

1 **The value of by-catch data: how species specific surveys can serve non-target species**

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25 **Abstract**

26 Camera trapping has a wide range of research application but, while research designs are often focused on the
27 study of a single focal species, cameras can also record other non-target species. Occupancy modelling using by-
28 catch data can be a valuable resource to gain information on these species maximizing the scientific effort and
29 efficiency of wildlife surveys. In this study we used by-catch data from a European wildcat (*Felis sylvestris*
30 *sylvestris*) survey in Southern Italy to assess the habitat covariates determinant for the occupancy of the crested
31 porcupine (*Hystrix cristata*). We recorded 33 detections at 17 out of 51 cameras (naïve occupancy = 0.33). The
32 best models fitted the data well and porcupine occupancy estimate was 0.58 (SE \pm 0.09) with a detection
33 probability of 0.11 (SE \pm 0.03). Average model showed that woodlands and number of shrub patches increased
34 porcupine occupancy, while the reverse was true for altitude. Our results have improved the insights on the
35 habitat use and ecological needs of this understudied species and it is the first study that develops occupancy
36 models for the porcupine using presence/absence data obtained from a camera trap survey. Our study is an
37 example of how camera trap surveys are often an under-exploited source of valuable information on a wider
38 spectrum of sympatric species beyond the focal species for which camera traps were deployed. Minimum
39 requirements for a camera trap survey to provide robust occupancy estimates for non-target species are
40 discussed.

41

42 **Keywords:** camera trapping; crested porcupine; habitat use; Mt. Etna; occupancy

43

44 **Introduction**

45 Scientific sound data on species presence, abundance, distribution and habitat use is the basis for effective
46 conservation and management actions. To gain this data in the last years camera trapping has almost
47 exponentially increased its use (Rovero and Zimmermann 2016) in the study of large to small mammals (e.g.
48 O'Brien 2008; Glen et al. 2013), birds (e.g. Dinata et al. 2008) and reptiles (e.g. Welbourne et al. 2015). Camera
49 trapping has a wide range of research application and the majority of the studies involving camera traps aims to
50 assess species detection and inventories, species occupancy and density estimation (O'Connell et al. 2010;
51 Rovero et al. 2013). Nevertheless, while research designs are often focused on the study of a single focal species
52 (or a set of similar species) cameras can record also other non-target species generating the so called "by-catch
53 data" (Pamplin 2013; Burton et al. 2015; Anile and Devillard 2016). Edwards et al. (2018) demonstrated how it
54 is possible to obtain important ecological information using data coming from camera traps deployed for another
55 focal species. The use of by-catch data do not only maximize the scientific outcome, but can also increase the
56 return on investment of the surveys (Pamplin 2013).

57 By-catch in the form of presence/absence data can be analyzed through occupancy modelling (O'Connell et al.
58 2010; MacKenzie et al. 2017), a robust statistical framework for testing numerous hypotheses (e.g. Rovero et al.
59 2014; Ferregueti et al. 2018). Occupancy is defined as the proportion of area, patches or sample units (i.e.
60 camera trap sites) occupied by a species, estimated whilst accounting for imperfect detection (MacKenzie et al.
61 2017).

62 In this study we used data collected from a camera trap survey focused on the European wildcat (*Felis silvestris*)
63 on Mt. Etna (Sicily- Italy), the highest active volcano in Europe and a recently declared UNESCO site. The
64 wildcat survey had the goal to identify ecological drivers and human induced determinants to estimate wildcat
65 detection and occupancy (Anile et al. 2019), but we used by-catch data to identify the ecological features of
66 detection and occupancy of the biggest Italian rodent, the crested porcupine (*Hystrix cristata*). The porcupine is
67 mainly an elusive nocturnal animal whose direct observations are rare, hence the use of camera traps is
68 particularly suited to study its ecology. Its diet consists in underground plant storage organs and roots, as well as
69 plant epigeal parts and fruits according to their seasonal availability (Bruno and Riccardi 1995; Mori et al. 2017).
70 The porcupine has very few natural predators in Italy, since its remains have been found just in the feces of red
71 foxes *Vulpes vulpes* (Lucherini et al. 1995) and, rarely, of wolves *Canis lupus* (Scandura et al. unpublished data).
72 However, human related activities as hunting with dogs and the presence of feral pigs can affect the porcupine
73 activity (Mori et al. 2014b; Mori 2017). In Europe the species is only present in Italy throughout the peninsula,
74 in Sicily and recently introduced in Sardinia, but historical and archaeological evidence point out to an initial

