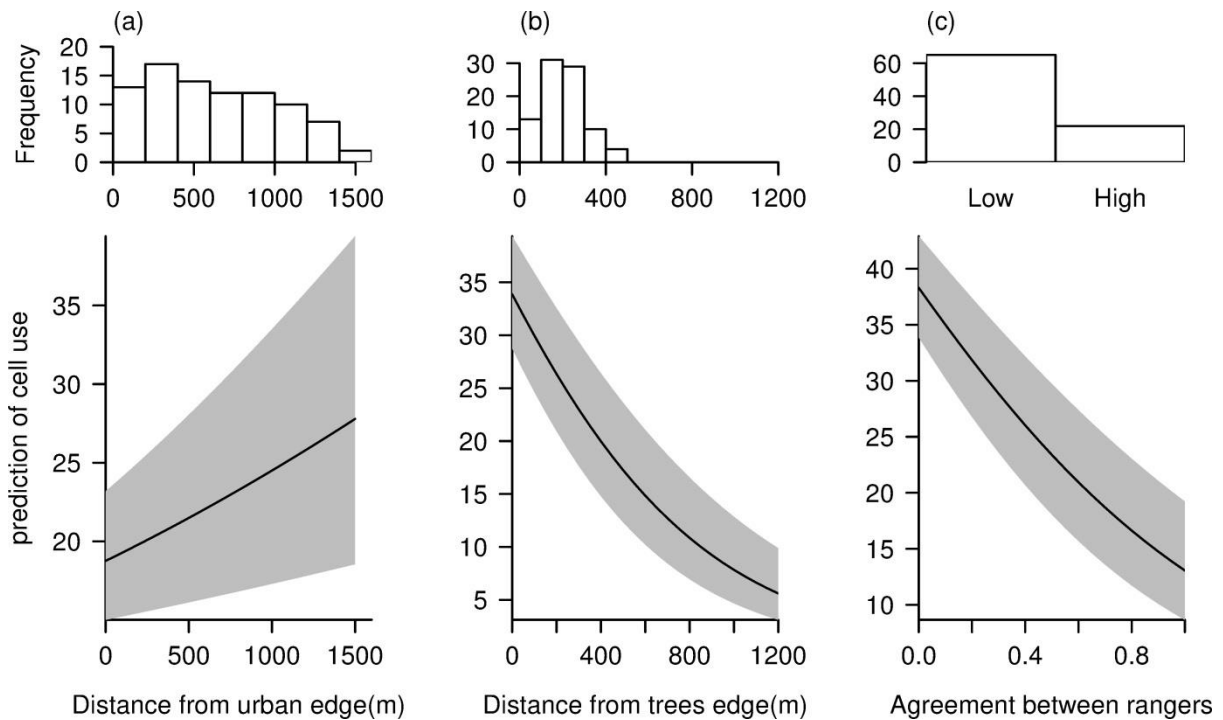
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583   **Fig. 4:** Predictors of baboon space use. The frequency of cells in the home range

584   (95% kernel density) (histograms; upper row), and estimated values of the intensity

585   of baboon grid cell use with their standard errors (grey area) (lower row) as a

586   function of (a) distance from the urban edge; (b) distance from the trees, and (c) field

587   ranger strategy agreement. "Low" agreement refers to a score of less than 50%, and

588   "high" agreement refers to a score higher than 50%. Baboon space use was

589   predicted by all three of the factors shown in the best fitting (AIC: 596.9) Spatial

590   Simultaneous Auto Regressive lag model (SAR lag) explaining the intensity of cell

591   use by baboons.

