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1 **Effects of density on lek-site selection by Black Grouse (*Tetrao tetrix*) in the Alps**

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16   **Capsule** The Black Grouse is a primarily lekking species, but low population density

17   and lack of suitable habitat can lead to establish non-lekking populations.

18   **Aims** To understand if differences in density could be related to differences in the

19   lekking system, if there were differences in lek-site selection, and if there was a direct

20   effect of habitat on the lek size.

21   **Methods** We compared two Black Grouse populations with different male density. We

22   carried out counts from randomly chosen sample points and estimated population

23   density by distance sampling. We compared the differences in the lek size distribution

24   between the two study areas by a permutation chi-square test. We considered land-cover

25   categories, landscape metrics and orographic variables and computed the Ivlev's

26   Electivity Index to evaluate habitat selection of males in the two study areas. We

27   performed a general linear model of the number of males attending the lek vs. habitat

28   variables to evaluate if the habitat had an effect on male abundance on lek sites.

29   **Results** We couldn't demonstrate the direct effect of density on the displaying behavior

30   but we found strongly different patterns of lek-site selection and different effects of

31   habitat on lek size according to the population density.

32   **Conclusions** We concluded that the high quality habitat for Black Grouse on the Alps

33   should be considered case by case, not considering only what literature reports.

34

35   **Keywords**: Black Grouse, displaying behavior, habitat selection, mating system, male

36   density, lek, T*etrao tetrix*.

37   **INTRODUCTION**

38   Mating systems are usually reported as being species-specific but intra-specific

39   variation may be observed for many taxa, mostly due to ecological factors (Lott 1984).

40   The Black Grouse (*Tetrao tetrix*) is well known to be a primarily lekking species

41   (Alatalo *et al.* 1992), in which males aggregate in groups during the mating season to

42   display and fight while females attend leks along boundaries to observe males. Yet this

43   behavior is not obligate and different studies in the last decades have described non-

44   lekking populations, in which males tend to attract females with solitary displays

45   (Hoglund & Stohr 1997, Angelstam 2004, Svobodová *et al.* 2011, Chamberlain *et al.*

46   2012). Hoglund & Stohr (1997) gave four possible explanations, describing a non-

47   lekking population of Black Grouse: 1) low population density: the frequency of

48   interactions between males, and thus lekking behavior, would increase with male

49   density; 2) lack of suitable habitat for establishing leks, as open bogs and clear cuts, 3)

50   high proportions of yearling birds in the population and 4) genetic differences in the

51   propensity of lekking between individuals and populations.

52   The first two hypothesis are the most likely to be the cause of the absence of leks. These

53   were described for Black Grouse and also for other and non-grouse lekking species. In

54   the study of Hoglund & Stohr (1997) they found that all solitarily displaying males

55   were adults so they discarded the third hypothesis and suggested low density and lack of

56   suitable habitats as the main causes of the lek absence. Warren & Baines (2008) found

57   that in North England a very productive metapopulation of Black Grouse was

58   characterized by a lower proportion of solitary males compared with another declining

59   and isolated British population. Pearce-Higgins *et al.* (2007) indicated in habitat change

60   as the decreasing of open-canopy forest one of the main causes of the decline of a Black

61   Grouse population in the Scottish Highlands from 1990 to 2002 with a direct effect on

62   both lek occurrence and lek size (i.e. number of males attending the lek). Angelstam

63   (2004), studying a population of Black Grouse in Sweden, found a clear threshold effect

64   of the percentage of suitable habitat, represented by young forest and open bog, in

65   predicting the presence of single or lekking Black Grouse males, in other words in the

66   choice of mating system. He found also that the presence of lekking Capercaillie

67   (*Tetrao urogallus*) was positively related to the amount of suitable habitat, represented

68   by old thinning and final felling forest and forested bog. Hamilton & Manzer (2011)

69   combined lek surveys and spatial modelling for Sharp-tailed Grouse (*Tympanuchus*

70   *phasianellus*) in a large area of Alberta and they found that lek occurrence was

71   positively related to the abundance of high-quality habitat for the species. Chamberlain

72   *et al.* (2012) analyzed data from 25-year surveys of an increasing Black Grouse

73   population on the Italian Alps and they found that the lekking proportion in their

74   population reached an apparent threshold while the number of solitary displaying males

75   continued to increase. They concluded that suitable lek habitat was not limiting but they

76   also showed that with the increase of population the solitary displaying males expanded

77   their range into higher and, possibly, less suitable altitudes.

78   The genetic aspect of the Black Grouse mating system was recently investigated by

79   Svobodová *et al.* (2011) who compared the genetic diversity between lekking and non-

80   lekking populations, finding higher genetic diversity in lekking populations than in non

81   lekking-ones, but in their conclusion no suggestion was given to understand if the

82   genetic diversity can be ascribed to the differences in mating system.

