



Swansea University
Prifysgol Abertawe



Cronfa - Swansea University Open Access Repository

This is an author produced version of a paper published in :
Animal Conservation

Cronfa URL for this paper:
<http://cronfa.swan.ac.uk/Record/cronfa29216>

Paper:

Fehlmann, G., O'Riain, M., Kerr-Smith, C. & King, A. (2016). Adaptive space use by baboons (*Papio ursinus*) in response to management interventions in a human-changed landscape. *Animal Conservation*

<http://dx.doi.org/10.1111/acv.12293>

This article is brought to you by Swansea University. Any person downloading material is agreeing to abide by the terms of the repository licence. Authors are personally responsible for adhering to publisher restrictions or conditions. When uploading content they are required to comply with their publisher agreement and the SHERPA RoMEO database to judge whether or not it is copyright safe to add this version of the paper to this repository.

<http://www.swansea.ac.uk/iss/researchsupport/cronfa-support/>

1 **Adaptive space use by baboons (*Papio ursinus*) in**
2 **response to management interventions in a human-**
3 **changed landscape**

4
5 **Running title: Adaptive space use by baboons**

6
7 Gaele Fehlmann^{*a}, M. Justin O’Riain^b, Catherine Kerr-Smith^{a,3}, Andrew J. King^a

8
9 ^aDepartment of Biosciences, College of Science, Swansea University, Singleton
10 Park, Swansea, SA2 8PP, UK

11
12 ^bDepartment of Zoology, Univeristy of Cape Town, Rondebosch, 7701, South Africa

13
14 *Corresponding author:
15 Email address: 798266@swansea.ac.uk,
16 +44 1792 606991
17 Department of Biosciences,
18 College of Science,
19 Swansea University, Singleton Park,
20 Swansea, SA2 8PP, UK

21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42

³Present: Department of Security and Crime, University College London, Gower Street, London WC1E 6BT

43 **ABSTRACT**

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

65

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

68 1. INTRODUCTION

69

70 With the growth of the human population, transition zones between small protected
71 natural areas and human landscapes are eroding (Woodroffe & Ginsberg, 1998).
72 This often results in more frequent human-wildlife interactions (Creachbaum,
73 Johnson, & Schmidt, 1998; Gurung, Smith, McDougal, Karki, & Barlow, 2008; Seiler,
74 2005) which can have negative consequences for both people and wildlife and
75 manifest in chronic Human Wildlife Conflict (HWC) (Marker, Mills, & Macdonald,
76 2003; Nijman & Nekaris, 2010; Redpath et al., 2013; Takahata, Nielsen, Takii, &
77 Izumiyama, 2014). Raiding behaviour – where animals venture into human-changed
78 landscapes to exploit high energy food resources – is one of the most frequent
79 drivers of HWC, and its occurrence is dependent upon the relative costs and benefits
80 associated with raiding (Beamish & O’Riain, 2014; Fourie et al., 2015; Palmeira,
81 Craivshaw, Haddad, Ferraz, & Verdad, 2008; C. E. Webber, Sereivathana, Maltby, &
82 Lee, 2011). Where the benefits of acquiring resources in human-changed
83 landscapes outweigh potential costs, wildlife populations alter their home range to
84 increase their spatial overlap with human dominated landscapes to exploit these new
85 food sources (Barnagaud, Devictor, Jiguet, & Archaux, 2011; Sih, 2013).

86

87 Among raiding species, primates are exceptionally difficult to manage because of
88 their diverse modes of locomotion, dexterity and problem solving (Naughton Treves,
89 1998; Nijman & Nekaris, 2010). For instance, deterrents have to be regularly inter-
90 changed because of rapid habituation (Catherine M. Hill & Wallace, 2012) and
91 standard fences do not act as barriers because of climbing abilities (Hoffman &
92 O’Riain, 2010). Some of the most high-profile and severe cases of HWC involving

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 m² 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 ($\leq 10\text{m}$) 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 \pm 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 \pm 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

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 m² 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

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

242

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

258 **3. RESULTS**

259

260 **3.1. Baboon troop ranging and habitat type**

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

269 **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 ($\mu \pm \text{sd} = 0.5 \pm 0.8$, Fig. 2
272 and Fig. 3), while scores for fynbos were high ($\mu \pm \text{sd} = 20.9 \pm 2.3$, 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

287 **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. Cowlshaw, 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 Cowlshaw, 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, Ouge, & 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,

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, & Cowlshaw, 2011; King, Douglas, Huchard, Isaac, & Cowlshaw,
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, &
408 King, 2011; Strum, 2010).

409 **ACKNOWLEDGEMENTS**

410 We thank Cape Town Nature for authorisation to work with the Cape Peninsula
411 baboons. Thanks to Ines Fürtbauer, Adrian Luckman, Emily Shepard, the Swansea
412 Lab for Animal Movement (SLAM) and SHOAL (Sociality, Heterogeneity,
413 Organisation And Leadership) Group at Swansea University for their assistance in
414 this work, and Human Wildlife Solutions, the two farms and their employees in Cape
415 Town for their cooperation and help. This work was supported by a research grant
416 from Swansea University and G. F. was supported by a Swansea University PhD
417 Scholarship.

