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Original article

Habitat selection by breeding rock ptarmigan *Lagopus muta helvetica* males in the western Italian Alps

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Knowledge of resource selection patterns can provide important information for species conservation. During spring 2010 and 2011, we investigated habitat selection by territorial rock ptarmigan *Lagopus muta helvetica* males in a protected area of the western Italian Alps. We located males from 30 randomly selected survey points, and we measured the proportions of cover-type categories found within a 37-ha area surrounding each observed bird using three classification maps of differing information and resolution. We also evaluated physical variables (altitude, slope and solar radiation) associated with the birds using a 75-m digital terrain model. We modelled land cover and physical attributes under these three alternative land-classification maps. The lowest resolution map, based on the Corine land-cover map, did not have high predictive value because only orographic variables described the presence of birds; in our case, we found a negative effect of slope and a positive effect of altitude on presence of ptarmigan. The next higher resolution map, a local forest resource map, showed that slope had a negative effect and rocky grasslands had a positive effect on ptarmigan presence. Finally, using the highest resolution map, a phytosociological map of our Natural Park study area, the best-ranked models were those having only cover-type variables, with alpenrose *Rhododendron ferrugineum* and blueberry *Vaccinium myrtillus* scrubland and pioneer vegetation negatively correlated with the presence of rock ptarmigan. We concluded that a staged approach that uses maps of differing detail was successful for obtaining useful information on rock ptarmigan habitat selection, but the most interesting results about rock ptarmigan habitat selection at the scale of breeding territories were obtained only using a very detailed vegetation map. Because such detailed information is difficult to obtain on larger scales, we suggest wildlife managers cooperate to build similar mapping tools that allow analyses similar to ours.

Key words: habitat selection, Italian Alps, Lagopus muta helvetica, land-cover maps, rock ptarmigan.

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While habitat selection is a hierarchical process (Johnson 1980), evaluating selection at a particular scale can be important for management (Graf et al. 2005, Schweiger et al. 2012).The rock ptarmigan *Lagopus muta* is a species for which this contention probably holds. Although it is widespread and classified generally as a species of Least Concern by the Global IUCN Red List Category and Criteria, in Italy the subspecies *L. m. helvetica* is declining and is listed on the Italian Red List as Vulnerable (Peronace et al. 2012). Italian populations have a discontinuous distribution (De Franceschi 1992, Spagnesi & Serra 2004) and spring densities are lower than in the rest of the subspecies range (Bocca 1990, Favaron et al. 2006, Lubrini 2006, Clementi et al. 2008, Zohmann & Wöss 2008, Nelli 2012).

The main reasons for this decline are degradation, fragmentation and loss of suitable habitat, climate change, disturbance factors such as sport activities (e.g. skiing), poaching and overhunting (Storch 2000a,b, Watson & Moss 2004, Rotelli 2006, Storch 2007a,b). Thus, it is important to identify the habitat conditions that are correlated with breeding areas so that such areas can either be conserved or other areas be managed to foster these characteristics. In species-habitat relationship studies, the scale at which dependent and independent variables are measured can strongly influence the quality of the results. Therefore, the choice of variable resolution represents a crucial step in the beginning of any habitat selection investigation (Cushman & McGarigal 2004).

Therefore, our main objectives were 1) to identify habitat requirements of rock ptarmigan at the scale of the breeding territory using resource selection methods, and 2) to evaluate the effect of map resolution on results.

Material and methods

Study area

Our study area (14.5 km^2) was the northeastern part of Veglia-Devero Natural Park in the western Italian Alps, close to the border of Switzerland (Fig. 1). Our study area had three main plateaus, each at different altitudes. Mean altitude was 2,387 m a.s.l. (minimum: 2,009 m a.s.l., maximum: 2,694 m a.s.l). The main cover types were alpine grasslands (50.0%), bare rocks (21.2%) and rocky grasslands (20.5%). The climate was alpine with an average yearly temperature of 4.6°C (minimum in January: -4.4°C, maximum in July: 12.4°C) and annual average precipitation of 1,467 mm, falling primarily as rain in the summer (meteorological station, data from 1991 to 2012, available at: http://www.regione.piemonte.it/ambiente/aria/rilev/ariaday/annali/idrologici).