83   European populations of Black Grouse show clear fluctuations in the last 50 years

84   (Storch 2007, Geary *et al.* 2012). Although the IUCN (International Union for

85   Conservation of Nature) classifies Black Grouse as Least Concern species, in Europe it

86   is listed as SPEC 3 with the "Vulnerable" status (Papazoglou & van Bommel 2004) and

87   it is in Annex I of the European Bird Directive (Council Directive 2009/147/EC of 30

88   November 2009 on the conservation of wild birds). The Alpine population decline is

89   clear (Storch 2007), yet the Italian law (Legge n. 157/92) allows the harvest of Black

90   Grouse.

91   Understanding the mechanisms that drive the mating system and the spatial distribution

92   of a species of conservation concern as the Black Grouse is therefore important to plan

93   correct management measures. Using the information about which habitat variables

94   influence the lek occurrence and male attendance in leks can help wildlife managers in

95   prioritizing management activities.

96   The main aim of our study was then to verify the first two hypotheses for the non-

97   lekking mating system, comparing two Black Grouse populations on the Italian Alps,

98   one with low male density and one with high male density. In particular we wanted to

99   understand 1) if differences in density can be related to differences in the lekking

100   system, 2) if there were differences in habitat selection between the two populations,

101   and 3) if there was a direct effect of habitat on the number of males attending the leks.

102   Our predictions were 1) that the population with higher male density had a higher

103   percentage of lekking males, 2) that solitary and lekking males of the two populations

104   selected different habitats and 3) that the lek size was positively affected by high quality

105   habitat.

106   **METHODS**

107   **Study area**

108   We selected two study areas in the Piedmont Region on the western Alps (Fig. 1). The

109   choice of the study areas, as being representative of low and high density, derived from

110   data collected by Natural Park wildlife managers. Both study areas were selected on a

111   belt along the timber line, in the econotal zone between forest and alpine meadows. The

112   first study area (22.4 km^2) was located in the northern part of the Orsiera-Rocciavrè

113   Natural Park (ORNP), at altitudes ranging from 1352m to 2526 m a.s.l. and slopes from

114   2.3° to 46.2°. Larch forest (33.8%), subalpine scrubland (19.4%) and alpine grasslands

115   (18.9%) were the dominant land cover types. Average yearly temperature was 6.9 °C,

116   with an average minimum in January of 0.7 °C and an average maximum in July of 14.9

117   °C. Precipitation averaged 837 mm per year, with the maximum falling as rain from

118   April to June (1,670 m a.s.l. meteorological station, data from 1997 to 2011). ORNP

119   was expected to be the study area with the low density population. Recently Viterbi *et*

120   *al.* (2015) analyzed the population dynamics of the same Black Grouse population,

121   through the years 1991-2009. They reported average densities ranging from 2.49 to 4.83

122   males/km^2, with no linear trends over time with exception of a weak but no significant

123   decline in one of their sampling areas. The second study area (9.5 km^2) was located in

124   the Alpi Marittime Natural Park (AMNP), close to the French border, with altitudes

125   ranging from 1526 to 2606 m a.s.l. and slopes from 0.6° to 48.7°. The dominant cover

126   types were larch forest (23.7%), subalpine scrubland (21.4%) and alpine grassland

127   (13.0%). Average yearly temperature was 5.9 °C, with an average minimum in January

128   of -2.7 °C and an average maximum in July of 15.4°C. Precipitation averaged 1349 mm

129   per year, with the maximum falling as rain from April to June and from September to

130   November (1390 m a.s.l. meteorological station, data from 1997 to 2011). AMNP was

131   the study area with an expected high density population. Giraudo & PNAM (2015)

132 reported an average density of 9.57 males/km^2, without a significant trend through the

133 years 1999-2014.

Data collection

135 <u>Black Grouse counts</u>

136 We carried out black grouse counts in 2010 and 2011 from 25 April to 31 May. Since

137 the traditional lek count methods generally don't take into account the single males

138 displaying (Bibby *et al.* 2000), we decided to use a random sampling design because we

139 wanted to have information about the whole male population, i.e. both lekking and not

140 lekking males. We established a total of 40 sample points with a survey effort

141 proportional to the size of each study area, with approximately 1 point/80 ha i.e. 30

142 points in ORNP and 10 in AMNP. We conducted the counts during the maximal bird-

143 calling activity, in the first hours of the morning from 05:00 to 06:30 (Cayford &

144 Walker 1991). To avoid the effect of our presence on the displaying behavior, we

145 arrived at the point at least 30 minutes before starting the survey, during which we

146 remained motionless and in silence. Each point was sampled twice each year, with an

147 interval of approximately 2 weeks. Data were collected by 4 different operators, one of

148 which surveyed both sites to ensure homogeneity of data collection protocol. Each

149 single male observation was mapped on aerial photographs and then transferred into the

150 software QGIS 2.6 (QGIS Development Team 2014), in case we observed a lek (two or

151 more males) we mapped the centroid of it. We classified the calling males as solitary

152 males when they were at least 150 m apart from another displaying cock, otherwise we

153 classified them as lekking. This distance was chosen as an average distance of what

154 reported by Angelstam (2004) and Chamberlain *et al.* (2012) who used, respectively,

155 200 m and 100 m. Using the GIS software we measured the radial distance from

156 observer.