418

419 **CITED REFERENCES**

420 Barnagaud JY, Devictor V, Jiguet F, Archaux F. 2011. When species become
421 generalists: on going large scale changes in bird habitat specialization. *Global*
422 *Ecology and Biogeography* **20**:630–640.

423 Beamish EK, O’Riain MJ. 2014. The Effects of Permanent Injury on the Behavior and
424 Diet of Commensal Chacma Baboons (*Papio ursinus*) in the Cape Peninsula,
425 South Africa. *International Journal of Primatology* **35**:1004–1020.

426 Calenge C. 2006. The package “adehabitat” for the R software: a tool for the
427 analysis of space and habitat use by animals. *Ecological modelling* **197**:516–
428 519.

429 Cape Nature. 2012. Protocol and Standard Operational Procedure (SOP) for using
430 paintball markers as baboon deterrents within the Cape Peninsula. Available
431 from [www.capenature.co.za/wp-content/uploads/2013/11/Protocol-and-SOP-](http://www.capenature.co.za/wp-content/uploads/2013/11/Protocol-and-SOP-for-Using-Paintball-Markers.pdf)
432 [for-Using-Paintball-Markers.pdf](http://www.capenature.co.za/wp-content/uploads/2013/11/Protocol-and-SOP-for-Using-Paintball-Markers.pdf).

- 433 Cowlshaw G. 1994. Vulnerability To Predation in Baboon Populations. Behaviour
434 **131**:293–304.
- 435 Cowlshaw G. 1997. Trade-offs between foraging and predation risk determine
436 habitat use in a desert baboon population. Animal Behaviour **53**:667–686.
- 437 Creachbaum MS, Johnson C, Schmidt RH. 1998. Living on the edge : a process for
438 redesigning campgrounds in grizzly bear habitat. Landscape and urban
439 planning **42**:269–286.
- 440 Dall SRX, Giraldeau L-A, Olsson O, McNamara JM, Stephens DW. 2005.
441 Information and its use by animals in evolutionary ecology. Trends in Ecology
442 & Evolution **20**:187–193.
- 443 Foley JA et al. 2005. Global Consequences of Land Use. Science **309**:570–574.
- 444 Fourie NH, Turner TR, Brown JL, Pampush JD, Lorenz JG, Bernstein RM. 2015.
445 Variation in vervet (*Chlorocebus aethiops*) hair cortisol concentrations reflects
446 ecological disturbance by humans. Primates **56**:365–373.
- 447 Fraser DF, Huntingford FA. 1986. Feeding and Avoiding Predation Hazard: the
448 Behavioral Response of the Prey. Ethology **73**:56–68.
- 449 Gurung B, Smith JLD, McDougal C, Karki JB, Barlow A. 2008. Factors associated
450 with human-killing tigers in Chitwan National Park, Nepal. Biological
451 Conservation **141**:3069–3078.
- 452 Hamilton WJ. 1982. Baboon sleeping site preferences and relationships to primate
453 grouping patterns. American Journal of Primatology **3**:41–53.
- 454 Henzi S, Byrne R, Whiten A. 1992. Patterns of Movement by Baboons in the
455 Drakensberg Mountains - Primary Responses to the Environment.
456 International Journal of Primatology **13**:601–629.

457 Hill CM. 2000. Conflict of interest between people and baboons: Crop raiding in
458 Uganda. *International Journal of Primatology* **21**:299–315.

459 Hill CM, Wallace GE. 2012. Crop protection and conflict mitigation: reducing the
460 costs of living alongside non-human primates. *Biodiversity and Conservation*
461 **21**:2569–2587.

462 Hoffman TS, O’Riain MJ. 2010. The spatial ecology of chacma baboons (*Papio*
463 *ursinus*) in a human-modified environment. *International Journal of*
464 *Primatology* **32**:308–328.

465 Hoffman TS, O’Riain MJ. 2012a. Landscape requirements of a primate population in
466 a human-dominated environment. *Frontiers in Zoology* **9**:1.

467 Hoffman TS, O’Riain MJ. 2012b. Troop size and human-modified habitat affect the
468 ranging patterns of a chacma baboon population in the cape peninsula, South
469 Africa. *American journal of primatology* **74**:853–863.

470 Hsiao SS, Ross C, Hill CM, Wallace GE. 2013. Crop-raiding deterrents around
471 Budongo Forest Reserve: an evaluation through farmer actions and
472 perceptions. *Oryx* **47**:569–577.

473 Kaplan BS, O’Riain MJ, Eeden R van, King AJ. 2011. A Low-Cost Manipulation of
474 Food Resources Reduces Spatial Overlap Between Baboons (*Papio ursinus*)
475 and Humans in Conflict. *International Journal of Primatology* **32**:1397–1412.

476 King AJ, Clark FE, Cowlshaw G. 2011. The dining etiquette of desert baboons: the
477 roles of social bonds, kinship, and dominance in co-feeding networks.
478 *American journal of primatology* **73**:768–774.