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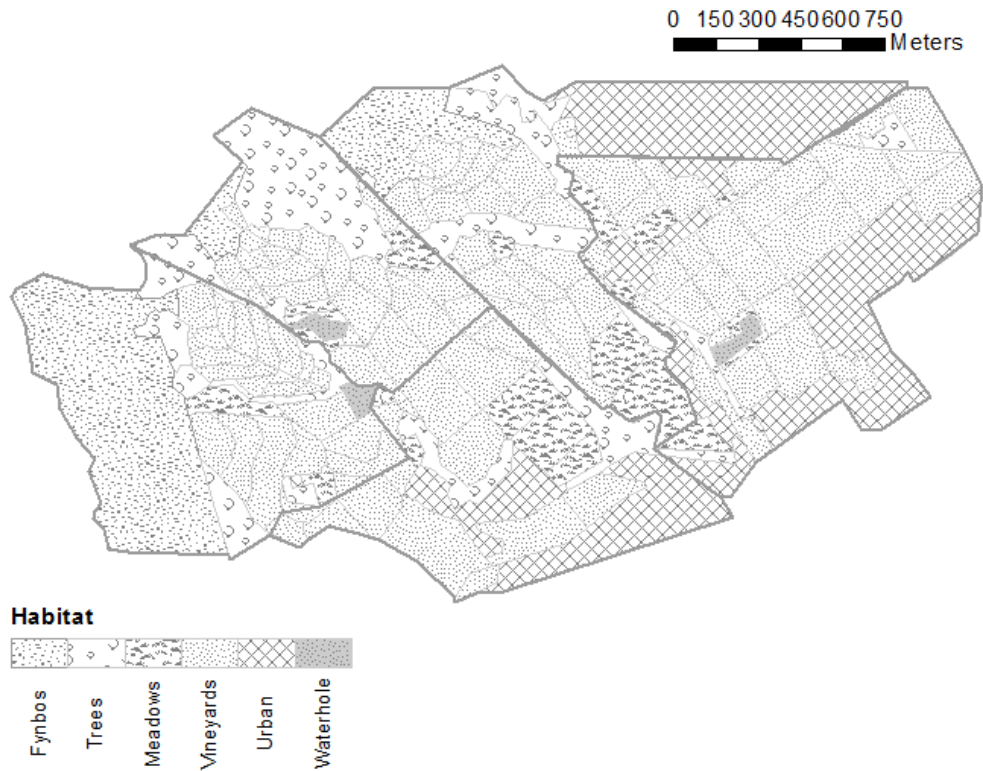
Fig. S1: A map of the study site, subdivided by habitat type areas boundaries (solid lines), that was presented to the field rangers during interviews. Each ranger was asked to colour the map (however they wanted) according to whether the baboons were "allowed at any time" (green), "allowed some of the time" (orange) or "never allowed" (red).
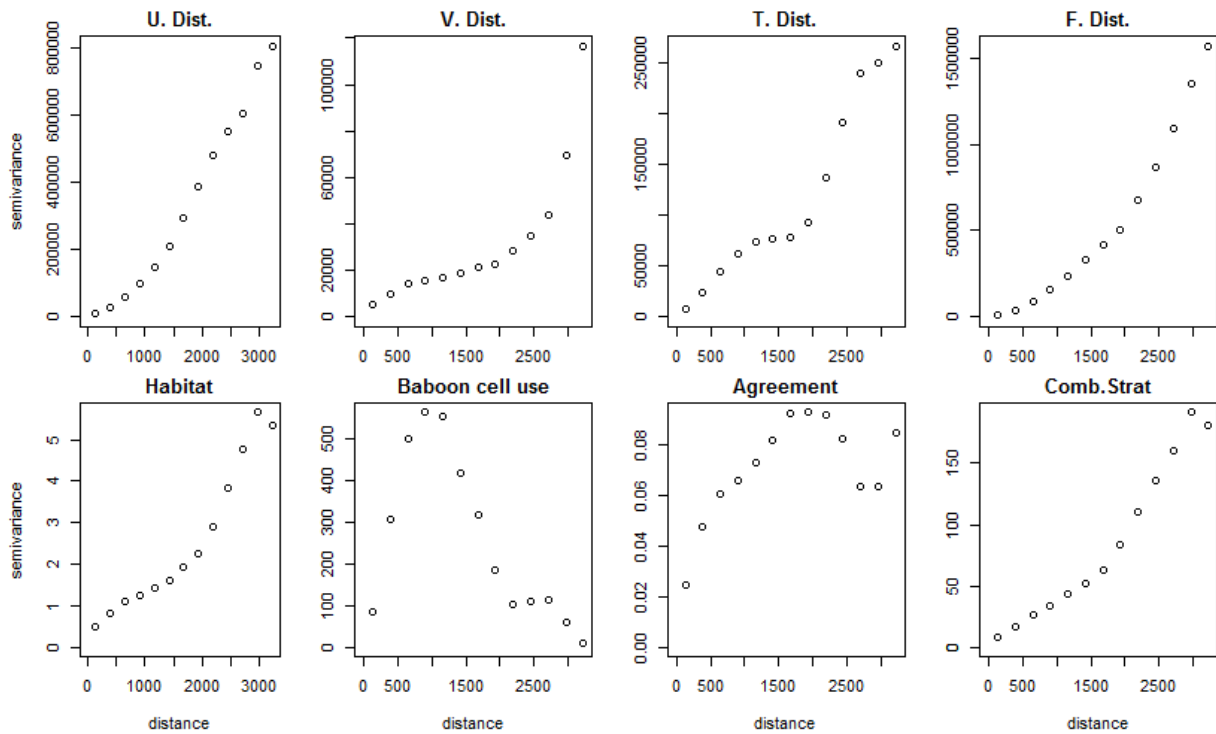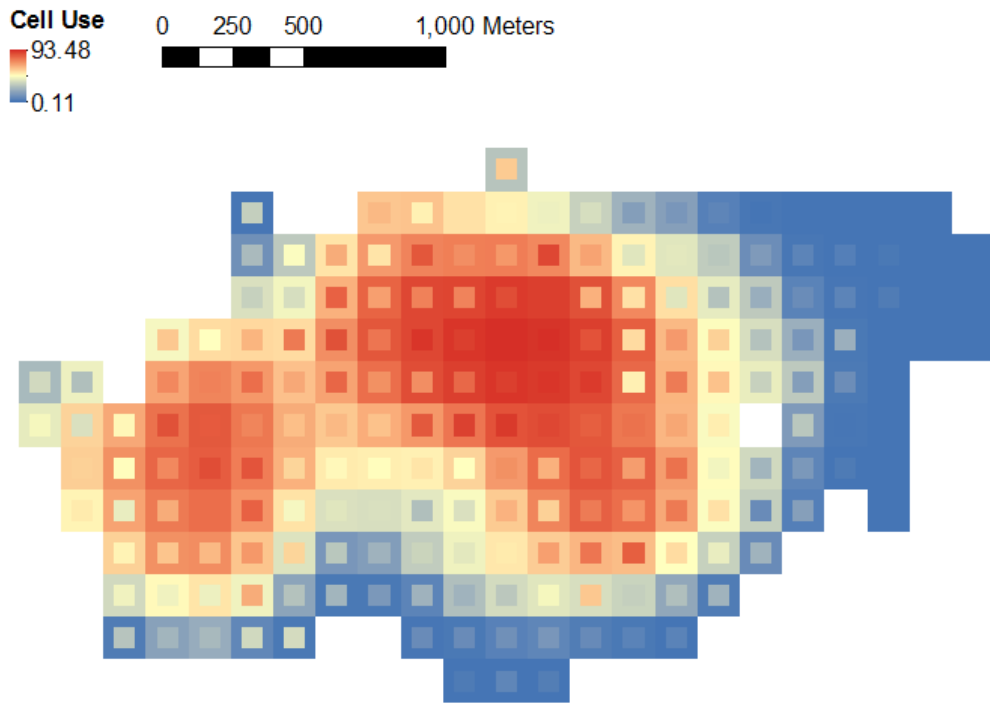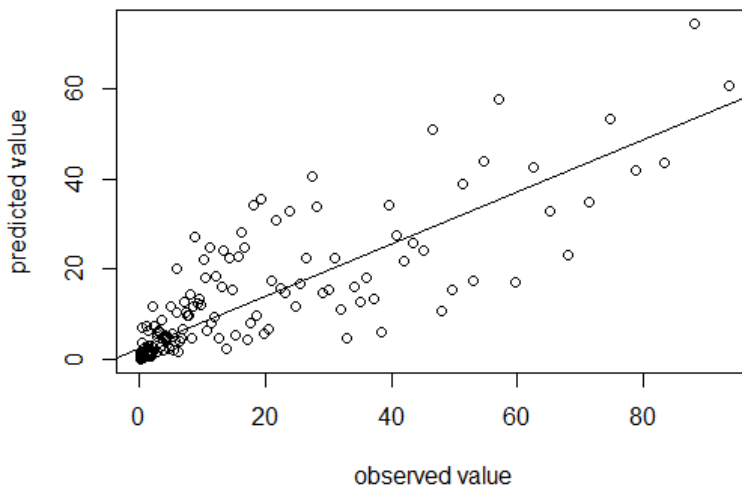
Fig. S2: Semivariogram for each factor studied: U. Dist, V. Dist, T. Dist, F. Dist being respectively Distance from urban areas, vineyards, trees and fynbos, and Comb. Strat. being combined rangers' strategy. Spatial autocorrelation exists as long as the variance between two points increases with the distance between them. As such, all fixed effects are spatially auto-correlated throughout the study area except for the agreement between rangers which are no longer spatially auto-correlated for points distant of more than 1500m.