157 <u>Habitat variables</u>

158 Using the GIS and digital maps, we measured habitat variables in a circular buffer

159 around each observation (solitary male or centroid of lek). Recently Geary *et al.* (2013)

160 investigated the occurrence of black grouse leks by comparing models with predictors

161 measured at different radii (from 0.2 km to 3 km) and they showed how all of them had

162 good and comparable predictive power (in terms of AUC), although the effect of some

163 habitat variables slightly varied. We decided to use a fixed radius of 500m as

164 representative of the lek site habitat (Pearce-Higgins *et al.* 2007). In particular we used

165 6 cover-type variables obtained from a local digital map "Land Cover Forestry Map of

166 the Piedmont Region", expressed in percentage: scrubland, beech (*Fagus sylvatica*)

167 forest, larch (*Laryx decidua*) forest, grassland, rocky grassland and rocks. Furthermore,

168 using the LecoS tool for QGIS (Jung 2013) we calculated 4 landscape metrics: the mean

169 shape index (MSI), given by the sum of each patch's perimeter divided by the square

170 root of patch area for each habitat class, that represent the shape complexity, the mean

171 patch size (MPS), the edge density (ED), that is the amount of edge relative to the 500

172 m round buffer, and the Shannon diversity index.

173 Finally we used a 20 m digital elevation model to evaluate the average altitude,

174 expressed in meters, and slope, expressed in degrees, and the amount of solar radiation

175 in each buffer during the period of our study. The latter variable accounts for how daily

176 and seasonal shift of sun angle, along with variation in elevation, orientation (slope and

177 aspect) and shadows cast by topographic features, affect the amount of solar radiation,

178 expressed in Wh/m^2.

179 **Data analysis**

180 We estimated the male densities by point transect distance sampling (Buckland 2001,

181 Buckland *et al.* 2004). This method was chosen because was recently proven to provide

182 better estimates, in terms of accuracy and precision, of breeding male black grouse

183 populations on the Alps than more traditional methods (Franceschi *et al.* 2014). We

184 used in particular the conventional distance sampling engine of the Distance software

185 (Thomas *et al.* 2010), pooling the observed distances to obtain a global estimate of the

186 detection function and expected cluster size and we stratified the encounter rate for the

187 two study areas to obtain two density estimates, pooled by years. We performed

188 estimation starting from half-normal, hazard-rate and uniform key functions with

189 Hermite and simple polynomial series adjustment then we chose the best model

190 according to the Akaike's Information Criterion (AIC) and Kolmogorov-Smirnov

191 goodness-of-fit statistics (GOF K-S). To estimate the expected cluster size we averaged

192 the size of detected clusters. The sampling variance was estimated empirically.

193 For each display site we grouped the maximum number of attending males into 4

194 classes: 1 male, 2-3 males, 4-6 males and > 6 males. By a permutation chi-square test

195 we tested the differences in the lek size distribution between study areas (Agresti 2007).

196 To test for difference in habitat structure between the two study areas we compared the

197 habitat variables measured in the circular plots with Kruskal-Wallis one-way non-

198 parametric analysis of variance for the following subsets: pooled data, solitary males,

199 pooled leks and for different lek size categories.

200 To evaluate habitat selection of breeding Black Grouse males in the two study areas, we

201 computed the Ivlev's Electivity Index (Ivlev 1961) by the formula

$$E_i = \frac{o_i - \hat{\pi}_i}{o_i + \hat{\pi}_i}$$

9

202   Where E_i is the i-habitat Electivity Index, o_i is the average proportion of used i-habitat,

203   measured in the circular plots around each observation and $\hat{\pi}_i$ is the sample proportion

204   of available i-habitat, measured in the study area. The index ranges between +1.0 and

205   −1.0, with positive values indicating preferences and negative values indicating

206   avoidance of a particular habitat. The 0 value indicates that the habitat type is used in

207   proportion to its availability. The index was calculated for pooled data, solitary males

208   and leks in each and in pooled study areas. For each subset we followed a bootstrap

209   approach, resampling the original samples 1000 times (Manly 2006) and re-calculating

210   the Ivlev's Electivity Index for each bootstrap sample. We calculated the average index,

211   standard errors and 95% confidence intervals for each habitat. To assess whether

212   selection of vegetation types deviated from randomness (i.e. $E_i = 0$) we checked if the

213   confidence intervals contained the 0 value.

