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'The early bird catches the nest' : possible competition between scops owls and ring-necked parakeets

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1 **“The early bird catches the nest”**: possible competition between scops owls and ring-  
2 **necked parakeets**

3

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19 Short title: competition between introduced parakeets and native owls

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26 **Abstract**

27

28 Competition for critical resources is one of the key mechanisms through which invasive  
29 species impact on native communities. Among birds, the widely introduced ring-necked  
30 parakeet *Psittacula krameri* locally affects cavity-nesting communities through competition  
31 for suitable tree-cavities, although it remains unclear to what extent such competition  
32 translates into population declines of native species. Here, we studied the potential for nest-  
33 site competition between ring-necked parakeets and the native scops owl *Otus scops*, a small  
34 nocturnal migratory raptor, by comparing the spatial distribution of the nest site locations of  
35 the raptor before (2002) and after (2015) the parakeet invasion. Pre-invasion nesting sites of  
36 scops owls (2002) strongly coincided with those selected by ring-necked parakeets, but  
37 despite the fact that both parakeet and scops owl populations increased during the study  
38 period, this was no longer true for 2015. Ring-necked parakeets took over several cavities  
39 formerly occupied by scops owls, and land-use data suggest that because of the higher overall  
40 breeding densities in 2015, scops owls were forced to occupy suboptimal breeding habitats to  
41 minimize nest-site competition with invasive parakeets. Ring-necked parakeets start breeding  
42 early in the season, a behaviour enabling them to secure the best nest sites first, before the  
43 owls return from their wintering grounds. Our study highlights that locally observed  
44 competition not necessarily impacts on population dynamics of competing species and thus  
45 warns against uncritical extrapolation of smaller-scale studies for assessing invasive species  
46 risks at larger spatial scales. Nonetheless, given the increasing number of studies  
47 demonstrating its competitive capacities, monitoring of ring-necked parakeet populations is  
48 prudent, and mitigation measures (such as mounting of man-made nest-boxes, which are used  
49 by scops owls, but not by parakeets) may be justified when the parakeets are likely to invade  
50 areas harbouring cavity-nesters of conservation concern.

51 **Keywords:** Attraction-inhibition analysis; biological invasions; cavity-nesters; nest  
52 displacement; *Otus scops*; *Psittacula krameri*.

53

## 54 **Introduction**

55

56 The competitive success of an alien species is mediated by its biological attributes  
57 (traits), the environmental features of the invaded range and the biotic interactions occurring  
58 in the receptive ecosystem (Huenneke & Thomson, 1995; Brown *et al.*, 2002; Duncan *et al.*,  
59 2003). Competition for limiting resources often represents one of the first interactions  
60 between an introduced species and its new environment (Wiens, 1977; Newton, 1994; Vilà &  
61 Weiner, 2004). For instance, grey squirrels (*Sciurus carolinensis*) introduced into Europe are  
62 more efficient than native red ones (*Sciurus vulgaris*) to exploit food resources, enabling them  
63 to reach high population densities (Kenward & Holm, 1993; Gurnell, 1996; Chung-  
64 MacCoubrey *et al.*, 1997; Bertolino *et al.*, 2015). Competition with introduced grey squirrels  
65 causes weight loss among native red squirrels, consequently reducing their reproductive  
66 fitness (Wauters & Dhondt, 2002; Wauters *et al.*, 2002). Among birds, the ring-necked  
67 parakeet *Psittacula krameri* (hereafter, RNP) is a well-known invader globally. Because of its  
68 popularity as a pet bird, this gregarious parrot, naturally distributed across much of  
69 subtropical Sub-Saharan Africa and large parts of Eastern Asia, has been introduced  
70 throughout the world, but especially across Europe (Menchetti *et al.*, 2016). Despite the fact  
71 that most of Europe is considerably colder than the climate conditions RNPs experience  
72 across their native range (Strubbe *et al.*, 2015), at least 90 self-sustaining populations are  
73 currently established across Europe (Pârâu *et al.*, 2016). The association of the species with  
74 human-modified habitats in its native range (Strubbe *et al.*, 2015) may be the key of its  
75 invasion success in anthropic habitats elsewhere (Clergeau & Vergnes, 2011; Holling *et al.*,