75 introduction of the crested porcupine in Italy in the Late Antique/early medieval period, or even in the early
76 modern times in Sicily (Masseti et al. 2010). The crested porcupine is protected under the Berne Convention
77 (Annex II) and the Habitat Directive (Annex IV) in Europe, and among the protected species within the National
78 Law 157/ 1992 in Italy. Despite this legal protection, the species is still widely poached because of its meat and
79 the supposed damage caused to the crops (Laurenzi et al. 2016; Mori et al. 2017; but see Lovari et al. 2017). The
80 crested porcupine space and habitat use has been investigated in low elevation Mediterranean habitat and
81 suburban areas in central Italy characterized by agricultural and woodland patches (Lovari et al. 2013, 2017;
82 Mori et al. 2014a), but less is known about its habitat preferences and behavior in high altitude natural
83 environments. Moreover, to the best of our knowledge, no scientific studies have explored the habitat use of this
84 species in Sicily, the largest Italian region. In this study we aim to demonstrated the possibility of using by-catch
85 data to obtain reliable scientific information on other sympatric species. We will identify which factors influence
86 the spatial distribution of the crested porcupine and assess the suitability of the habitat in the Etna Regional Park.
87 The crested porcupine may play an important role in the preservation of the peculiar ecosystem on the volcano
88 since it is the biggest seed disperser with dwelling habits (Bruno and Riccardi 1995; Monetti et al. 2005; Mori et
89 al. 2017). Therefore, identifying the crested porcupine habitat preferences could lead to actions aimed at the
90 preservation of the species in the Park. Based on what is known on the ecology of the crested porcupine in
91 Mediterranean habitats, we predict that (1) woodlands and shrublands will promote the species occupancy
92 because of food availability and suitable areas for denning; (2) habitat richness will positively affect the
93 occupancy while (3) the altitude negatively. Moreover, we expect that (4) the presence of feral pigs will
94 negatively affect the crested porcupine detectability and/or occupancy. Finally, we will develop a porcupine
95 occupancy model for the entire Etna Regional Park to elucidate the crested porcupine potential distribution.

96

97 **Materials and Methods**

98 **Study area**

99 The Etna Regional Park (~590 km²) covers the slopes of the biggest active European volcano, Mt. Etna. With an
100 altitude range from 550 up to ~3360 m a.s.l., the Park is divided into four main management units (zone A, B, C,
101 D) according to different level of protection. Our cameras were deployed within zone A and B; the “Integral
102 reserve”- zone A is subject to more constraints in order to ensure maximum protection of plants and animal
103 species and vehicle access is subject to permission and restricted to unpaved roads used for forest management,
104 sheep farming and tourism. The “General reserve”- zone B is where educational activities and regular excursions
105 are permitted. The most remote areas (zone A) of Mt. Etna have been declared a world heritage site by UNESCO
106 in 2013.

107 The landscape is characterized by recent large lava flows and inactive secondary cones of different ages,
108 intermixed with areas dominated by trees (Corsican pine *Pinus laricio*, different species of oak *Quercus*
109 *pubescens*, *Quercus ilex*, chestnut *Castanea sativa*, aspen *Populus tremulus*, European beech *Fagus sylvatica*
110 and Mt. Etna broom *Genista aetnensis*). Forest cover usually lies between 1000 – 2000 m a.s.l. and areas at
111 higher altitude are characterized by low shrub vegetation. The most widespread habitat within the forest cover
112 range consists of large woodland patches intermingled with relatively small open fields, sometimes surrounded
113 or interrupted by lava flows of variable extensions (Fig. 1).

114 The climate is typically Mediterranean at the lower altitudes with warm springs and hot dry summers. Rainfall is
115 concentrated during autumn and winter with a yearly mean of 1000 – 1400 mm. Snow cover is common in
116 winter and usually abundant at higher altitudes.

117

118 **Camera trap survey**

119 Cameras were initially set up to study the European wildcat in the area. We deployed camera traps along 4 arrays
120 on the north side of the Park: one array of 15 cameras and one of 12 active between September and December
121 2015 and two arrays of 12 cameras active between April and June 2016. Within each array, cameras were
122 randomly placed along unpaved road and trails, resulting in a spacing of 731 ± 200 m (mean \pm SD; range 300 –
123 1114) between adjacent cameras, and at a mean elevation of 1328 ± 163 m a.s.l. (mean \pm SD; range = 1108-
124 1750). We used 15 digital cameras DFV® equipped with Sony®DSC-W55 (built-in flash Auto ISO: W: 0.2-
125 3.9m; T: 0.3-2.0m) (Fototrappolaggio S.r.l., Forlì, Italy). Each camera was accommodated in an iron box, locked
126 with a padlock and tied to a tree with a chain at 50 ± 10 cm from the ground. Cameras had a 0.4 s trigger speed

127 and we set them with a delay time of 10 min between successive bursts ($n = 3$) of photos. No lure or bait was
128 used. Cameras were checked twice per week for camera functioning, batteries and data download.