214   To evaluate if the lek structure had an effect on males abundance on lek sites, we

215   performed a general linear model (GLM) with Poisson distribution (Zuur *et al.* 2009) of

216   the number of displaying males vs. standardized habitat variables and interactions

217   between habitat variables and study areas. For the variables selection we followed the

218   information theoretic approach (Burnham & Anderson 2002), starting from the subsets

219   of variables that resulted significantly different between study areas and between

220   solitary and lekking plots. To validate the models we evaluated the McFadden pseudo-

221   R^2 (McFadden 1974, Cameron & Windmeijer 1997, Faraway 2005) and we tested the

222   residual normality by Shapiro-Wilk test (Shapiro 1985) and the residuals

223   autocorrelation by Moran's I test (Dormann *et al.* 2007). For the analyses we used the

224   software R 3.1.2 (R Development Core Team 2014).

225   **RESULTS**

226 In the two pooled years, we collected 27 observations with a mean cock number of 3.0

227 (±3.40 SD) in AMNP and 33 observations with a mean cock number of 2.8 (±3.03 SD)

228 in ORNP. The best detection function, in terms of AIC, was a hazard-rate model

229 without series adjustments (σ = 323.0, β = 4.95, GOF K-S *P* = 0.417). The effective

230 detection radius was 359.3 m and we estimated a density of 9.2 males/km^2 (95%

231 confidence intervals: 7.6 – 10.9) in AMNP and 5.2 males/km^2 (95% confidence

232 intervals: 4.2 – 6.4) in ORNP.

233 In the two pooled study areas we found that 49.2% of observations were solitary males,

234 25.4% were leks with 2-3 males, 15.3% leks with 4-6 males and 10.1% leks with more

235 than 6 males. The lek size distribution did not differ between the two study areas (Table

236 1, Fig. 2).

237 Pooling all the observations, the AMNP had significantly higher percentage of pioneer

238 vegetation, scrubland, beech forest and rocky grassland, higher values of Shannon

239 diversity index and a lower percentage of larch forest than the ORNP while all the other

240 habitat variables did not show differences (Table 2). Pioneer vegetation was

241 significantly different in particular for pooled and large lek observations but we did not

242 find differences for solitary males. On the contrary, the percentages of scrubland and

243 larch forest were different in solitary male plots. Percentage of beech forest was

244 significantly higher in AMNP both for solitary males and for leks, in particular small

245 and medium leks. On the contrary, the percentage of larch forest was higher in ORNP

246 both for solitary males and for leks but with no differences within the lek size classes.

247 Shannon diversity index was different in particular for solitary males but not for lek

248 observations. All the other landscape metrics were significantly different between the

249 two study areas. In particular the AMNP had higher edges density while the ORNP had

250 higher mean shape index and mean patch size.

251 The confidence intervals of Ivlev's electivity indexes never contained the 0 value and

252 all the t-test for difference from 0 were highly significant ($P < 0.001$), indicating a non

253 random use for all the habitat types. The pioneer vegetation was always avoided in

254 ORNP while in AMNP it was avoided by solitary males but positively selected by leks.

255 Scrublands were always selected, except for solitary males in ORNP that avoided it.

256 Larch forests were selected in all considered cases but not in ORNP leks, where they

257 were avoided. Grasslands were always avoided but in AMNP they were selected by

258 leks. Finally Beech forests, rocky grasslands and rocks were always avoided (Table 3).

259 Ranking the GLM models by ΔAIC_c, we only obtained a best model since all the other

260 had a $\Delta AIC_c > 2$. The model had a pseudo-R^2 of 0.767, a normal distribution of residuals

261 ($P = 0.375$), and absence of spatial autocorrelation ($P = 0.714$). Scrubland and the mean

262 patch size had a significant and positive effect on the number of males attending the

263 leks whereas the mean shape index had a negative effect (Table 4, Fig. 3). The

264 interaction between Shannon index and the ORNP study area had a significant and

265 positive effect. Finally the interaction between scrubland and the ORNP study area had

266 a negative and significant effect on lek size (Table 4).

267 **DISCUSSION**

268 We compared a high male density population with a low one. The choice to investigate

269 only two populations can represent a limit of our study, however from our results we

270 can draw some suggestions to explain the mating system of Black Grouse populations

271 on the Alps.