76 2011; Mori *et al.*, 2013). Impacts of introduced RNP range from competition with native  
77 species (e.g. the nuthatch *Sitta europaea*: Strubbe *et al.*, 2009; the starling *Sturnus vulgaris*:  
78 Braun *et al.*, 2009; Dodaro & Battisti, 2014; noctule bats *Nyctalus* spp.: Hernandez-Brito *et*  
79 *al.*, 2014; Menchetti *et al.*, 2014; the hoopoe: Yosef *et al.*, 2016), to agricultural damage  
80 (Menchetti & Mori, 2014) and the transmission of parasites and diseases (Sa *et al.*, 2014;  
81 Mori *et al.*, 2015). For reproduction, the RNP largely depends on tree cavities (Khan *et al.*,  
82 2004; Menchetti *et al.*, 2016), which may represent a limiting resource (Cornelius *et al.*,  
83 2008). In its native range, the species is known to readily accept crevices in wall or rocks as  
84 nesting sites when tree cavities are in insufficient supply (Lamba, 1996), and such behaviour  
85 has been reported from across Europe too (anecdotal observations in Belgium, the  
86 Netherlands, Germany, Israel and Italy; pers. obs. of the authors). A plethora of native  
87 European species, e.g. tits, flycatchers, nuthatches, woodpeckers and bats, also use tree  
88 cavities as nesting or roosting sites (Newton, 1994; Hernandez-Brito *et al.*, 2014), which may  
89 elicit competition with introduced RNPs. RNPs are fierce, medium-sized birds (body mass:  
90 120-140g, Butler *et al.*, 2013), capable of winning aggressive encounters with raptor species  
91 such as lesser kestrels *Falco naumanni* (Hernandez-Brito *et al.*, 2014). In addition, RNPs may  
92 take advantage of their early breeding phenology (parakeet egg-laying can start from half-  
93 February: Butler *et al.*, 2013), enabling them to occupy the best nesting-cavities first (Strubbe  
94 & Matthysen, 2009). Displacement behaviour by introduced RNPs is particularly concerning  
95 when directed against threatened species, e.g. native parrots living in oceanic islands or  
96 endangered bats (Hernandez-Brito *et al.*, 2014; Menchetti & Mori, 2014). In Europe, RNPs  
97 have been observed while harassing or displacing native species from breeding sites (birds:  
98 Strubbe & Matthysen, 2007; Braun *et al.*, 2009; Strubbe *et al.*, 2009; Czajka *et al.*, 2011,  
99 mammals: Hernandez-Brito *et al.*, 2014; Menchetti *et al.*, 2014). In addition, RNP can also  
100 enlarge existing tree holes, thereby potentially making cavities unsuitable for smaller cavity-

101 nesters (Orchan *et al.*, 2013). Hernandez-Brito *et al.* (2014) found that, in urban parks of  
102 Seville (Spain), aggressive interspecific interactions and cavity-modification by RNPs caused  
103 a decline in the number of roosting greater noctules *Nyctalus lasiopterus*, and detected a  
104 pattern of mutual spatial segregation between breeding parakeets and the remaining roosting  
105 bats. In Italy, Germany and the UK, no relationship was found between breeding densities of  
106 parakeets and native starlings (*Sturnus vulgaris*), yet parakeets were found to occupy the  
107 highest tree cavities. This suggests that the competition with parakeets forces starlings to  
108 breed in lower cavities, likely increasing nest predation risk by terrestrial predators (DEFRA  
109 2010; Czaika *et al.*, 2011; Dodaro & Battisti, 2014).