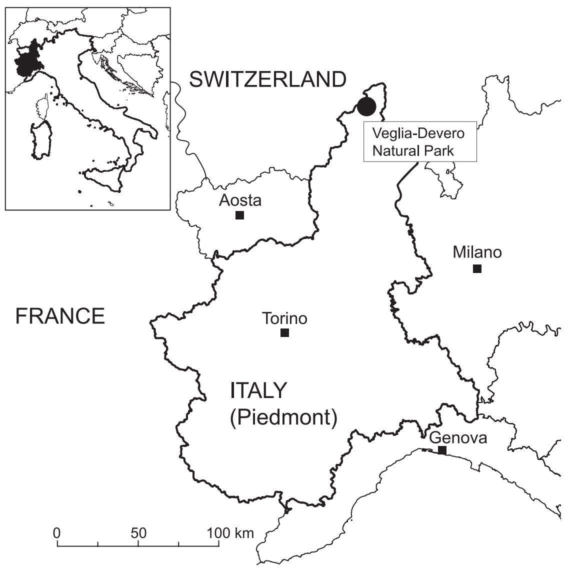

Figure 1. Location of our study area.

Data collection

We conducted surveys from 20 May - 20 June in 2010 and 2011, using counts of calling cocks. We established 30 random sampling points within our study area using a GIS (ArcGis 10.1). Each point was sampled for 60 minutes during the hours of maximal calling activity (04:00-05:30; Wöss & Zohmann 2004, Nopp-Mayr & Zohmann 2008). We recorded each calling cock and the exact time of each call. We then mapped each bird position on aerial photographs (1:5,000 scale) and later transferred them to our GIS. By comparing time and the mapped positions, we eliminated double counts.

Around each bird detected, we designated a circle of 343.3 m (37 ha), which corresponded to the estimated average core area of a male rock ptarmigan during the breeding season (Favaron et al. 2006). Using our GIS and cover-type maps, we estimated the proportions of cover-type categories within each sampling area. In particular, we used three different digital maps: 1) the Corine Land Cover (CLC; European Environment Agency 2007), 2) the forestry and other land-use categories map of the Piedmont Region (FMP) and 3) the phytosociological map of the Veglia-Devero Natural Park (PSM). The three maps have increasing detail in terms of the number of cover types classified in our study area and polygon dimension (Fig. 2). The CLC is a European digital map obtained from satellite images recorded in 2006 (± 1 year), available for the whole of Europe. The nominal scale is 1:100,000, the minimum mapped unit is 25 ha and the minimum polygon width is 100 m. It classified our study area into three categories. The FMP has a higher resolution with the minimum polygon for our study area being 0.15 ha. This map is available only for the Piedmont Region and classified our study area into seven categories. Finally, the PSM has the highest resolution of the three maps, and our study area was classified into 10 different categories with a minimum mapped polygon being 0.01 ha. It was available only for the Veglia-Devero Park. We also used a 75-m digital terrain model to estimate several orographic variables. These orographic variables were the average and standard deviation of altitude, slope and the amount of solar radiation during the period of our study. We estimated the standard deviation of altitude to evaluate whether ptarmigan were found over an