According to our first hypothesis, we should have found a higher proportion of lekking males in high male density population. Our two populations had a significantly different male density but we did not find any difference in lek size distribution. In both cases half part of observations were solitary males and half were leks. The two populations indeed had a significantly different male density but anyway both were higher if compared to the study of Hoglund & Stohr (1997). In their study they investigated a non lekking population in central Sweden with very low density, between 0.43 males/km^2 in 1995 and 0.80 males/km^2 in 1996, and they found only one lek with two males in 1995 while all the other observations were solitary males. They concluded that the absence of leks was due mostly to the low population density. In our case we cannot draw neither similar nor opposite conclusion but it did not seem to exist a direct effect of density on displaying behavior, at least not at these densities. We can hypothesize that there must be a threshold to which the male density have an effect on the choice of displaying strategy but to demonstrate it for the Alpine population we probably need to compare a higher number of populations, taking into consideration a wider range of density level, starting from those comparable to the low density of the study of Hoglund & Stohr (1997).

Since there were no substantial differences in mating system, we could not verify the second hypothesis for our populations, i.e. lack of suitable habitat to establish leks. Notwithstanding, we found that the two populations showed some differences in habitat selection though the two study areas had few differences in habitat composition, suggesting that male density could have an effect on the choice of habitat to establish leks.

295   The more evident difference in habitat structure was the percentage of beech and larch

296   forests: beech was significantly higher in low density area and larch was significantly

297   higher in high density area. Nevertheless, in both populations the Ivlev's electivity

298   index indicated that males avoided beech forest and positively selected larch forest. This

299   indeed can be the reason for the different males density, since beech forest on the Alps

300   is characterized by closed canopy and thus low quality habitat for Black Grouse

301   (Pearce-Higgins *et al.* 2007)..

302   Pioneer vegetation, according to the pooled observations, was selected by males of high

303   density population and avoided by those of low density population. At a first sight we

304   may conclude that pioneer vegetation represent a low suitable habitat because when

305   competition is low, all males tend to prefer better quality habitat but when the

306   competition is high we expect that even poor habitats are selected (Fretwell & Lucas

307   1970, Van Horne 2002). The presence of pioneer vegetation on the Alps is often a

308   consequence of pasture abandonment that lead to a decrease in open ground habitat and

309   reduces heterogeneity in the landscape (Laiolo *et al.* 2004). The British populations of

310   Black Grouse are negatively affected by the maturation of plantation forestry (Pearce-

311   Higgins *et al.* 2007, Geary *et al.* 2013, White *et al.* 2013). If this is true also for the

312   Alpine populations we would expect that solitary males in high density area were the

313   most likely to select pioneer vegetation, yet we found an avoidance of it by solitary

314   males in both populations and a selection by leks in high density area. Evaluating the

315   selection for grasslands, we found exactly the same result: avoidance by solitary males

316   in low density area and selection by solitary males in high density area, yet a preference

317   by leks in high density area. These two results may indicate that the density-dependence

318   on the selection of these two habitats acts mostly on leks, and not on solitary males.

319 Scrublands were positively selected by pooled and lekking males in both and in pooled

320 study areas but solitary males of low density population avoided it. It is known that

321 open bogs with sparse scrubland is a high quality habitat for Black Grouse because it

322 allows to gather in leks both in Britain (Watson & Moss 2008) and on the Alps

323 (Immitzer *et al.* 2014) but solitary males during the breeding season tend to display on

324 the top of larch trees (Hoglund & Stohr 1997), more than on the ground and actually

325 larch forest was the only habitat positively selected by solitary males of low density

326 population.

327 For the British population of the species it was demonstrated that the quantity of each

328 habitat that is considered suitable changes at different radii around leks and in particular

329 that Black Grouse prefers a complex mosaic with different mixes of habitat immediately

330 around the lek (Geary *et al.* 2013). For our Alpine population we can draw similar

331 conclusion, as our results showed that in almost all considered cases the species

332 positively selected both scrublands and larch forests.

333 From the regression analyses we found that the interaction between scrublands and the

334 low density area had a negative effect on the number of males attending the lek. In

335 contrast in the high density area scrublands have a positive effect on the number of

336 males attending the lek.

337 It also emerged a clear avoidance of low altitude habitats as beech forests and high

338 altitude habitats as rocks and rocky grassland in all considered cases.

339 Besides the differences in habitat composition, the two study areas had difference in

340 habitat structure, as emerged from the comparison between the landscape metrics. High

341 density area had greater habitat diversity with smaller and more complex patches. This

342 may indicate that a more complex habitat is linked to a higher population density.

343 Patthey *et al.* (2012), analyzing habitat preference of both male and female Black

344 Grouse in different study sites of Swiss and Italian Alps, showed that patchy and

345 heterogeneous microhabitats played an essential role for the occurrence of the species.

346 Schweiger *et al.* (2012) also found that a mosaic structure of dwarf shrubs and grassy

347 patches (i.e. high patchiness) generally increased the probability of Black Grouse

348 presence. Nevertheless from our regression analysis we found that the mean shape index

349 had a negative effect on the number of males attending the lek. MSI is equal to 1 when

350 all patches are circular and it increases with increasing patch shape irregularity so a

351 negative effect of it in indicates that plot with more complex shapes have a negative

352 effect on males number in leks. So we may conclude that more complex habitats have

353 indeed a positive effect on population density but that it acts mostly on solitary males

354 rather than on lekking males. The positive effect of mean patch size and the negative

355 effect of the diversity index, although not significant, seem to lead the same conclusion.