129

130 **Covariates**

131 Spatial analysis of habitat covariates were performed using the software QGIS v 3.4.5 (QGIS Development
132 Team 2019) and its plugins. We expected the detection probability (p) to be influenced by the covariates
133 reported in Table 1. The covariate “season” was classified as “cold” for September-December and “warm” for
134 April-June (Mori et al. 2014a) as we expected that the porcupine activity may vary between the above periods.
135 The covariate *feral_pig* refers to the number of pig detections per camera and we did not calculate the RAI
136 (Relative Abundance Index; O’Connell et al. 2010) for this metric as the mean number of functional days per
137 camera was fairly constant ($38.9 \pm SD 5.2$; range = 20 – 44). Ecological covariates to model the porcupine
138 occupancy (ψ) (Table 1) were created from the land map “Nature map of the Sicilian region” at the scale of
139 1:50.000 created in 2008 with a resolution of 1 ha. Map accuracy was screened through extensive field-ground
140 verifications. For each camera we created a circular buffer of 793 m radius (197.99 ha) corresponding to the
141 mean home range size of the porcupine in a Mediterranean habitat (Lovari et al. 2013; Mori et al. 2014a). The
142 map included 41 different layers which we then merged into main habitat classes (Online Resource 1):
143 woodlands, shrublands and meadows (91% of the area of all camera buffers). The selection of these classes was
144 made in accordance to the porcupine ecology (Lovari et al. 2013, 2017; Mori et al. 2014a); other habitat classes
145 (e.g. farmland and anthropized areas) were not considered because not relevant for the species or not
146 present/under-represented in the buffers’ area. For each camera buffer we extracted the following variables: (1)
147 the area of each habitat class; (2) the number of the habitat classes as a proxy of habitat structure complexity; (3)
148 the total number of patches per habitat as a proxy of fragmentation for a given habitat class; (4) the number of all
149 patches as a proxy of overall habitat fragmentation (Table 1). To avoid multicollinearity, Pearson’s correlation
150 coefficient was used to test for non-independence between covariate pairs. Covariate pairs with ($r > |0.70|$) were
151 considered highly correlated, hence only one covariate of the pair was included within our occupancy models.
152 Before estimating the model coefficients, covariates were standardized to have mean 0 and unit variance by
153 subtracting the covariate mean from each site value and then dividing the difference by the covariate standard
154 deviation.

155 **Occupancy modeling**

156 Data were arranged in a detection matrix where each entry indicated if the porcupine was detected (score=1) or
157 not (score=0) at the site during that occasion, in addition with an occasion matrix reporting if the camera was

158 active (score=1) or missing data because of malfunction (score=0) (R package *camtrapR*, Niedballa et al. 2016).
159 The detection matrix had a resolution of 8 days to minimize the risk of non-independent detections at each site.
160 Although our survey was split into two non-consecutive periods, we used a single-season occupancy model as
161 adult porcupines are mostly territorial with minimal home range overlap, therefore shifts in individual territories
162 between seasons can be consider minimal (Mori et al. 2014a) and hence changes in occupancy between these
163 two periods were assumed negligible. Based on the above considerations, we then run a single-species single-
164 season occupancy analysis using the R package *unmarked* (Fiske and Chandler 2011).
165 A two step approach was used to identify the most parsimonious occupancy models ($\Delta AIC < 2$) (MacKenzie et
166 al. 2017). We first tested the effects of the covariates on the detection probability (p), whilst keeping the
167 occupancy process (ψ) constant and over parameterized (all relevant habitat classes included as occupancy
168 predictors, e.g. Strampelli et al. 2018). Covariates were tested both individually and in combination with the null
169 model ($p(\cdot)$), for a total of other 11 possible combinations investigated based on plausible ecological hypotheses
170 (Table 2). In the second step, the best models for the detection probability were combined with a total of 28
171 occupancy models (Online Resource 2) which reflected *a priori* plausible ecological hypothesis about the
172 porcupine occupancy in the study area. Potentially occupancy processes were limited to a maximum of 3
173 additive terms. All models with convergence issues were discarded. We used the Akaike Information Criterion
174 (AIC) to rank candidate models and calculate their Akaike weights (Burnham and Anderson 2004). Goodness of
175 fit for the best models was checked with the function *mb.gof.test* (500 replicates) within the R package
176 *AICcmodavg* (Mazerolle 2016) to test for overdispersion. The relative importance of covariates (\mathcal{EAIC}_w) was
177 calculated for each covariate included in those models within the cumulative AIC weight of 0.95.
178 Finally, we mapped occupancy probability across Mt. Etna by deriving occupancy estimates from covariates
179 computed on a spatial grid (n cells= 420) with a cell size of 1407 m (1.98 km²) in accordance to the mean home-
180 range for a porcupine in a Mediterranean habitat (Lovari et al. 2013; Mori et al. 2014a). Elevation data was
181 downloaded as GMTED (<<https://earthexplorer.usgs.gov>>) and the mean elevation value for each grid cell was
182 extracted.
183

184 Results

185 The 51 camera traps set accumulated 1984 camera trap days with 58 events of porcupine recorded. One camera
186 recorded 28 events of porcupine, so to remove the effect of this outlier we kept only 5 events (maximum number
187 of porcupine detections among the remaining cameras) from this camera, hence reducing the events to 33
188 independent porcupine detections from 17 camera traps (naïve occupancy= 0.33). Collinearity was detected for
189 the following pair of covariates: *shrubs* and *Np_shrubs* ($r = 0.7$), *shrubs* and *woods* ($r = -0.8$), *Np_woods* and
190 *Np_tot* ($r = 0.9$) which therefore were independently included in our models. The detection process selection
191 resulted in 3 top-ranking models (Table 2) which were then combined with the 28 *a priori* occupancy models,
192 for a total of 84 models tested. Seventy five models were discarded due to lack of convergence and weighted
193 model-averaging was used on the two top-ranking models (Table 3) to derive parameter estimates: porcupine
194 occupancy estimate and detection probability were 0.58 (SE \pm 0.09), and 0.11 (SE \pm 0.03) respectively.
195 Detectability was negatively affected, even if not significantly ($p > 0.05$), only by one covariate, *feral_pig*, hence
196 detectability decreased in sites with higher number of feral pig detections (Table 4; Fig. 2). We recorded feral
197 pigs on 26 sites all part of the two camera arrays active September- December 2015; those cameras collected on
198 average $17.54 \pm$ SD 26.50 feral pig photos with $1.51 \pm$ SD 1.19 individuals per photo.