110         Among hole nesters, the scops owl *Otus scops* is a small nocturnal migratory raptor  
111 (body mass: 64-135 g: Cramp, 1985) which breeds in tree cavities, even if sometimes (e.g.  
112 when suitable tree cavities are not available), it may build nests in wall cavities as well (EM,  
113 personal observation). In Europe, the species is present during the breeding period only, as  
114 most individuals migrate to sub-Saharan Africa for winter, with only few sedentary  
115 populations in southern Europe (Mori *et al.*, 2014). Scops owls mainly forage in grasslands  
116 and ecotones between woodland and open areas, i.e. the typical habitats for orthopterans, their  
117 main food resources. Scops owls are negatively affected by human-driven landscape  
118 modification (Marchesi & Sergio, 2005; Treggiari *et al.*, 2013), as intensification of  
119 agriculture reduce the availability of insects, as well as of trees with cavities (Arlettaz, 1990;  
120 Sergio *et al.*, 2009; Treggiari *et al.*, 2013). The species is currently declining throughout its  
121 range (Marchesi & Sergio, 2005), despite being classified as “Least Concern” by BirdLife  
122 International (2012) on the most recent global and European red lists. In Central Italy, the  
123 species often nests in man-made structures close to human settlements (Panzeri *et al.*, 2014),  
124 probably because tree cavities in these environments represent a limiting resource. As a  
125 consequence, competition with introduced RNPs may occur. To date, competition between

126 RNPs and nocturnal raptors has been poorly studied. In its native range, the RNP is  
127 responsible for displacement behaviour against small owl species (e.g. the forest owlet  
128 *Heteroglaux blewitti*: Ishtiaq & Rahmani, 2005 and the spotted owlet *Athene brama*: Pande *et*  
129 *al.*, 2007). By contrast, in the introduced range, interactions of RNPs with nocturnal raptors  
130 are only known from anecdotal observations (e.g. harassment against little owls *Athene*  
131 *noctua*, Menchetti & Mori, 2014). RNPs are non-migratory early breeders (Strubbe &  
132 Matthysen, 2009), preferably colonizing areas characterized by edge habitats, thus their  
133 ecological requirements at least partially overlap with those of scops owls during the breeding  
134 season (Panzeri *et al.*, 2014; Menchetti *et al.*, 2016).

135         Here, we test the hypothesis that RNPs compete for nesting cavities with a nocturnal,  
136 cavity-breeding raptor by analysing the spatial distribution of the scops owl nesting sites  
137 before and after the invasion by RNP of an urban area in Central Italy. We expect that (a)  
138 semi-colonial ring-necked parakeets will exhibit spatial clustering of nest site locations while  
139 territorial scops owls should show spatial segregation, (b) if these species compete for nest  
140 sites, locations of their breeding sites should show a strong spatial segregation. If competition  
141 occurs, reproducing scops owls may be forced to use lower quality areas as breeding  
142 territories. Accordingly, we predicted that activity centres of scops owls after RNP invasion  
143 (2015) will show lower amounts of potential high-quality foraging habitat (grasslands and  
144 edges) than sites occupied before the RNP invasion (2002).

145

## 146 **Materials and methods**

147

### 148 *Fieldwork*

149         The work was carried out within the urban area of Follonica, on the coastal area of  
150 Southern Tuscany (Province of Grosseto, Central Italy: 42.92°N, 10.76°E). The study area

151 (about 56.6 km<sup>2</sup>) is located in the Mediterranean temperate zone at 5 m above sea level, with a  
152 mild climate. Mean annual temperature is about 6°C, while annual precipitation is about 650-  
153 700 mm. The urban area is surrounded by cultivations (cereals and sunflower mainly) and a  
154 wide coastal pinewood (*Pinus pinea*: Lippi *et al.*, 2000). No major changes in the structural,  
155 floristic and environmental attributes of the study area occurred during the period of our  
156 study, nor are we aware of any significant changes in management practices for the area.