479 King AJ, Douglas CMS, Huchard E, Isaac NJB, Cowlshaw G. 2008. Dominance and
480 affiliation mediate despotism in a social primate. *Current biology: CB*
481 **18**:1833–1838.

482 Krief S, Cibot M, Bortolamiol S, Seguya A, Krief J-M, Masi S. 2014. Wild
483 Chimpanzees on the Edge: Nocturnal Activities in Croplands. PLoS ONE
484 **9**:e109925.

485 Kubo T, Shoji Y. 2014. Spatial tradeoffs between residents' preferences for brown
486 bear conservation and the mitigation of human-bear conflicts. Biological
487 Conservation **176**:126–132.

488 Lima SL, Dill LM. 1990. Behavioral decisions made under the risk of predation: a
489 review and prospectus. Canadian Journal of Zoology **68**:619–640.

490 Marker LL, Mills MGL, Macdonald DW. 2003. Factors influencing perceptions of
491 conflict and tolerance toward cheetahs on Namibian farmlands. Conservation
492 Biology **17**:1290–1298.

493 Naughton Treves L. 1998. Predicting Patterns of Crop Damage by Wildlife around
494 Kibale National Park, Uganda. Conservation biology **12**:156–168.

495 Nijman V, Nekaris KA-I. 2010. Testing a model for predicting primate crop-raiding
496 using crop- and farm-specific risk values. Applied Animal Behaviour Science
497 **127**:125–129.

498 Ogada MO, Woodroffe R, Oguge NO, Frank LG. 2003. Limiting Depredation by
499 African Carnivores: the Role of Livestock Husbandry. Conservation Biology
500 **17**:1521–1530.

501 Palmeira FBL, Craivshaw PG, Haddad CM, Ferraz KMPMB, Verdad LM. 2008.
502 Cattle depredation by puma (*Puma concolor*) and jaguar (*Panthera onca*) in
503 central-western Brazil. Biological Conservation **141**:118–125.

504 Ramesh T, Kalle R, Downs CT. 2016. Predictors of mammal species richness in
505 KwaZulu-Natal, South Africa. Ecological Indicators **60**:385–393.

506 Redpath SM et al. 2013. Understanding and managing conservation conflicts.
507 Trends in Ecology & Evolution **28**:100–109.

508 Richardson P. 2012. Baboon Management Monthly Report. Available from
509 www.capetown.gov.za/en/EnvironmentalResourceManagement/publications/
510 [Documents/Baboon-Management-monthly-report-HWS-Sep_2012-09.pdf](http://www.capetown.gov.za/en/EnvironmentalResourceManagement/publications/Documents/Baboon-Management-monthly-report-HWS-Sep_2012-09.pdf).

511 Richardson P. 2014. HWS Monthly Report. Available from
512 www.capenature.co.za/wp-content/uploads/2013/11/Baboon-Management-
513 [June-2014-HWS-Report.pdf](http://www.capenature.co.za/wp-content/uploads/2013/11/Baboon-Management-June-2014-HWS-Report.pdf).

514 Seiler A. 2005. Predicting locations of moose–vehicle collisions in Sweden. Journal
515 of Applied Ecology **42**:371–382.

516 Sih A. 2013. Understanding variation in behavioural responses to human-induced
517 rapid environmental change: a conceptual overview. Animal Behaviour
518 **85**:1077–1088.

519 Simpson EH. 1949. Measurement of diversity. Nature **163**:688–688.

520 Sitati NW, Walpole MJ. 2006. Assessing farm-based measures for mitigating human-
521 elephant conflict in Transmara District, Kenya. Oryx **40**:279–286.