199 The two top-ranking models didn't show overdispersion (first model Table 3: $\chi^2 = 92.35$, $p = 0.38$, $\hat{c} = 0.98$;
200 second model Table 3: $\chi^2 = 95.13$, $p = 0.31$, $\hat{c} = 0.97$). Occupancy was affected by 3 covariates: 1) the area of
201 woodlands (*woods*), which had a positive effect, in which porcupine occupancy significantly increased in larger
202 wooded areas; 2) number of patches of shrublands (*Np_shrubs*), which had a positive relationship (though p was
203 slightly above the 0.05 significance level) in which occupancy increased with a higher number of patches of
204 shrub vegetation; and 3) altitude (*elevation*) which predicted a negative relationship with occupancy ($p > 0.05$)
205 (Table 4; Fig 2).

206 Spatially explicit predictions of porcupine occupancy for Mt. Etna (Fig. 3) showed that the distribution of cells
207 with high predicted porcupine occupancy was widespread along the slopes of the volcano, with the majority of
208 suitable cells located on the northern slope.

209

210

211 **Discussion**

212 In this study we demonstrated the possibility of using data collected during a target species survey to obtain
213 reliable scientific information on other sympatric species. In particular, even though the survey which generated
214 our by-catch data was designed for the European wildcat, we were also able to study the occupancy and the
215 detection probability of the crested porcupine, a different species in terms of ecological needs. However, this
216 study was possible thanks to some survey characteristics suitable for both species. The wildcat and the porcupine
217 have similar size and both move along trails (Mori 2017; Anile et al. 2019), hence camera trap displacement was
218 appropriate to study both species and cameras were equally triggered. Moreover, the site spacing suited both the
219 wildcat and the porcupine since the minimum home range for a wildcat in a Mediterranean habitat (Monterroso
220 et al. 2009; Anile et al. 2018) is about the size of the average porcupine home range (Lovari et al. 2013; Mori et
221 al. 2014a). Finally, both species are associated to areas characterized by vegetation cover (Lovari et al. 2017;
222 Anile et al. 2019). Future surveys that would have the porcupine as target species, should survey woodlands and
223 shrublands important for food sources and denning sites, respectively. Farmlands, even if not present in our
224 surveyed area, should also be considered especially in the summer time (Mori et al. 2014a). Lastly, in the case of
225 the presence of predators (e.g. red fox) and/or competing species (e.g. feral or wild Suidae), their occurrence
226 should be considered in the analyses. In particular, the soil overturned by feral/wild Suidae nearby the camera
227 site should be measured as a good proxy for indirect effect of Suidae on the porcupine.

228 The best models fitted the data well (as shown by the value of the test for the goodness of fit); this underlines the
229 suitability of occupancy modeling as a tool to analyze by-catch data generated by camera-trapping surveys. Most
230 of the covariates tested for the detection probability were not retained in the final model. Since the categorical
231 factor indicating the camera trap array didn't affect the detection, all the areas had similar probabilities to detect
232 the porcupine indicating the adequacy of selected sites. We expected a reduced detection probability in the cold
233 months because during the winter in Central Italy the activity and the home range size of porcupines decrease
234 (Corsini et al. 1995; Mori et al. 2014a; Mori 2017). Although the factor season was quite balanced among our
235 cameras, it had no effect on the detection process. During our survey the absence of snow on Mt. Etna may have
236 not affected and reduced the activity of the porcupine.

237 As expected, the occupancy of the porcupine was significantly promoted by the presence of forested areas and
238 by patches of shrubs. Space use and habitat selection of the porcupine are mostly affected by two limiting
239 factors: food resources and den sites. Woodlands are the most suitable habitat for the exploitation of
240 underground plant storage organs and roots, as well as plant epigeal parts and fruits according to their seasonal