157 A playback census was performed to assess the number of breeding pairs through the  
158 use of two recordings (advertising and alarm calls broadcast one after the other in the same  
159 bout) to avoid results being affected by the features of a single recording. Scops owl counts  
160 were carried out in summer 2002 and in summer 2015: the same stations were visited once a  
161 week throughout the study after dusk, regardless of weather. Researchers stayed for 2 minutes  
162 in silence at each station to record spontaneous calls of the target species. Then, a playback  
163 was broadcast for 2 minutes and a reaction was waited for three further minutes following the  
164 protocol by Bibby *et al.* (2000), but modified by Mori *et al.* (2014). Broadcast volume was  
165 adjusted every time to obtain the clearest vocal rendition possible (Mori *et al.*, 2014). Each  
166 response to playback/spontaneous call was noted and recorded on a GPS device. **Points were**  
167 **located according to the trees used by scops owls; in some cases, it has not been possible to**  
168 **exactly locate the cavity (i.e., where canopy and leaves covered most of the highest branches).**  
169 **This also prevented us to determine hole availability.** A population of RNP is present in the  
170 vicinity of Follonica since 1999, when the first two individuals were observed, and no more  
171 than 3 breeding pairs were present in 2002 (Mori *et al.*, 2013). Population size in 2015,  
172 obtained through roost counts, is about 30-35 individuals, roosting on plants of *Platanus*  
173 *orientalis* or *Pinus pinea*. At the Follonica roost site, counts started 30 min. before sunset and  
174 finished 5 min after no more birds came to the roost. Given the relatively small population  
175 size, incoming parakeets were counted individually. We discarded movements between

176 roosting trees and subtracted any individuals who left the roost, mostly to return a bit later  
177 (Luna *et al.*, 2016). A census of parakeet breeding was carried out through direct observations  
178 of parakeets present in the study area. Tree cavities were deemed occupied if parakeets were  
179 observed entering the cavity on at least three occasions and/or when a parakeet showing signs  
180 of breeding (broken tail feathers, incubation patch) was seen leaving or entering a cavity  
181 (Strubbe & Matthysen, 2009).

182

### 183 *Statistical analyses*

184         The spatial (geographical) location of RNP and scops owl breeding cavities can be  
185 analyzed as a spatial point pattern (Baddeley *et al.*, 2006). Spatial point pattern analyses model  
186 interactions through the use of an intensity function, whereby the probability of establishment  
187 of other breeding pairs is increased (aggregated, clustered, overdispersed) or decreased  
188 (regular, underdispersed), and/or a zone from which other pairs are totally excluded. The  
189 method can be used to test for patterns of spatial competitive exclusion by comparing the  
190 observed spatial pattern against a hypothesized spatial process model assuming no interaction  
191 exists between study species. Examples include its use to detect competition between ant  
192 species by assessing the locations of their nests (Harkness & Isham, 1983), to study  
193 interspecific competition among goose species breeding in the Arctic (Reiter & Anderson,  
194 2013) and the spatial arrangement of barnacles across intertidal surfaces (Hooper & Eichhorn,  
195 2016). To verify whether the assumption of stationarity ('spatial homogeneity', i.e. that the  
196 probability of observing some point pattern at a specific location is independent of the  
197 location), we first applied a kernel-smoothed intensity estimate for the breeding locations of  
198 each species, and then plotted **the** ratio of owl and RNP smoothed intensity estimates to  
199 visually assess spatial trends in this ratio (Baddeley *et al.* 2006). As this plotted ratio was  
200 largely constant across the study area, data can be considered to be spatially homogeneous.

201 We proceeded with fitting a multitype hard core Strauss model to our datasets. This model  
202 employs two components, namely a ‘hard core distance’ which represents a total exclusion  
203 zone around a breeding cavity, and an ‘interaction radius’ in which the probability of finding  
204 further nests is in-or decreased (Baddeley *et al.*, 2006, Blanco-Moreno *et al.*, 2014).