Fig. S3: Observed against predicted baboon cell use. (a) Colour ranges from red for high cell use to blue for low cell use, with the inset square showing the predicted values following the same colour scheme. (b) Plot of observed versus predicted cell intensity across the study area.

Table S1: Correlation matrix (Spearman) of all fixed effects (U. Dist, V. Dist, T. Dist,

616 F. Dist being respectively Distance from urban areas, vineyards, trees and fynbos,

617 and Comb. Strat. referring to combined rangers' strategy) considered to explain

618 baboon space use. Fixed effects correlated with a coefficient greater than 0.5

619 (highlighted in grey) were not added in the same model.

	Habitat	U. Dist.	V. Dist.	T. Dist.	F. Dist.	Agreement	Comb. Strat.
Habitat	1						
U. Dist.	0.75	1					
V. Dist.	-0.37	0.11	1				
T. Dist.	0.49	-0.45	-0.2	1			
F. Dist.	-0.75	-0.81	-0.26	0.54	1		
Agreement	0.06	-0.23	0.64	0.23	0.11	1	
Comb. Strat.	-0.85	0.86	0.26	-0.59	-0.83	-0.18	1

620

621

622 **Table S2:** Results from Partial Mantel Tests (10000 permutations) for the rangers

623 strategy according to the environmental fixed effects. Results show the Mantel

624 statistic r and their significance, with the most highly correlated effects highlighted in

625 grey.

	Combined Strategy		Overall Agreement	
	r	p	r	p
Habitat	0.47	< 0.01	0.31	< 0.01
U. Dist	0.39	< 0.01	0.23	< 0.01
V. Dist	0.05	0.01	0.40	< 0.01
T. Dist	0.69	< 0.01	-0.02	0.88

626

627

628 **Table S3:** Spatial Simultaneous Auto-Regressive lag models (SAR lag) predicting

629 baboon space use; U. Dist, V. Dist, T. Dist, F. Dist being respectively Distance from

630 urban areas, vineyards, trees and fynbos, and Comb. Strat. being combined rangers'

631 strategy. The model selected according its AIC is highlighted in grey. Comparative

632 loglikelihood statistics are indicated for each model in comparison to the model

633 selected. Loglikelihood ratio (L.ratio) and its significance (p) are reported. The best

634 performing model (without the spatial components and residuals) was as follows:

635 $$I = \frac{e^{0.0003U - 0.0018T - 1.4187A}}{1 + e^{0.0003U - 0.0018T - 1.4187A}}$$

636 With I as the intensity of cell use by baboons

637 U as the distance from the urban area

638 T as the distance from the trees

639 And A as the level of agreement between rangers.

640

Model	df	AIC	logLik	L.ratio	p
Agreement + U. Dist + T. Dist.	6	596.90	-292.45		
Agreement + Habitat + T. Dist	6	625.24	-306.62		
V. Dist. + U. Dist. + T. Dist.	6	600.58	-294.29		
Agreement + U. Dist	5	627.58	-308.79	32.68	< 0.01
Agreement + T. Dist.	5	598.86	-294.43	3.97	0.05
Agreement + F. Dist	5	612.80	-301.40	17.90	< 0.01
Agreement + Habitat	5	625.74	-307.87	30.85	< 0.01
Comb. Strat. + Agreement	5	608.80	-299.38	13.87	< 0.01
Comb. Strat. + V. Dist	5	611.34	-300.67	16.44	< 0.01
U. Dist + T. Dist.	5	622.11	-306.05	27.21	< 0.01
V. Dist. + T. Dist.	5	607.70	-298.84	12.78	< 0.01
V. Dist. + F. Dist.	5	621.41	-305.70	26.51	< 0.01
Agreement	4	643.25	-317.62	50.35	< 0.01
Comb. Strat.	4	645.58	-318.79	52.69	< 0.01
U. Dist	4	658.87	-325.44	65.98	< 0.01
V. Dist.	4	664.52	-328.26	71.62	< 0.01
T. Dist.	4	621.14	-306.57	28.24	< 0.01
F. Dist	4	640.96	-316.48	48.06	< 0.01
Habitat	4	660.35	-326.18	67.46	< 0.01

641

642

643 **Table S4: Factors explaining baboons' space use.** The best model explaining the

644 intensity of cell use was estimated by a spatial Simultaneous Auto Regressive lag

645 model (SAR lag) taking into account the distance from trees and urban edges and

646 monitors agreement towards the strategy (AIC : 596.9). All factors are found

647 significant. The spatial component rho was 0.62913, (LR test value: 175.69, $p <$

648 0.001) and no spatial autocorrelation was found in the residuals (Moran I: 0.097, $p =$

649 0.133).

	Estimate	SE	*Z*	*p*
Agreement	-1.4187	0.269	-5.290	<0.001
Urban Distance	0.0003	0.000	1.988	0.047
Trees Distance	-0.0018	0.000	-5.738	<0.001
Intercept	-0.0939	0.199	-0.472	0.636

650