241 availability (Bruno and Riccardi 1995; Mori et al. 2017). The positive selection of woodlands has been recorded
242 in Central Italy (Mori et al. 2014a; Lovari et al. 2017) and now also confirmed in Sicily. Moreover, during the
243 daylight this species rests in a den made of a network of chambers and tunnels with one or several entries
244 (Monetti et al. 2005). The porcupines selects steep compact soils covered in dense vegetation such as bramble
245 thicket to dig its den and it could explain why the occupancy was positively related to areas with a higher
246 number of shrub patches (Monetti et al. 2005; Lovari et al. 2017). Meadows did not explain the presence of the
247 porcupine on Mt. Etna confirming a preference for covered areas (as the woods), as reported by (Sonnino 1998).
248 Our second hypothesis based on the habitat richness promoting the porcupine occupancy was not confirmed.
249 (Lovari et al. 2013) reported an inverse effect of the habitat richness on the home range size of the porcupine,
250 with smaller home ranges when the number of habitat types per ha was higher. We tested this covariate (number
251 of habitat classes per camera buffer) but it was not retained in the average model (and neither in the best
252 models). This difference we recorded might be explained as in this study we used macro- habitat classes to
253 depict plant habit (e.g. woodland, shrubland, meadow) rather than the plant association (phytosociology *sensu*
254 *strictu*). Therefore, we suggest that future studies should also consider a more detailed vegetation description to
255 provide a deeper view of the plant association (and hence habitat richness) selected by the porcupine. The
256 negative effect of altitude on the porcupine occupancy was confirmed by our by-catch data. Despite we recorded
257 the presence of the porcupine up to 1750 m a.s.l., its occupancy leveled at about 1500 m a.s.l., as also found by a
258 previous study (Mori et al. 2013). Snow cover can represent an obstacle for locomotion, research and
259 exploitation of underground food resources as well as for the digging of the den (Mori 2017; Mori et al. 2018).
260 This could explain the negative relationship between occupancy and altitude with a gradual reduction of the
261 occupancy above 1200 m a.s.l.. (Mori et al. 2018) predicted that the ongoing global warming may help the
262 porcupine in colonizing higher altitudes thanks to a reduction of the duration of snow and ice cover at the ground
263 level and the shift of the forest distribution to high elevations. However, global warming can also result in more
264 robust snowfall (Trenberth 2011; Kunkel et al. 2012) and hence this hypothesized positive effect of global
265 warming might be counterbalanced by periods of robust snowfall, which can increase the porcupine's mortality.
266 More long term studies are needed to further elucidate the role of global warming on the ecology of the
267 porcupine as unpredictable events (usually manifested with larger magnitude) can lead to contrasting effects.

268 Porcupine detection was negatively associated with feral pigs, but not the occupancy. The porcupine could be
269 indirectly disadvantage by the feeding habits, primarily rooting disturbance, of the feral pigs. In fact, Suidae
270 overturn large patches of soil looking for plant underground storage organs (Barrios-Garcia and Ballari 2012;

271 Gaskamp et al. 2018), and it could lead to a food resources or space competition (Mori et al. 2014b; Melletti and
272 Meijaard 2017; Nie et al. 2019) in which the porcupine would avoid the areas with presence of pigs. Contrary to
273 our hypothesis, Mori (2017) hypothesized a possible positive/attractive effect of the rooting activity on the
274 porcupine, because the turnover of the soil could enhance the access to food, especially when the ground is
275 covered in snow. However, our results showed that the occupancy was not affected by the feral pig. On the
276 contrary, the probability to detect the porcupine decreased with the increasing of feral pig detections, sign of an
277 avoidance by porcupines of areas with high activity of pigs.

278 The map generated by our by-catch data showed a potential distribution of the porcupine on all slopes of the
279 volcano, even if ample and well connected areas of highly predicted occupancy occur more on the Northern
280 slope than on the Southern one. In fact, the Southern slope of Mt. Etna is characterized by wider areas of
281 farmlands and meadows at lower elevations, while the Northern slope by well connected patches of forest and
282 shrubs.

283 **Conclusions**

284 Our study is an example of how camera trap surveys are often an under-exploited source of valuable information
285 on a wider spectrum of sympatric species beyond the focal species (if any) for which the camera-trapping was
286 conducted. Researchers have deeply investigated the use of camera trapping in ecology (O'Connell et al. 2010;
287 Rovero et al. 2013; Rovero and Zimmermann 2016), but future studies that wanted to make the most out of by-
288 catch data should consider some sensitive factors while planning on the study design. Hofmeester et al. (2019)
289 identified four main factors that can highly influence species detection at different spatial scales: animal
290 characteristics (body mass, diet type, movement), camera trap specifications and set up, and environmental
291 characteristics. Since the use of by-catch data implies a change in the specific research question compared to the
292 one for which the cameras were initially deployed, corrections can be done using the appropriate covariates in a
293 statistical framework (Hofmeester et al. 2019).

294 To our best knowledge, this is the first study that develops occupancy models for the porcupine using
295 presence/absence data obtained from a camera trap survey. Our results have improved the insights on this
296 understudied species and it is the first study reporting ecological information and needs of the porcupine on Mt.
297 Etna and Sicily in general. Mt. Etna represents a good refuge for this species from the highly populated areas
298 surrounding the volcano and its unique environment should be kept highly protected to ensure the preservation
299 of the porcupine, as well as of the wildcat. Since the woodlands represent the main habitat for the porcupine,

300 logging should be avoided during its reproductive period to minimize the impact on the species and forest
301 clearing should preserve patches of shrub to protect den sites. As the porcupine is the largest dwelling herbivore
302 on Mt. Etna, its role into the ecosystem as seed disperser might be critical for the maintenance and persistence of
303 the peculiar ecosystem found on the highest active volcano in Europe.