205         Hard-core distances were estimated from the data using minimum inter-point distances  
206 (i.e. minimum distances between scops owl nests, between RNP nests and between scops owl  
207 and RNP nests: Baddeley *et al.*, 2006). These distances were estimated at 59 to 62 m for scops  
208 owl (in 2002 and 2015, respectively) and at 0.76 m for RNP (2015). The between-species  
209 hard-core distance was 42 m (in 2015). To test for changes in scops owl spatial nest  
210 distribution since the colonization of the park by RNP, we superimposed the 2015 RNP nest  
211 locations on the 2002 scops owl breeding distribution, resulting in a 0.12m hard-core distance  
212 for the superimposed 2002-2015 owl-parakeet data). Interaction radii were estimated based on  
213 the species ecology. While the average home range of breeding scops owl can be  
214 approximated by a circle with a radius of about 300 m (Martinez *et al.*, 2007), the species is  
215 known to respond to the presence of congeners over longer distances (Galeotti *et al.*, 1997).  
216 Scops owl calls can be heard from a distance of approximately 800 m (E.M. pers. obs.) and  
217 we therefore selected this distance as an upper limit for the scops owl interaction radius. By  
218 contrast, RNPs are not territorial and often nest in loose, semi-colonial groups. When a  
219 predator is noticed, RNPs often engage in frantic mobbing behaviour, drawing neighbouring  
220 parakeets from a distance up to approximately 150 m (all authors, personal observation).  
221 Consequently, RNP-RNP and RNP-scops owl interaction radii were set at 150 m. Spatial  
222 point pattern analyses output an interaction parameter  $\gamma$ , whereby  $\gamma < 1$  indicates *inhibition*  
223 between species and  $\gamma > 1$  point to *attraction* between species. We first assessed within-  
224 species interaction (scops owl in 2002 and in 2015, RNP in 2015), and then tested for  
225 between-species interactions (scops owl *vs* RNP in 2015). Significance of within and

226 between-species interaction estimates was tested by means of 249 Monte Carlo simulations of  
227 the null model and refitting the null and the alternative models (Blanco-Moreno *et al.*, 2014).  
228 All analyses were carried out using the R package ‘spatstat’ (Baddeley *et al.*, 2015).

229 In order to quantify scops owl breeding habitat quality before and after the parakeet  
230 invasion, land use and land cover was obtained by photointerpretation of satellite images  
231 (scale 1:25000). We extracted the amount of grassland and edge habitat present within a 300  
232 m radius (known home range of breeding scops owls: Martinez *et al.*, 2007) as a proxy for  
233 available hunting grounds, and thus breeding habitat quality. Pre- and post-invasion measures  
234 of scops owl habitat quality were then assessed using linear models specifying year as fixed  
235 effect. Assumptions of normality and homoscedasticity of residuals were met (Shapiro-Wilk  
236  $W > 0.90$ ). It should be noted that from 2002 to 2015, breeding scops owl increased from 12  
237 to 16 territories and that any decrease in average habitat-quality could thus be due to  
238 intraspecific competition. For a stricter test of parakeet impacts, we therefore performed an  
239 additional analysis in which we considered only the 12 highest-quality scops owl territories of  
240 2015 (i.e. those twelve territories with the highest amounts of grassland and edge habitat).  
241 Spatial analyses were conducted in QGIS 1.6. Differences were considered significant when  
242  $P < 0.05$ . XLSTAT (Addinsoft) was used for statistical analyses.