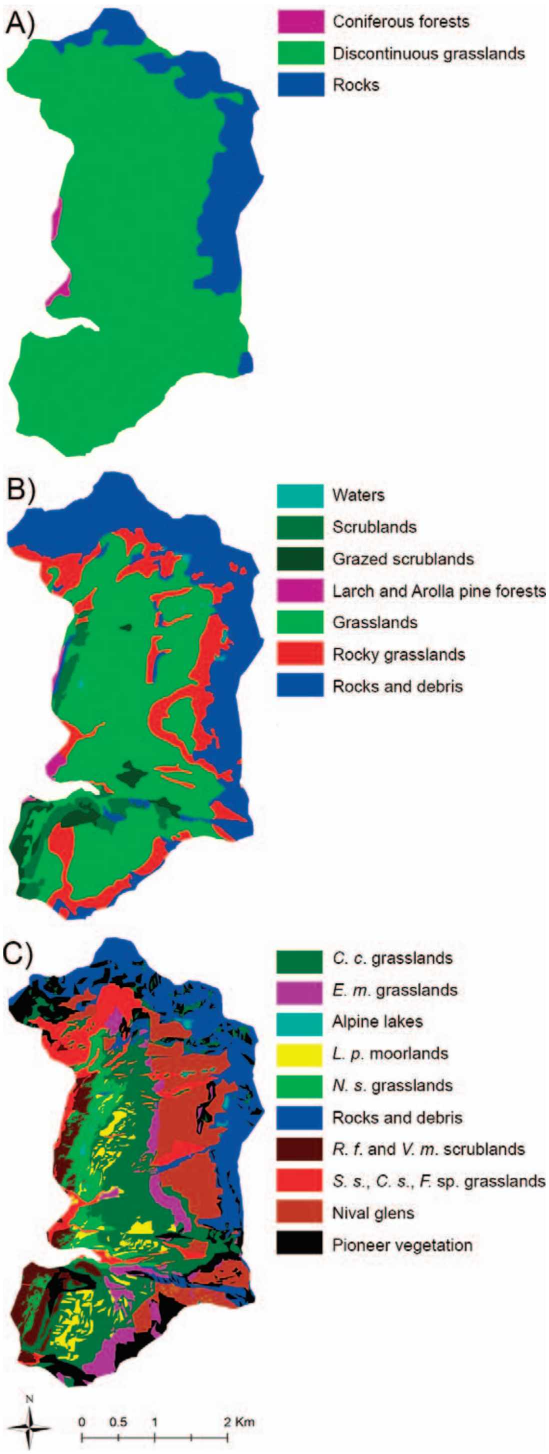

Figure 2. Land-use of our study area and classifications of the three digital mappings A) Corine land cover, B) forestal map of Piedmont region and C) phytosociological map of Veglia-Devero natural Park. *C. c.* = *Carex curvula*, *E. m.* = *Elina myosuroides*, *L. p.* = *Loiseleuria procumbens*, *N. s.* = *Nardus stricta*, *R. f.* = *Rhododendron ferrugineum*, *V. m.* = *Vaccinium myrtillus*, *S. d.* = *Sesleria disticha*, *C. s.* = *Carex sempervires* and *F.* sp. = *Festuca* sp.

altitudinal gradient or within a restricted altitudinal range. The solar radiation accounts for how daily and seasonal shifts of sun angle, along with variations in elevation, orientation (slope and aspect) and shadows cast by topographic features, affect the amount of solar radiation, expressed as Wh/m^2.

Data analysis

We used distance sampling to estimate the density of breeding males (Buckland et al. 2001). To evaluate the effect and the importance of habitat variables on male ptarmigan presence, we formulated different resource selection functions (RSF) following a use vs availability design (Boyce et al. 2002). In particular, we used logistic regression analyses to identify characteristics of cock territories relative to an equal number of random locations. We measured these characteristics (predictor variables) within a 37-ha circle surrounding these locations. To compare the three different cover-type maps, we developed three groups of models, each composed of variables derived from the cover-type map and orographic variables. We also included a quadratic effect of altitude and slope because we hypothesised there might be an optimal altitude or slope, a year effect and the interactions between year and altitude and between year and slope because the optimal conditions at physical locations might vary.

We conducted an exploratory analysis with each group of models. We assessed correlations by estimating Pearson product moment coefficients among habitat variables, and we identified all the possible subsets of uncorrelated ($P > 0.05$) predictor variables.

We used an information theoretic approach to rank the subsets in each group of models (Akaike 1973). We computed the corrected value of Akaike's information criterion (AIC_c) because we had a small sample size (Burnham & Anderson 2002). We selected the model with the lowest AIC_c as the best model, ranking the following ones by their differences from the lowest AIC_c (Δ_i). Furthermore, we measured the relative importance of models by their Akaike weights (w_i; Anderson et al. 2000, 2001). Finally, we used model averaging of models with $AIC_c < 2$ from the top model to obtain the model averaged coefficients and to rank them according to their predictive importance ($\sum w_i$). To validate the final models, we tested their performance by the percentage of correct classifications of original cases and Receiver Operating Characteristic (ROC) curve analysis.