304

305 **Table 1** Covariates used to model the detection (p) and occupancy (ψ) of the crested porcupine on Mt. Etna
306 (Sicily, Italy)

| Model component | Covariate | Description |
|----------------------|-------------------|---|
| Detection (p) | <i>days</i> | camera trap working days |
| | <i>array</i> | categorical factor indicating camera trap array (1-4) |
| | <i>season</i> | categorical factor (cold- warm) |
| | <i>feral_pig</i> | number of detections of feral pigs per camera trap |
| Occupancy (ψ) | <i>woods</i> | |
| | <i>shrubs</i> | area per habitat class |
| | <i>meadows</i> | |
| | <i>Nhabitat</i> | number of habitat classes |
| | <i>Np_woods</i> | |
| | <i>Np_shrubs</i> | number of patches per habitat class |
| | <i>Np_meadows</i> | |
| | <i>Np_tot</i> | number patches of all habitat classes |
| | <i>elevation</i> | altitude of each camera |
| | <i>feral_pig</i> | number of detections of feral pigs per camera trap |

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308

309 **Table 2** Crested porcupine detection (p) models. Occupancy (ψ) is kept constant and overparametrized. Models
310 with $\Delta AIC < 2$ in bold

| | nPars | AIC | ΔAIC | AICwt | cumltvWt | Rsqr |
|---|----------|---------------|--------------|---------------|-------------|---------------|
| Ψ (woods, meadows); p (feral_pig) | 5 | 169.76 | 0.00 | 0.3778 | 0.38 | 0.0695 |
| Ψ (woods, meadows); p (.) | 4 | 171.28 | 1.52 | 0.1768 | 0.55 | 0.0000 |
| Ψ (woods, meadows); p (feral_pig, season) | 6 | 171.69 | 1.93 | 0.1438 | 0.70 | 0.0708 |
| Ψ (woods, meadows); p (days) | 5 | 172.18 | 2.42 | 0.1127 | 0.81 | 0.0223 |
| Ψ (woods, meadows); p (season) | 5 | 172.98 | 3.22 | 0.0754 | 0.89 | 0.0060 |
| Ψ (woods, meadows); p (days, season) | 6 | 173.59 | 3.83 | 0.0557 | 0.94 | 0.0340 |
| Ψ (woods, meadows); p (feral_pig, array) | 8 | 175.52 | 5.76 | 0.0212 | 0.96 | 0.0741 |
| Ψ (woods, meadows); p (array) | 7 | 176.96 | 7.20 | 0.0103 | 0.97 | 0.0065 |
| Ψ (woods, meadows); p (feral_pig, season, array) | 9 | 177.45 | 7.69 | 0.0081 | 0.98 | 0.0755 |
| Ψ (woods, meadows); p (days, array) | 8 | 177.65 | 7.89 | 0.0073 | 0.99 | 0.0328 |
| Ψ (woods, meadows); p (days, array, season) | 9 | 177.83 | 8.07 | 0.0067 | 1.00 | 0.0682 |
| Ψ (woods, meadows); p (array, season) | 8 | 178.75 | 8.99 | 0.0042 | 1.00 | 0.0107 |

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Table 3 Crested porcupine occupancy (ψ) models. Models with $\Delta AIC < 2$ in bold.

| Model | nPars | AIC | ΔAIC | AICwt | cumltvWt | Rsqr |
|---|----------|---------------|--------------|--------------|-------------|-------------|
| Ψ (woods, Np_shrubs,elevation); p (feral_pig) | 6 | 162.04 | 0.00 | 0.513 | 0.51 | 0.25 |
| Ψ (woods, Np_shrubs); p (feral_pig) | 5 | 163.67 | 1.63 | 0.227 | 0.74 | 0.19 |
| Ψ (woods, Np_shrubs,elevation); p (.) | 5 | 165.02 | 2.98 | 0.116 | 0.86 | 0.17 |
| Ψ (woods, Np_shrubs); p (.) | 4 | 165.83 | 3.79 | 0.077 | 0.93 | 0.12 |
| Ψ (woods, Np_shrubs; Nhabitat); p (.) | 5 | 166.92 | 4.88 | 0.045 | 0.98 | 0.14 |