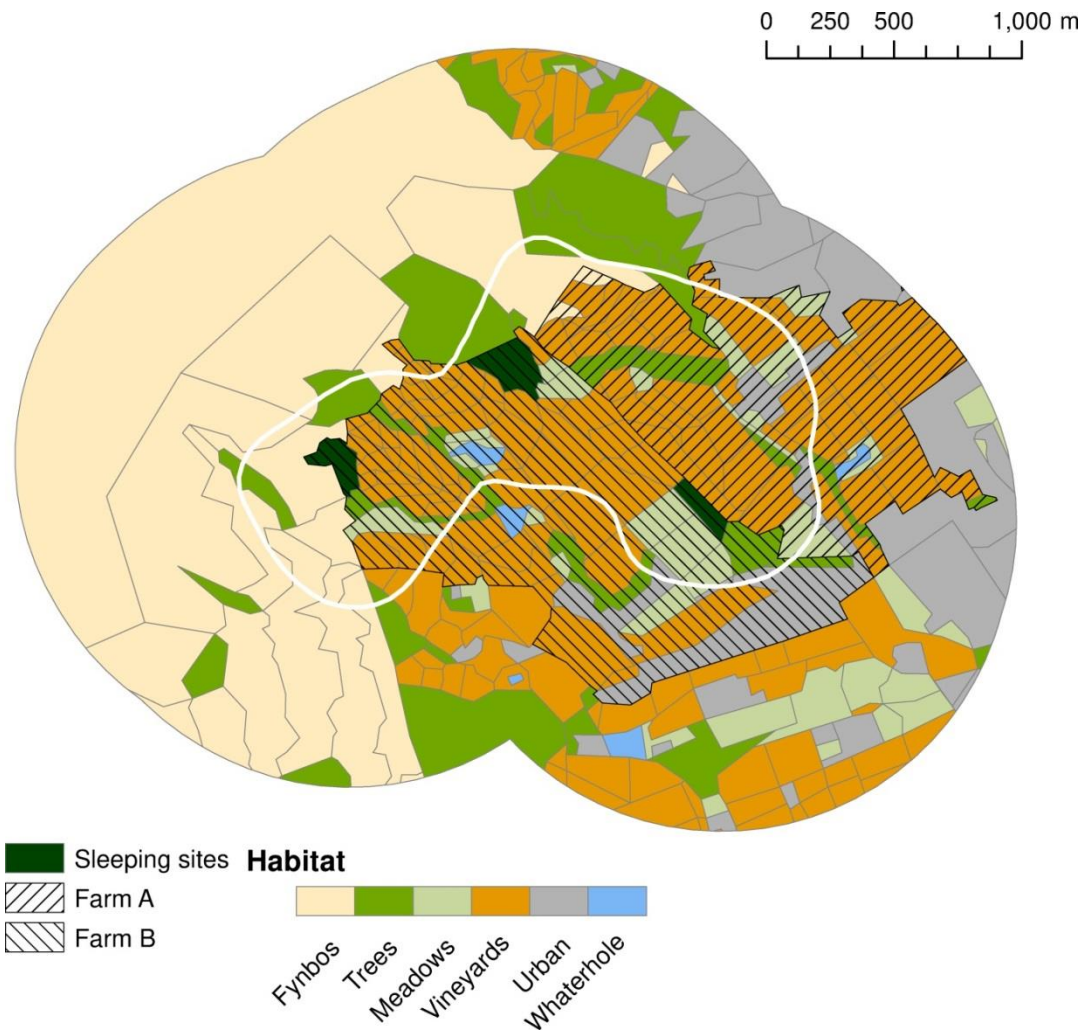
522 Snell-Rood EC. 2013. An overview of the evolutionary causes and consequences of
523 behavioural plasticity. Animal Behaviour **85**:1004–1011.

524 Sol D, Lapiedra O, González-Lagos C. 2013. Behavioural adjustments for a life in
525 the city. Animal Behaviour **85**:1101–1112.

526 Strum SC. 2010. The Development of Primate Raiding: Implications for Management
527 and Conservation. International Journal of Primatology **31**:133–156.

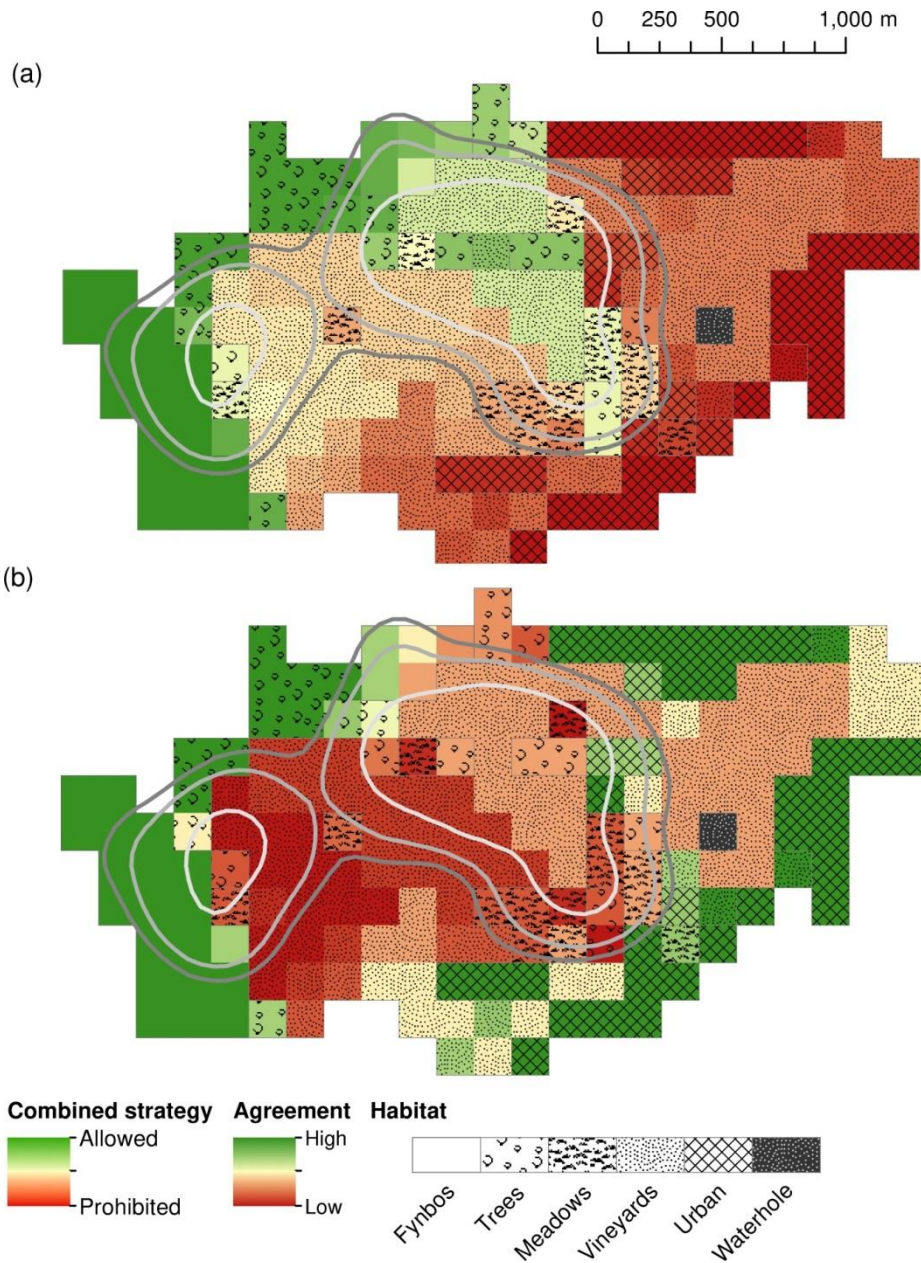
528 Takahata C, Nielsen SE, Takii A, Izumiyama S. 2014. Habitat Selection of a Large
529 Carnivore along Human-Wildlife Boundaries in a Highly Modified Landscape.
530 PLoS ONE **9**:e86181.