Table 1. Top models for predicting male rock ptarmigan presence in the western Italian Alps based on variables derived from three cover-type maps and orographic variables. CLC = Corine land cover map, FMP = forest resources map of the Italian Piedmont Region, PSM = phytosociological map of Veglia-Devero Natural Park, DTM = orographic variables from the digital terrain model. Alt_SD = standard deviation of altitude, alt = average altitude, *R. f.* = *Rhododendron ferrugineum*, *V. m.* = *Vaccinum myrtillus*, *C. c.* = *Carex curvula* and *L. p.* = *Loiseleuria procumbens*. AIC_c = Akaike's Information Criterion corrected for small sample size, w = Akaike weight.

Group of models	Variables	AIC_c	ΔAIC_c	w
CLC + DTM	Alt_SD	231.74	0.00	0.28
	Alt + alt_SD + Alt	232.01	0.27	0.25
	Alt_SD + solar radiation	232.65	0.91	0.18
	Alt + alt_SD	233.02	1.28	0.15
	Alt_SD + rocks	233.10	1.36	0.14
FMP + DTM	Alt_SD + rocky grassland	221.70	0.00	0.56
	Alpine lakes + alt_SD+ rocky grassland	223.48	1.79	0.23
	Alt + alt_SD+ rocky grassland	223.60	1.90	0.21
PSM + DTM	*R. f.* and *V. m.* scrubland + pioneer vegetation	227.11	0.00	0.51
	C. c. grassland + *R. f.* and *V. m.* scrubland + pioneer vegetation	228.25	1.14	0.29
	L. p. moorland + *R. f.* and *V. m.* scrubland + pioneer vegetation	229.02	1.91	0.20

Results

We detected 88 male rock ptarmigan during our two-year study (46 in 2010 and 42 in 2011). We estimated a density (± SE) of 6.0 ± 1.35 males/km^2 in 2010 and 5.5 ± 0.99 males/km^2 in 2011.

The variables derived from the CLC map showed no support in predicting the presence of male rock ptarmigan. The highest ranked models within the first group were those that included only orographic variables (Table 1). The most important variable was standard deviation of altitude, with a negative effect. The second most important variable was the average altitude, with a positive effect (Table 2). These results suggest that male rock ptarmigan are found at high elevations, but within a narrow altitudinal range characterised by more gentle slopes. Among competing models, 'Rocks' was the only variable included in a model that was not specifically an orographic variable, but it had the lowest predictive importance.

Table 2. Model-averaged coefficients (β) of land-use and orographic variables for prediction of male rock ptarmigan presence in Veglia-Devero Natural Park, Italy. Results are subdivided in three groups, each starting from the variables of the cover-type map and the orographic variables. CLC = Corine land cover map, FMP = forest resources map of the Italian Piedmont Region, PSM = phytosociological map of Veglia-Devero Natural Park, DTM = orographic variables from the digital terrain model. Alt_SD = standard deviation of altitude, alt = average altitude, *R.f.* = *Rhododendron ferrugineum*, *V.m.* = *Vaccinum myrtillus*, *C.c.* = *Carex curvula* and *L.p.* = *Loiseleuria procumbens*. LCI = 95% lower confidence interval, UCI = 95% upper confidence interval, w = Akaike weights.