356 Finally in the best model we found a positive effect of the interaction between the

357 Shannon index and the low density study area, so we may conclude that a more

358 complex habitat, besides favoring solitary males, has a greater effect on the lek size in

359 low density population, rather than in high density population.

360 Geary *et al.* (2012) identified a clear effect of lek size on lek longevity and resilience,

361 indicating that maintenance of large leks is crucial in buffering the population against

362 declines. This can potentially complicate our findings, because it may be possible that

363 large leks are now present were habitat has changed. We didn't have data about habitat

364 change and not even precise location of single males and leks through the years but it

365 would be interesting to extend our research to a longer term research, following a

similar approach done by White *et al.* (2013), who investigated the role of habitat change in lek establishments and extinctions.

When dealing with habitat and resource selection, the choice of the detail level at which carrying out the analyses, can affect the quality of the results (Brambilla *et al.* 2009). Pearce-Higgins *et al.* (2007) obtained good results on modelling Black Grouse occurrence and lek size when considering the effect of variables such as forest maturation, undergrowth characteristics and moorland habitat composition. In a previous work on habitat selection by breeding Rock Ptarmigan males, we compared the habitat variables obtained from the same land cover digital map that we used in the present work (Land Cover Forestry Map of the Piedmont Region) with a more detailed phytosociological map (Nelli *et al.* 2013). Unfortunately, the same detail level was not available for our two Black Grouse study areas. For the Rock Ptarmigan, with the fine-scale map we obtained more interesting results on habitat selection of the species, but with the forestry map we obtained good predictive models and we were able to obtain useful information as well (Nelli *in press*).

Concluding, with the present study we were not able to properly answer our main question, as we couldn't demonstrate that Black Grouse populations with different density have a different lekking system. Nevertheless from our results we stressed the fact that the patterns of habitat selection in Black Grouse may strongly vary according to the population density. Some normally considered high quality habitat and habitat complexity may in fact play a different role on selection by solitary or lekking males when different population density are considered. Thus we suggest that this remarks should be acknowledged when management decision are taken, in particular it should be

389   necessary to evaluate the potential high quality habitat case by case, considering more

390   than just what has been reported in the literature.

391   **ACKNOWLEDGEMENTS**

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Table 1 - Percentage of lek size distribution in the two separated and pooled study areas and permutation chi-square test. ORNP: Orsiera-Rocciavrè Natural Park; AMNP: Alpi Marittime Natural Park.

Lek size	ORNP	AMNP	Pooled
solitary males	50.9	48.2	49.2
small lek (2-3 males)	31.3	18.5	25.4
medium lek (4-6 males)	6.3	25.9	15.3
big lek (≥7 males)	12.5	7.4	10.1

$\chi^2 = 5.034$
df= 3
P = 0.169

Table 2 - Average values (SE) of habitat variables in the circular plot around the observations of Black Grouse and significance of Kruskal-Wallis ANOVA between the two study areas, divided by pooled observations, solitary males and leks.

Variables	Pooled Observations		Solitary males		Leks	
	ORNP	AMNP	ORNP	AMNP	ORNP	AMNP
Pioneer vegetation	0.6 (0.37)	6.6 (2.10)**	1.0 (0.73)	4.1 (1.72)	0.1 (0.09)	8.8 (3.7)*
Scrubland	26.3 (4.14)	26.9 (4.37)	14.8 (4.78)	31.8 (6.53)	37.7 (5.49)	22.3 (5.81)
Beech forest	2.1 (1.56)	17.9 (4.08)**	4.2 (3.08)	17.3 (5.05)*	0.0 (0.02)	18.4 (6.51)**
Larch forest	42.1 (5.07)	15.7 (4.54)**	49.8 (7.04)	17.0 (7.69)*	34.3 (6.97)	14.5 (5.34)*
Grassland	18.9 (2.7)	17.2 (2.77)	22.2 (4.32)	15.7 (3.69)	15.6 (3.17)	18.6 (4.19)
Rocky grassland	4.6 (1.47)	6.1 (1.41)	5.1 (2.19)	6.5 (1.73)	4.1 (2.02)	5.8 (2.26)
Rocks	5.1 (1.57)	9.6 (3.21)	2.0 (0.87)	7.5 (3.36)	8.2 (2.85)	11.6 (5.43)
Altitude	1927 (26.9)	1845 (32.7)	1900 (46.0)	1857 (45.4)	1954 (28.0)	1835 (48.3)
Slope	24.6 (0.49)	25.3 (0.64)	24.9 (0.74)	25.8 (0.91)	24.2 (0.65)	24.8 (0.92)
Solar radiation $\times 10^3$	88.4 (0.90)	87.1 (0.90)	89.4 (1.64)	87.5 (1.66)	87.5 (0.76)	86.8 (0.88)
MSI	1.7 (0.02)	1.6 (0.01)**	1.8 (0.03)	1.6 (0.01)**	1.7 (0.04)	1.6 (0.02)*
MPS $\times 10^3$	61.6 (4.71)	31.9 (3.84)**	73.2 (7.95)	25.8 (4.55)**	50.0 (3.22)	37.6 (5.84)*
ED	6.9 (0.26)	10.4 (0.47)**	6.4 (0.44)	11.2 (0.65)**	7.3 (0.23)	9.6 (0.61)*
Shannon	1.6 (0.1)	2.0 (0.08)*	1.5 (0.15)	2.0 (0.14)*	1.7 (0.12)	1.9 (0.08)