- 531 Taylor RA, Ryan SJ, Brashares JS, Johnson LR. 2016. Hunting, food subsidies, and
532 mesopredator release: the dynamics of crop-raiding baboons in a managed
533 landscape. *Ecology* **97**:951–960.
- 534 van Doorn A. 2009. The interface between socioecology and management of
535 chacma baboons (*Papio ursinus*) in the Cape Peninsula. South Africa:
536 University of Cape Town.
- 537 van Doorn A c., O’Riain M j., Swedell L. 2010. The effects of extreme seasonality of
538 climate and day length on the activity budget and diet of semi-commensal
539 chacma baboons (*Papio ursinus*) in the Cape Peninsula of South Africa.
540 *American Journal of Primatology* **72**:104–112.
- 541 Vitousek PM, Mooney HA, Lubchenco J, Melillo JM. 1997. Human Domination of
542 Earth’s Ecosystems. *Science* **277**:494–499.
- 543 Warren Y. 2009. Crop-raiding Baboons (*Papio anubis*) and Defensive Farmers: A
544 West African perspective. *West African J. Appl. Ecol.***14**:1–11.
- 545 Webber AD, Hill CM. 2014. Using Participatory Risk Mapping (PRM) to Identify and
546 Understand People’s Perceptions of Crop Loss to Animals in Uganda. *PLoS*
547 *ONE* **9**:e102912.
- 548 Webber CE, Sereivathana T, Maltby MP, Lee PC. 2011. Elephant crop-raiding and
549 human-elephant conflict in Cambodia: Crop selection and seasonal timings of
550 raids. *ORYX* **45**:243–251.
- 551 Woodroffe R, Ginsberg JR. 1998. Edge effects and the extinction of populations
552 inside protected areas. *Science* **280**:2126–2128.
- 553 Worton BJ. 1989. Kernel Methods for Estimating the Utilization Distribution in Home-
554 Range Studies. *Ecology* **70**:164–168.
- 555 Yeo J-H, Neo H. 2010. Monkey business: human-animal conflicts in urban
556 Singapore. *Social & Cultural Geography* **11**:681–699.
557



559

560 **Fig. 1:** Study area (-34.0349, 18.4156) showing the baboon troop home range (solid
 561 white line) estimated by a 95% kernel density, major habitat types, and location of
 562 baboon sleeping areas used over the study period.



563

564 **Fig. 2:** Management strategies and baboon space use. A map of study area divided

565 up into 150m x 150m grid cells. Baboon home range, defined by kernel densities are

566 represented by the contour lines from light to dark grey that represent 70%, 90%

567 95% contours respectively in both (a) and (b). (a) Overall field ranger strategy with