243

## 244 **Results**

245 In 2002, field censuses detected 12 breeding couples of scops owls while in 2015, 16  
246 scops owl nests and 8 RNP nests were found. Direct, aggressive interactions between the  
247 species have never been observed, yet, but at least 5 cavities used by scops owl in 2002 were  
248 taken over by RNPs in 2015 (Fig. 1). There was no convincing evidence for within-species  
249 interactions among scops owls. In 2002, the interaction estimate  $\gamma$  was 1.16 (indicating mild  
250 attraction) whereas in 2015 it was 0.91 (suggesting mild inhibition), but both these estimates

251 failed to reach statistical significance ( $P=0.16$  and  $0.23$ , resp.). By contrast, RNPs show strong  
252 intraspecific attraction ( $\gamma = 3.60$ ,  $P < 0.01$ ). The 2015 data are suggestive of mild inhibition  
253 between scops owl and RNP ( $\gamma = 0.88$ ), but data do not allow strong conclusions as the  
254 associated  $P$ -value is  $0.15$ . Yet, when superimposing the 2002 scops owl data onto the 2015  
255 RNP nest distribution, we find strong attraction between these two cavity-nesters ( $\gamma = 2.98$ ,  $P$   
256  $< 0.01$ ).

257 Compared to the year 2002, in 2015, scops owl nests were characterized by  
258 significantly lower amounts of grassland and edge habitats (grassland: from  $16.00 \pm 6.6$  to  
259  $6.1 \pm 3.9\%$ , ANOVA  $F_{1,26}=24.63$ ,  $p < 0.001$ ; edge habitat: from  $750 \pm 203$  to  $425 \pm 253$  m,  
260 ANOVA  $F_{1,26}=28.22$ ,  $P < 0.001$ ). This result holds also when considering the 12 highest-quality  
261 2015 territories only (grassland: ANOVA  $F_{1,22}=28.32$ ,  $p < 0.001$ ; edge habitat: ANOVA  
262  $F_{1,22}=33.23$ ,  $p < 0.001$ ).

263

## 264 **Discussion**

265 Although both the number of breeding scops owls and parakeets increased over the  
266 course of our study, spatial patterns in nest site choice nevertheless suggest that competitive  
267 interactions take place between these obligate cavity nesters. Our attraction-inhibition  
268 analysis indicated that pre-invasion nesting sites of scops owls strongly coincide with those of  
269 RNP (post-invasion). After the invasion by RNPs, this is no longer true, indirectly pointing to  
270 an impact of RNP on the spatial distribution of scops owl breeding distributions. We did not  
271 observe any direct aggressive interaction or nest displacement of scops owls by invasive  
272 RNPs, but our data clearly showed that, if in 2015 owls were to be found at the same breeding  
273 sites as in 2002, a strong positive association between spatial distribution of these species  
274 would have been apparent. The fact that such a spatial association was not detected in 2015  
275 suggests that RNPs and scops owl compete for nesting cavities. Indeed, at least 5 cavities

276 formerly occupied by scops owl in 2002 were taken over by parakeets in 2015, leading to a  
277 marked decrease in scops owl numbers (from five to one breeding pair only) in the Ex Ilva  
278 park (a 10.35 ha large park at the centre of our study area), where the bulk of the parakeet  
279 population currently breeds (at least 6 pairs in 2015). All tree cavities used by scops owls in  
280 2002 were still present in 2015, and apart from the five cavities taken over by the parakeets,  
281 all other nesting cavities used by scops owl in 2002 were used by owls in 2015 as well. No  
282 other major changes occurred within our study area between 2002 and 2015, corroborating  
283 our interpretation of competition as main driver of the changes observed.