ORNP: Orsiera-Rocciavrè Natural Park
AMNP: Alpi Marittime Natural Park.MSI – mean shape index
MPS – mean patch size
ED – edge density
* - significant difference at 0.05
** - significant difference at 0.001

Table 3 – Average values (SE) of Ivlev's electivity indices for habitat selection of Black Grouse on the Italian Alps. Positive values indicate preferences and negative values indicate avoidance of a particular habitat.

Habitat	Pooled observations			Solitary			Lekking		
	ORNP	AMNP	PSA	ORNP	AMNP	PSA	ORNP	AMNP	PSA
Pioneer vegetation	-0.34 (0.010)	0.19 (0.005)	-0.21 (0.005)	-0.12 (0.014)	-0.04 (0.007)	0.05 (0.006)	-0.80 (0.004)	0.30 (0.007)	0.28 (0.008)
Scrubland	0.07 (0.002)	0.14 (0.002)	0.17 (0.002)	-0.23 (0.005)	0.22 (0.003)	0.08 (0.003)	0.25 (0.002)	0.03 (0.004)	0.24 (0.002)
Beech forest	-0.34 (0.011)	-0.14 (0.004)	-0.05 (0.004)	-0.03 (0.014)	-0.17 (0.005)	-0.01 (0.005)	-0.99 (0.000)	-0.15 (0.006)	-0.11 (0.007)
Larch forest	0.10 (0.002)	0.14 (0.004)	0.01 (0.002)	0.18 (0.002)	0.12 (0.008)	0.08 (0.003)	-0.01 (0.003)	0.09 (0.006)	0.09 (0.003)
Grassland	-0.12 (0.002)	0.02 (0.002)	-0.08 (0.002)	-0.04 (0.003)	-0.03 (0.004)	-0.06 (0.002)	-0.22 (0.003)	0.05 (0.003)	-0.11 (0.002)
Rocky grassland	-0.15 (0.005)	-0.26 (0.003)	-0.17 (0.003)	-0.13 (0.007)	-0.24 (0.004)	-0.14 (0.004)	-0.22 (0.008)	-0.31 (0.006)	-0.22 (0.005)
Rocks	-0.31 (0.004)	-0.22 (0.005)	-0.22 (0.004)	-0.65 (0.004)	-0.35 (0.006)	-0.43 (0.005)	-0.10 (0.006)	-0.15 (0.007)	-0.08 (0.005)

PSA: pooled study areas

ORNP: Orsiera-Rocciavrè Natural Park

AMNP: Alpi Marittime Natural Park.

Table 4 – Coefficients (β) of general linear model for Poisson distribution of lek size vs. habitat variables in the two considered study areas.

Variable	β	LCI	UCI	*P*
(Intercept)	1.390	1.039	1.715	< 0.001
Scrubland	0.329	0.075	0.577	0.010
MPS	0.257	0.057	0.455	0.011
MSI	-0.455	-0.718	-0.191	0.001
Shannon	-0.123	-0.618	0.357	0.620
Study area (ORNP)	0.435	-0.042	0.907	0.359
Scrubland*Study_area(ORNP)	-0.878	-1.286	-0.477	< 0.001
Shannon*Study_area(ORNP)	0.625	0.110	1.159	0.019

LCI= 95% lower confidence interval
UCI = 95% upper confidence interval mean patch size
MPS = mean patch size
MSI = mean shape index

Figure 1 – Location of the two study areas in Piedmont Region on the Western Italian Alps.ORNP: Orsiera-Rocciavrè Natural Park; AMNP: Alpi Marittime Natural Park.

Figure 2 – Lek size distribution in the two separated and pooled study areas. ORNP: Orsiera-Rocciavrè Natural Park; AMNP: Alpi Marittime Natural Park.