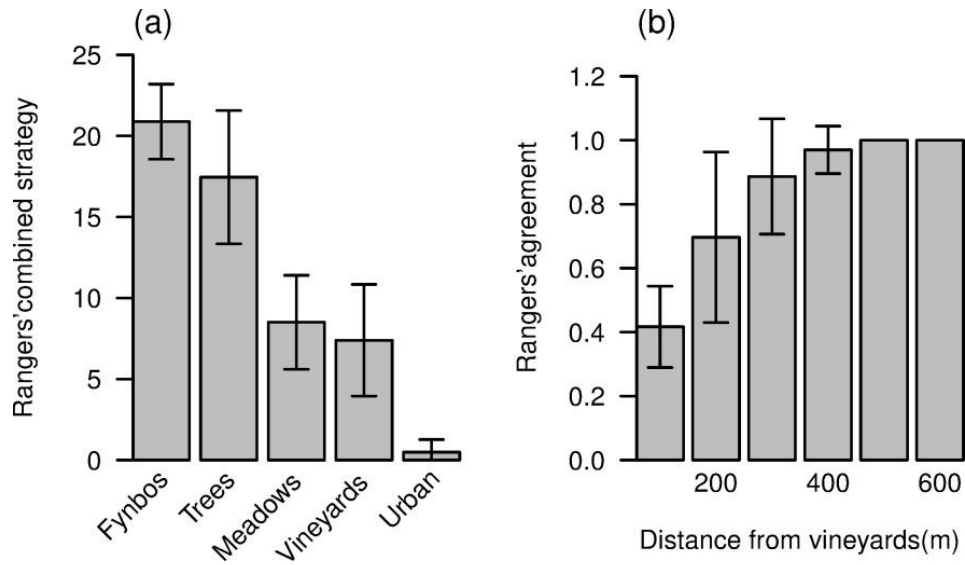
568 cells coloured according to whether baboons were 'allowed' or 'prohibited' based on

569 field ranger interviews. (b) Overall ranger agreement across the 11 individuals

570 interviewed, with cells coloured according to the level of field ranger agreement; from

571 'low agreement' to 'full agreement'.

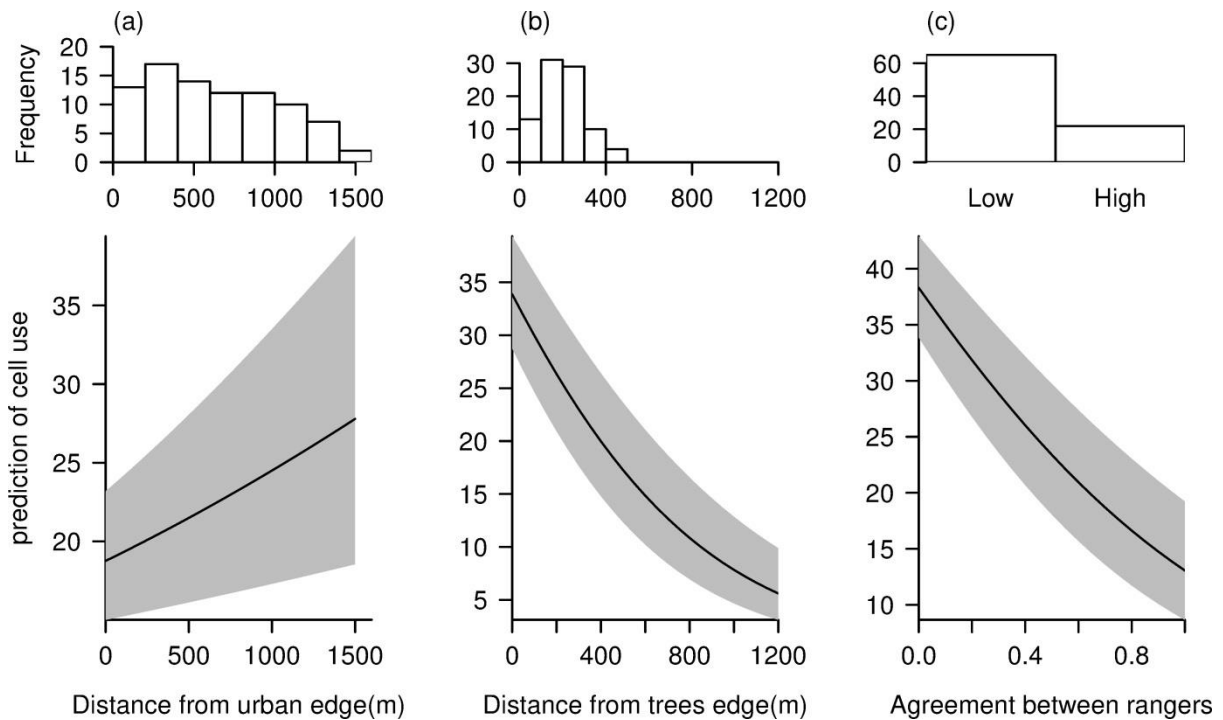
572



573

574 **Fig. 3:** Field ranger's combined strategy according to habitat type and distance to
575 vineyards. (a) The mean \pm 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 \pm 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, $R=0.401$, $p<0.001$).