284         Strubbe *et al.* (2009) found that due to their early breeding phenology (first eggs can  
285 be laid by half February: Butler *et al.*, 2013), RNPs have a competitive advantage over native  
286 cavity-breeders, enabling them to occupy high-quality nesting cavities first. This mechanism  
287 may have occurred in this case as well. RNPs have been observed entering and occupying  
288 multiple cavities previously used by scops owls, forcing the owls to search for other,  
289 potentially suboptimal nesting sites when they return from their wintering grounds. Indeed,  
290 scops owl are known to prefer to breed in edge habitats surrounded by wide grasslands  
291 (Panzeri *et al.*, 2014), as such habitats represent good foraging areas (Latkovà *et al.*, 2012). A  
292 comparison of the amount of grassland surrounding scops owl nests in 2002 versus 2015  
293 showed that, in the latter year, scops owl territories contained significantly less grassland and  
294 edge habitats. This could be partly due to the fact that higher intraspecific competition (from  
295 12 breeding pairs in 2002 to 16 in 2015) forced scops owls to occupy suboptimal sites.  
296 However, even when considering only the 12 ‘best’ scops owl territories of 2015 (i.e. those  
297 with the highest amount of grassland and edge habitats), these still included less grassland and  
298 edges than the pre-invasion territories.

299         In its native Asian range, RNPs are known to compete with nocturnal raptors  
300 comparable to scops owls in terms of body size and ecology (Ishtiaq & Rahmani, 2005; Pande

301 *et al.*, 2007) and it is thus not surprising that such nest-site competition also takes place in  
302 invaded Europe. Yet, while there is increasing evidence for local competition between  
303 parakeets and a variety of native species that depend on tree cavities, it remains unclear  
304 whether and how such local impacts translate into detrimental effects upon population  
305 dynamics of native species at large spatial scales.

306 Current invasive species risk assessment schemes advise to search the literature for  
307 any impact documented and rank invasive species according to their worst documented  
308 impact (Evans *et al.*, 2016). Our study **may suggest** that such an approach overestimate  
309 invasive species impacts, as while we can reasonably argue that ring-necked parakeets are  
310 able to locally displace native scops owls, this does not translate into regional population  
311 declines – on the contrary in this case. Similarly, in Brussels, Belgium, Strubbe & Matthysen  
312 (2007) found that while native nuthatches (*Sitta europaea*) were less abundant than expected  
313 in areas with higher parakeet densities, longer-term population monitoring trends derived  
314 from point counts suggested a fluctuating but overall stable trend in nuthatch abundance.  
315 Nonetheless, given the general lack of autecological studies on invasive species impacts  
316 (Strubbe *et al.*, 2011), any evidence of interactions between native and invasive species  
317 constitutes crucial information to prioritize conservation actions and control efforts (Ruscoe *et*  
318 *al.*, 2011; Orchan *et al.*, 2013). The RNP is one of the most successful avian invaders in  
319 Europe in general and in the Mediterranean basin specifically (Menchetti *et al.*, 2016). This  
320 study adds to the growing body of evidence that RNP can, at least locally, impact native  
321 species breeding behaviour. A recent review of RNP population growth trends showed that  
322 there are many, fast-growing RNP populations across the Mediterranean (Pârâu *et al.*, 2016).  
323 Accordingly, statistical models of invasion risk (Di Febbraro & Mori, 2015; Strubbe *et al.*,  
324 2015) indicate that across the Mediterranean, there is ample suitable habitat available for  
325 RNPs to spread into. Moreover, differently from the parakeet populations in the coldest parts

326 of Europe, the species may be able to spread outside of the urban strongholds where the bulk  
327 of the populations currently reside (Strubbe *et al.* 2015). Therefore, especially in the  
328 Mediterranean, monitoring of RNP distributions and population trends is prudently required.  
329 In case RNPs are likely to invade areas where cavity-nesters of conservation concern are  
330 present, mitigation measures such as providing man-made nest-boxes (allowing entrance by  
331 scops owls, but excluding parakeets: Lambrechts *et al.*, 2012) or trapping/numerical control  
332 of parakeets (Genovesi & Shine, 2004) may have to be considered.

333

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335

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342

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521

522 **Figure captions**

523

524 **Figure 1.** Localization of breeding places of scops owls and RNP in 2002 and 2015. Symbols do  
525 not refer to single nests but to nesting locations, i.e. more than one nest may be identified by one  
526 symbol.