Figure 3 – Number of males attending the leks in the two pooled study areas as a linear function of percentage of scrubland, mean patch size (MPS) and mean shape index (MSI) in a 500m circular plot around the lek.
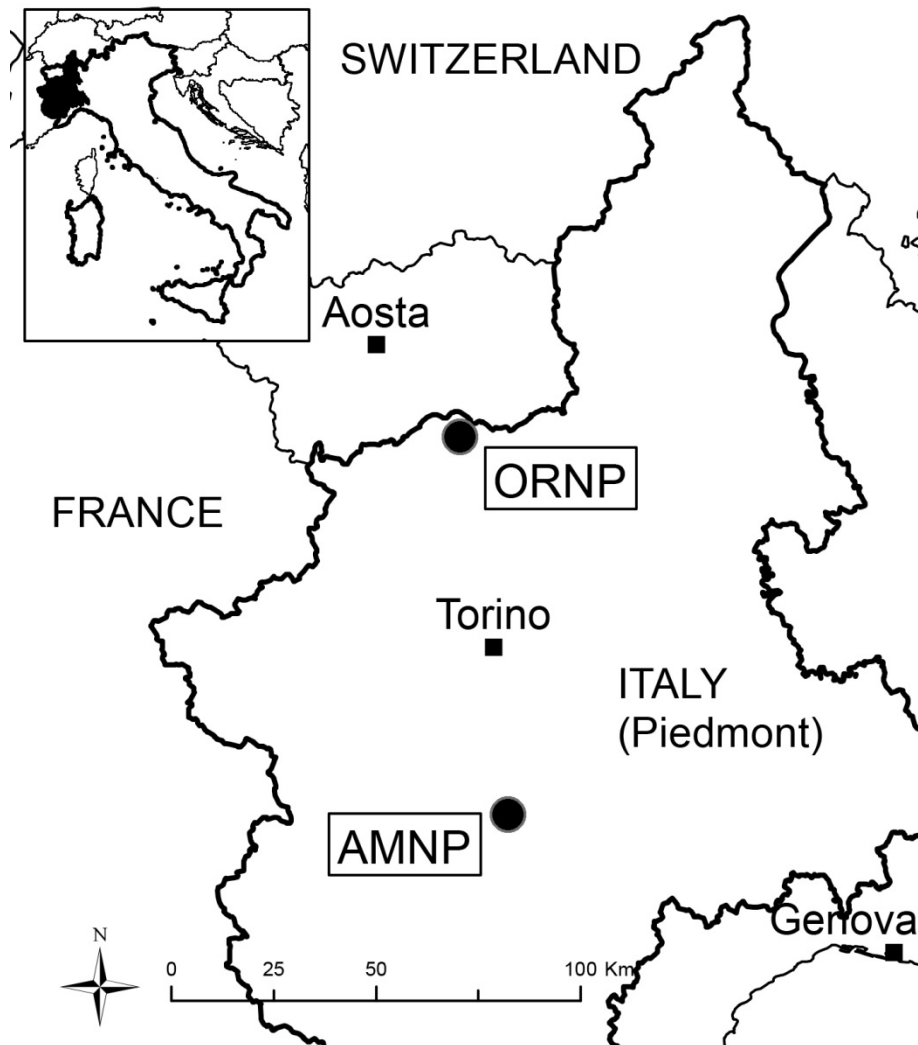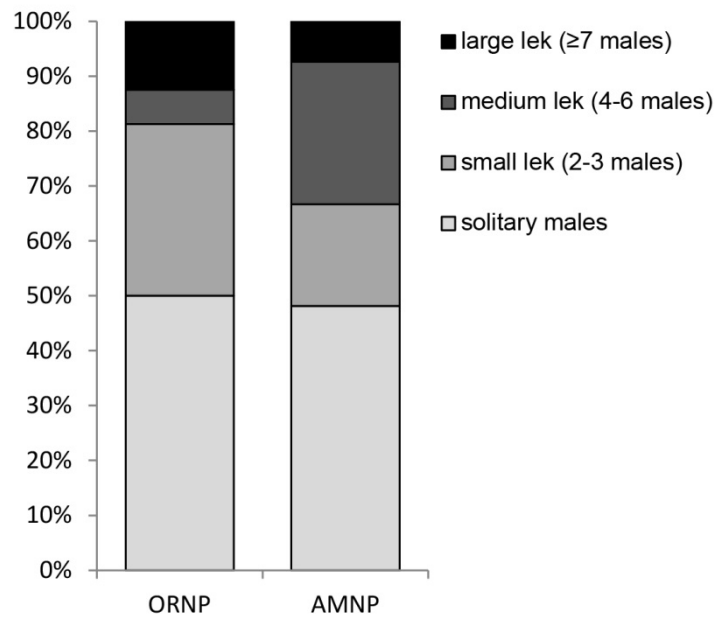
Figure 1

Figure 2

Figure 3