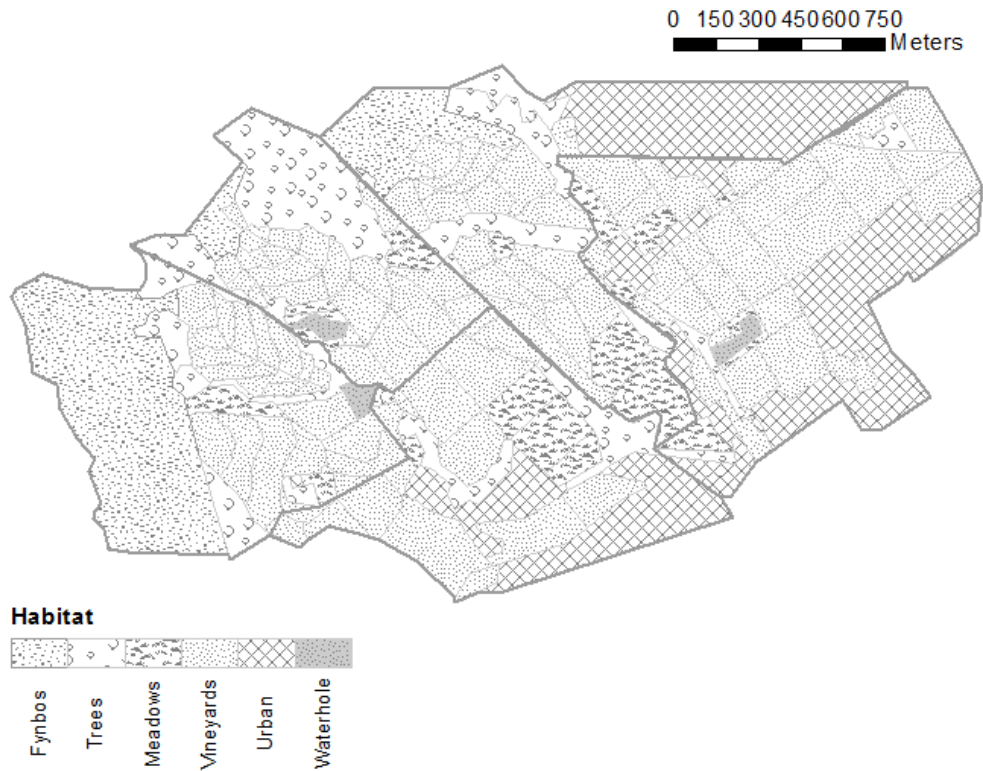
581



582 Distance from urban edge(m) Distance from trees edge(m) Agreement between rangers

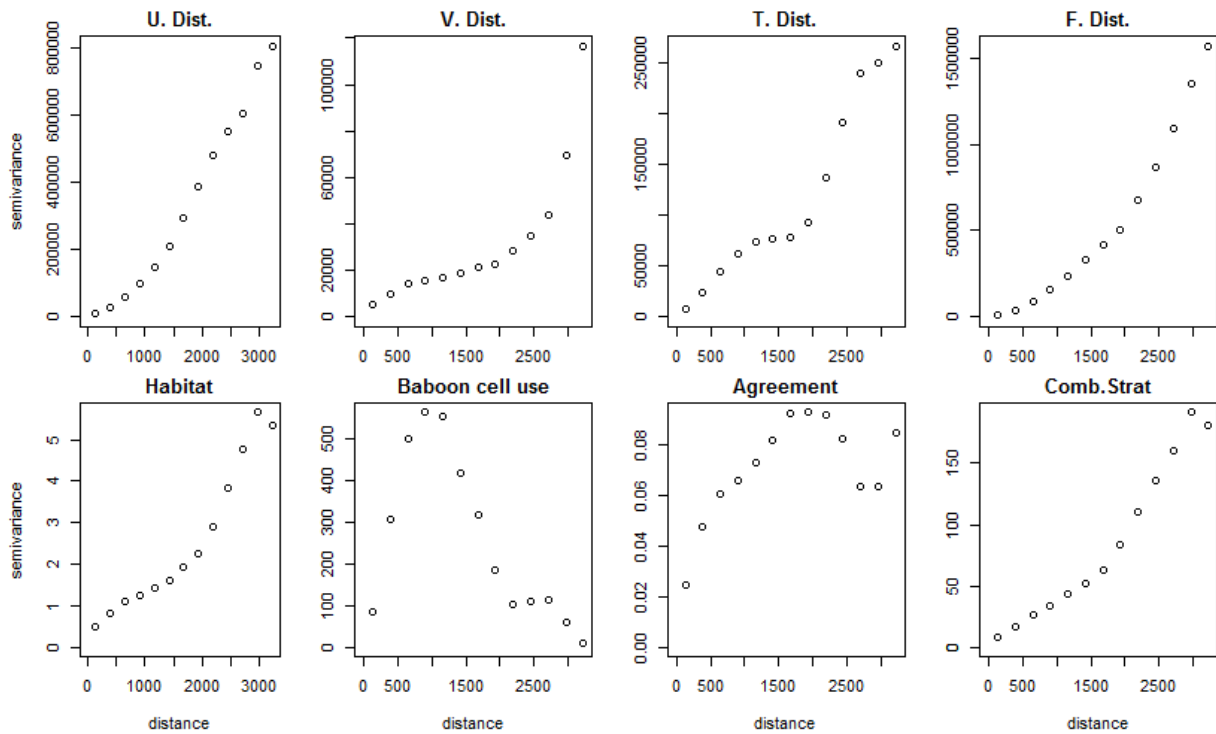
583 **Fig. 4:** Predictors of baboon space use. The frequency of cells in the home range
 584 (95% kernel density) (histograms; upper row), and estimated values of the intensity
 585 of baboon grid cell use with their standard errors (grey area) (lower row) as a
 586 function of (a) distance from the 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.