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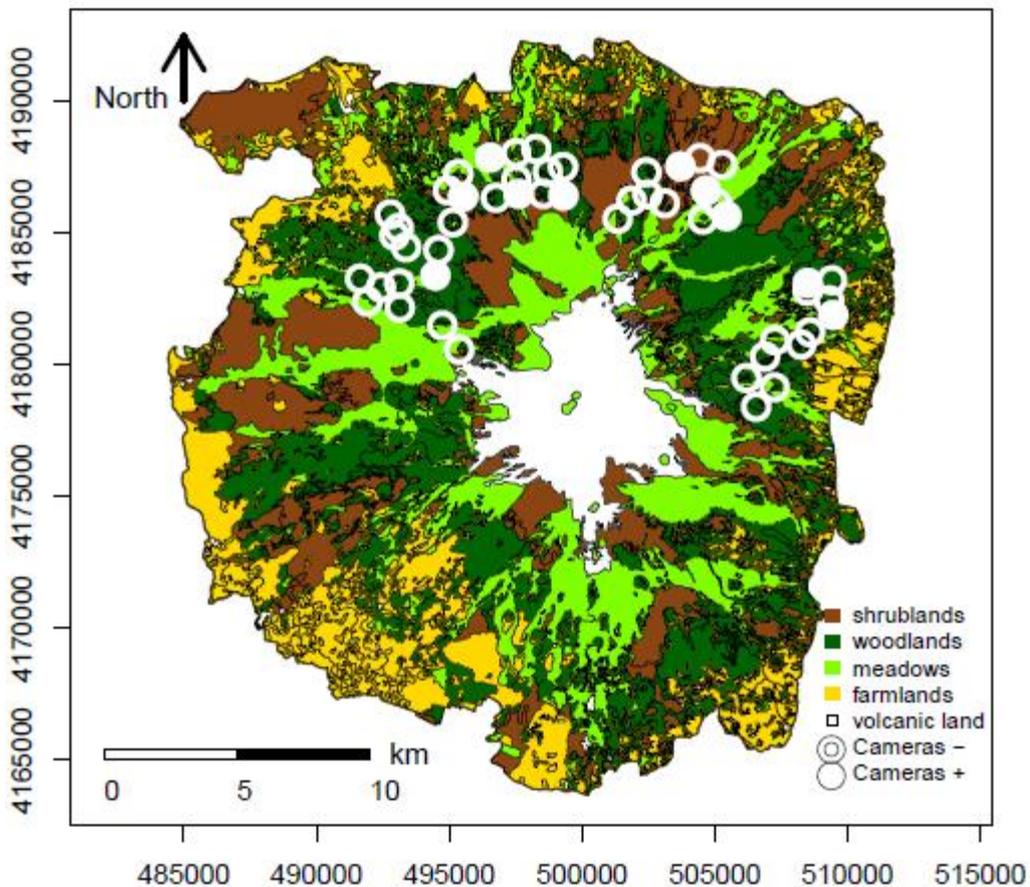
318 **Table 4** Results of the averaged best model describing the occupancy of the crested porcupine on Mt. Etna
 319 (Sicily, Italy)

| Covariate | β | SE | z | p |
|-------------------------------------|---------|--------|-------|-------------|
| Occupancy ψ | | | | |
| Intercept | 15.499 | 11.606 | 1.335 | 0.1817 |
| <i>woods</i> | 26.729 | 13.443 | 1.988 | 0.0468 |
| <i>NP_shrubs</i> | 30.476 | 15.678 | 1.944 | 0.0519 |
| <i>elevation</i> | -14.871 | 0.9319 | 1.596 | 0.1105 |
| Detectability p | | | | |
| Intercept | -20.518 | 0.3276 | 6.262 | $<2e^{-16}$ |
| <i>feral_pig</i> | -12.234 | 0.8164 | 1.498 | 0.1340 |

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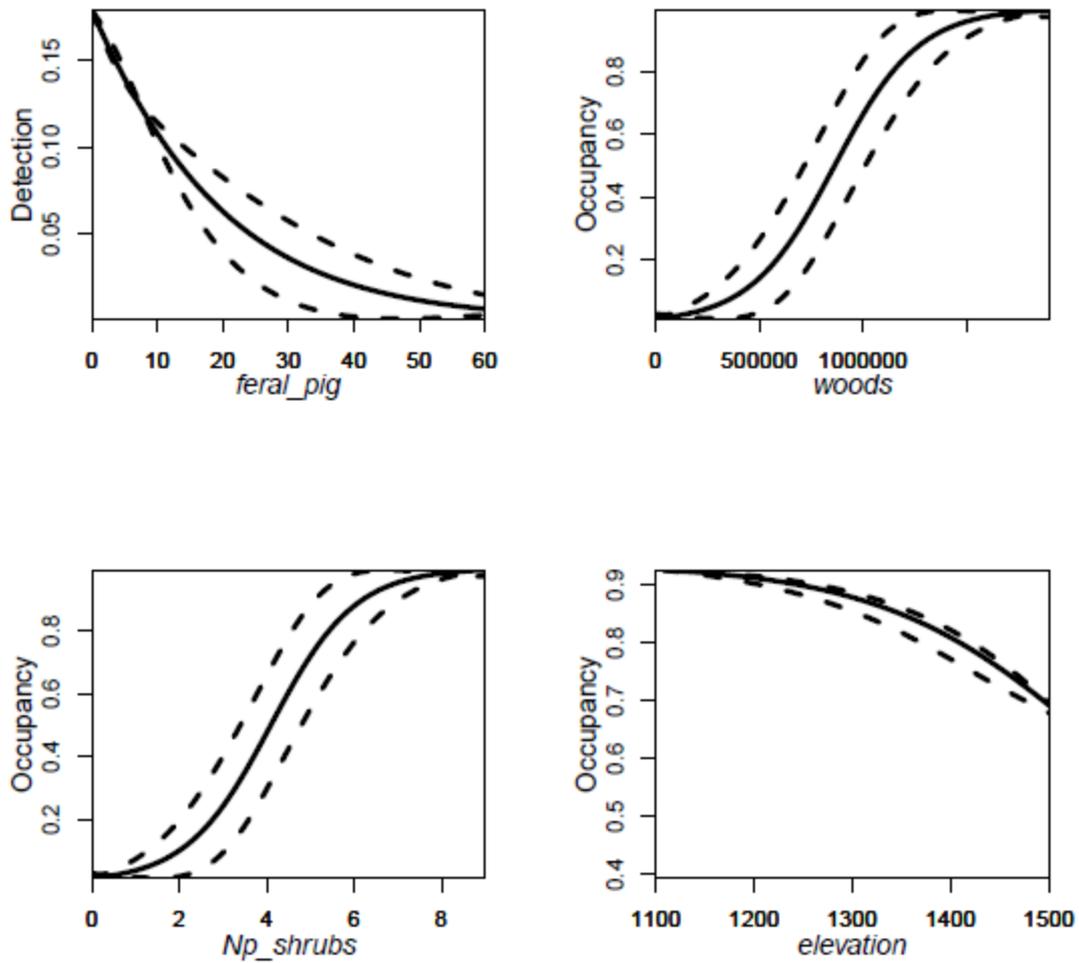
322 **Fig. 1** Distribution of the habitat classes tested on Mt. Etna (Sicily, Italy). Camera traps are shown in the picture
 323 as positive if they ever detected the crested porcupine (solid white circle) and negative if they never detected it
 324 (white empty circle).