Group of models	Variable	β	LCI	UCI	$\sum w$
CLC + DTM	Alt_SD	-2.940×10^{-2}	-0.045	-0.014	1.00
	Alt	3.646×10^{-2}	-0.039	0.112	0.40
	Alt^2	-1.200×10^{-5}	-2.612×10^{-5}	2.040×10^{-6}	0.25
	Solar radiation	8.403×10^{-4}	0.000	0.002	0.18
	Rocks	4.426×10^{-3}	-0.006	0.015	0.14
	(Intercept)	-17.301	-24.276	-10.324	-
FMP + DTM	Alt_SD	-0.030	-0.046	-0.014	1.00
	Rocky grassland	0.036	0.014	0.058	1.00
	Alpine lakes	0.103	-0.265	0.471	0.23
	Alt	0.001	0.000	0.002	0.21
	(Intercept)	0.006	-2.773	2.785	-
FSM + DTM	*R. f.* and *V. m.* scrubland	-0.033	-0.062	-0.004	1.00
	Pioneer vegetation	-0.074	-0.113	-0.035	1.00
	C. c. grassland	-0.007	-0.021	0.007	0.29
	L. p. moorland	0.008	-0.029	0.045	0.20
	(Intercept)	0.743	0.235	1.251	-

This indicates that rocky habitats were positively correlated with ptarmigan although the positive effect was not significant. The average CLC model took the following form (see Table 2):

$$\text{probability of presence} = e^{z}/(1 + e^{z})$$

where z = - 17.301 - 2.940 × 10^{-2} × alt_SD + 3.646 × 10^{-2} × alt - 1.200 × 10^{-5} × alt^2 + 8.403 × 10^{-4} × solar radiation + 4.426 × 10^{-3} × rocks. The model correctly classified 63.1% of the original cases, and the area under the ROC curve was significantly greater than that of a model that randomly classified the cases (AUC = 0.674, $P < 0.001$).

Considering the FMP map, three models predicted male rock ptarmigan presence well (see Table 1). The best model was the one that included the standard deviation of altitude and rocky grassland. The second-ranked and competing model was similar to the top-ranked model, but also contained the variable 'Alpine lakes'. However, the most important variable was, again, the standard deviation of altitude with a negative effect and the rocky grassland with positive effect on ptarmigan presence (see Table 2). This result again suggested that in zones at high altitude with predominantly rocky habitats, male rock ptarmigan will be more likely to be detected.

In the average FMP model, we had z = 0.006 - 0.030 × alt_SD + 0.036 × rocky grassland + 0.103 × alpine lakes + 0.001 × alt (see Table 2). The model correctly classified 64.2% of the original cases and the area under the ROC curve was significantly greater than that of a model that randomly classified the cases (AUC = 0.741, $P < 0.001$).

The best ranked models obtained using the PSM map variables did not include any orographic variable (see Table 1). Alpenrose *Rhododendron ferrugineum*, blueberry *Vaccinium myrtillus* and pioneer vegetation were the most important variables in the top model and both were negatively associated with male rock ptarmigan presence. Alpine sedge *Carex curvula* grassland also had a negative effect, but it was not significant (see Table 2). Alpine azalea *Loiseleuria procumbens* moorland was the only variable with a positive effect, but had the lowest predictive importance (see Table 2). In the average PSM model, we had z = 0.743 - 0.033 × *R. f.* and *V. m.* scrubland - 0.074 × pioneer vegetation - 0.007 × *C. c.* grassland - 0.008 × *L. p.* moorland (see Table 2). The model correctly classified 72.2% of the original cases, and the area under the ROC curve was significantly greater than that of a model that randomly classified the cases (AUC = 0.761, $P < 0.001$).

Discussion

In the first two groups of models, which represented the lowest and intermediate level resolution maps, we found a positive effect of the average altitude and a negative effect of its standard deviation, indicating that male rock ptarmigan selected zones characterised by high altitude, but within a narrow elevational range and gentler slope than random locations (Bocca 1986, 1990, De Franceschi & Bottazzo 1991, Favaron et al. 2006, Zohmann & Wöss 2008). In our study, we did not directly include aspect as a predictor variable, but we used the integrated metric of solar radiation to reduce the number of variables and to include only continuous variables in the model. In the first group of models, solar radiation had low predictive importance but a positive effect. Solar radiation is strongly influenced by aspect, and a selection for solar radiation can be interpreted as a general preference for south-facing slopes, in contrast with that reported by Revermann et al. (2012). This apparent contradiction can be explained by the sampling method that we used. We sampled males during the first hours of the day when birds displayed in the first areas exposed to morning sun. Furthermore, the reproductive success of rock ptarmigan is demonstrated to be positively related to an early date of snowmelt (Novoa et al. 2008, Wilson & Martin 2010), so we hypothesise that the territories that confer higher chick survival are already selected when our sampling occurs.