592



594

595 **Fig. S1:** A map of the study site, subdivided by habitat type areas boundaries (solid
596 lines), that was presented to the field rangers during interviews. Each ranger was
597 asked to colour the map (however they wanted) according to whether the baboons
598 were “allowed at any time” (green), “allowed some of the time” (orange) or “never
599 allowed” (red).

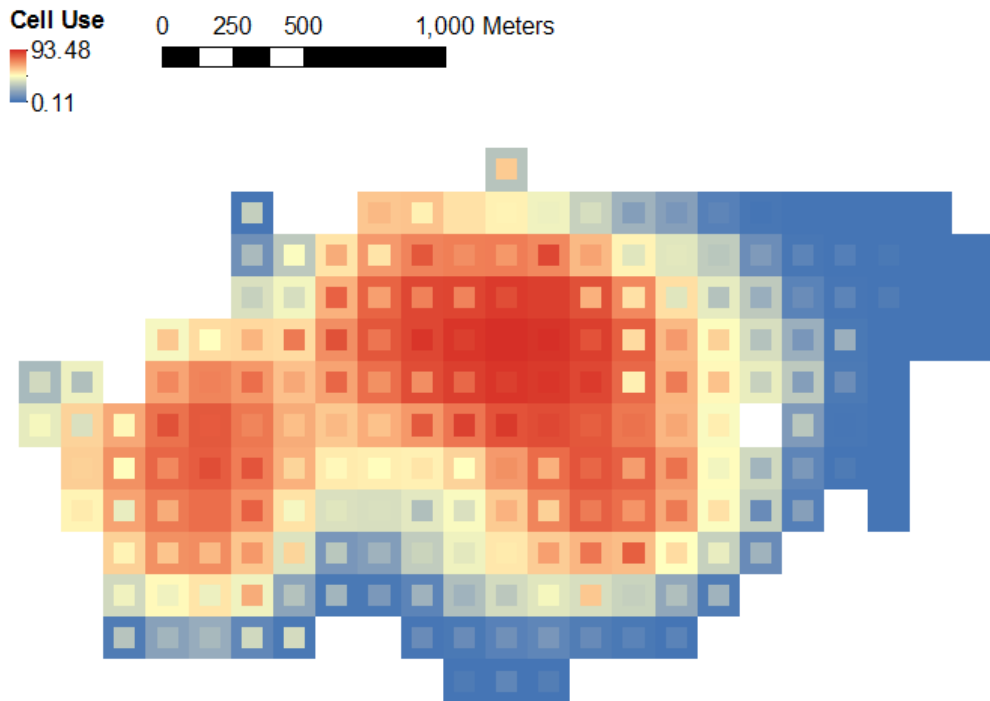


600

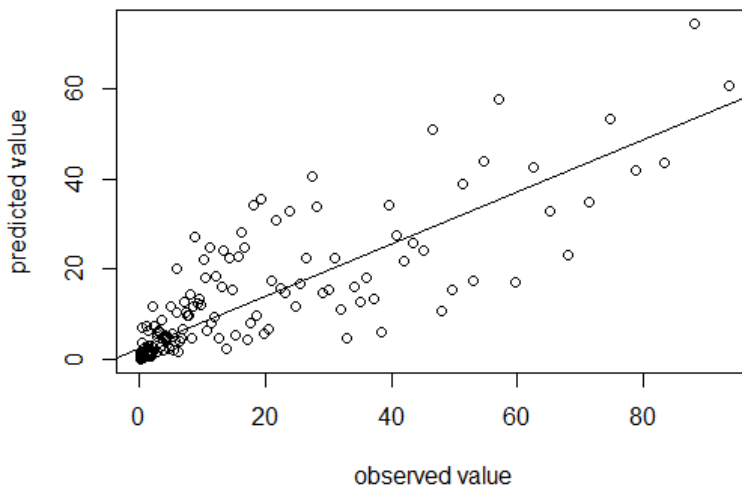
601 **Fig. S2:** Semivariogram for each factor studied: U. Dist, V. Dist, T. Dist, F. Dist being
 602 respectively Distance from urban areas, vineyards, trees and fynbos, and Comb.
 603 Strat. being combined rangers' strategy. Spatial autocorrelation exists as long as the
 604 variance between two points increases with the distance between them. As such, all
 605 fixed effects are spatially auto-correlated throughout the study area except for the
 606 agreement between rangers which are no longer spatially auto-correlated for points
 607 distant of more than 1500m.

608

a.



b.



609

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

614

615 **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	
620 Comb. Strat.	-0.85	0.86	0.26	-0.59	-0.83	-0.18	1

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
626 T. Dist	0.69	< 0.01	-0.02	0.88

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:

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

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