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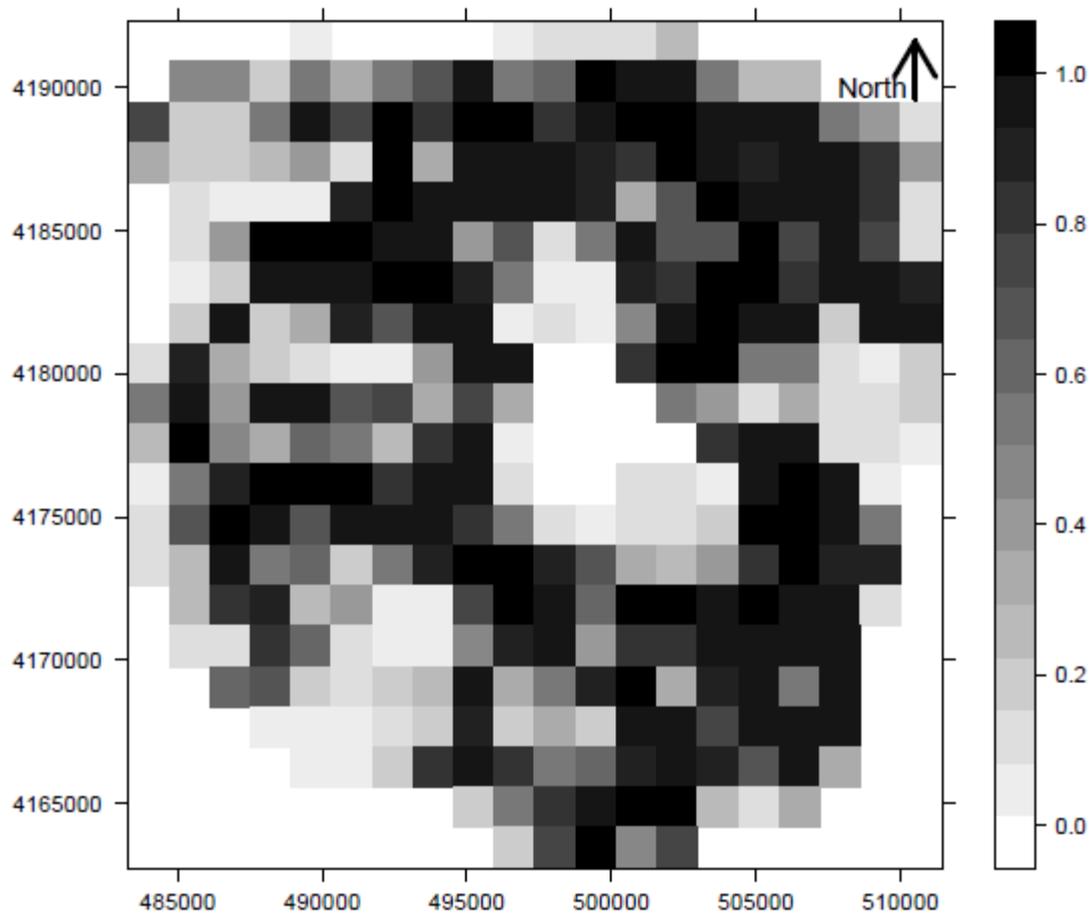
327 **Fig. 2** Predictions from the best model Ψ (woods, Np_shrubs, elevation); p (feral_pig) describing the occupancy
328 of the crested porcupine on Mt. Etna (Sicily, Italy). For definition of model covariates see Table 1



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331 **Fig. 3** Spatially explicit predictions from the best model Ψ (woods, Np_shrubs,elevation); p (feral_pig)
332 describing the occupancy of the crested porcupine on Mt. Etna (Sicily, Italy)



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