According to the first two groups of models, rocks and rocky grasslands were positively selected. Many authors describe rocky habitats as a very important factor to define the suitable habitat for the rock ptarmigan (Favaron et al. 2006, Wilson & Martin 2008, Revermann et al. 2012). However, it is difficult to find a biological explanation for the positive relationship between alpine lakes and bird presence. The zones around the lakes could be particularly rich in arthropods and this could constitute an advantage for the survival of chicks during the first weeks of life, or it is a simple artifact of sampling. Another possible explanation is that the lakes are found in plain zones, which confirms the negative relationship with standard deviation of altitude.

With the third group of models, we obtained information about the selection of resources from phytosociological conditions. Alpine sedge grasslands were probably avoided because they lack rocks and diversified vegetation that provide food resources, nesting sites, sentry points and shelter from predators and severe weather (Schweiger et al. 2012). Furthermore, these grasslands in our study area were usually used by cattle for grazing during the summer, which could impact them negatively. Alpine azalea moorlands were represented in the FSM as tiny but numerous polygons that were concentrated especially within zones of Alpine sedge grasslands. The selection of Alpine azalea moorlands could thus indicate a preference for grasslands characterised by a certain discontinuity of space and species and structural diversity of vegetation as has been documented in previous studies (Bossert 1995, Favaron et al. 2006, Zohmann & Wöss 2008). It could also mean that the specific elements found within the moorlands themselves are important. Pioneer vegetation in our study area was represented substantially by *Asplenietea rupestris* and *Thlaspietea rotundifolii* on predominantly rocky substrata in the highest zones of the study area, which corresponded to many mountain peaks, so the avoidance of this habitat may have been related to avoidance of high slopes. The lack of correlation with alpenrose and blueberry can be explained by the timing of our study because these habitats are selected by rock ptarmigan, especially in fall and winter when they move to lower altitudes. In particular, a study conducted in the Carnic Alps (De Franceschi 1992) reported that the percentage of alpenrose and blueberry in the diet of rock ptarmigan increase from September to December. Furthermore, Revermann et al. (2012) showed how these habitats were good predictors of ptarmigan at the macro scale but not territory scale.

Our results showed that the orographic variables were important predictors of male rock ptarmigan territories during the breeding season, especially when cover-type variables were measured with a low level of detail. As predicted, the CLC alone was not appropriate to give reliable results because all the orographic variables in the models with the most predictive power had a higher weight than the habitat variables derived from the CLC.

The use of the FMP provided more informative results. Using the FMP, we obtained three models that contained, in addition to the orographic variables, two variables of the land use.

When we used the most detailed map, the PSM, the orographic variables did not enter any of the highest-ranked models and the presence of male rock ptarmigan was explained entirely by the vegetation variables. Furthermore, the average model of the PSM group was the best model in terms of validation.

The resolution of the CLC is not useful for a study that takes into consideration a core area of < 40 ha like that of rock ptarmigan males, but at the moment it is the only digital map that homogeneously covers the entire Alpine Arc, not only in Italy, but also in the whole of Europe. The FMP has a higher resolution, but this map is available only for the Piedmont Region. Other regions in Italy and the Alps have similar maps, but the data and resolution are patchy so it would be hard to compare results using similar analyses in different areas of the Alps. Finally, the PSM has a very high resolution. This map allows obtaining important information about the habitat selection of the male rock ptarmigan during the breeding season. Nevertheless, the editing of such a phytosociological map is complicated, time consuming and expensive, so it would be difficult to obtain similar information as our study on a larger scale.

Identifying suitable breeding areas for a species of conservation concern, such as the rock ptarmigan in the Alps, is of fundamental importance. With our study, we were able to obtain useful results because we had access to detailed information derived from the PSM. Because it is difficult to obtain such information on a larger scale, we suggest that cooperation among parks, hunting districts and other public administrations in charge of wildlife management should occur to build similar maps to allow analyses similar to ours, but on larger scales.

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