Central Apennines Rewilding Area:
habitat and species assessment in a sample area

Simone Giovacchini
Piero Visconti
Mario Cipollone

November 2019

Table of contents

List of Figures

List of Tables

1. Introduction

Biodiversity is indissolubly linked with life. Humane life depends on ecological functions of ecosystems and biosphere, and these so-called “ecosystem services” (MEA 2005; IPBES 2019) – in a very anthropocentric point of view – have such a primary importance as they provide also an economic value. So, biodiversity supports ecological, economical and also social aspects of human life (Chivian and Bernstein 2008; IPBES 2019).

But biodiversity is decreasing all over the world. The first global threat to biodiversity is habitat loss, degradation and fragmentation, mainly due to the change of human land use (IUCN 2004; Primack et al. 2013). It is urgent to find solutions for sustainable land planning in order to guarantee a balance between nature exploitation and ecosystem functions, which are provided over time. On the other hand, we need to counteract the biodiversity loss we recorded in the last decades, trying to restore ecosystems and to save endangered species.

Rewilding Europe is a non-profit organization trying to enhance wilderness in Europe, bringing back wildlife and restoring natural processes. To understand if management actions are effective, it is necessary to monitor the areas where the organization is working (McComb et al. 2010). Well-planned monitoring is very important and useful, especially if used in an adaptive management framework. Management actions can be corrected if the results of the monitoring are not affecting dependent variables of the considered system. Therefore, Rewilding Europe has proposed a monitoring system, called Rewilding Scale, based on some quantitative parameters connected with habitat, wildlife and landscape connectivity for wildlife (Table 1), in order to assess progress in those so-called Rewilding Areas.

As in many other parts of the world, the landscapes and environments in the Central Apennines have changed over centuries due to humane activities. This has historically been linked to sheep-farming as a subsistence economy, meaning parts of this Rewilding Area are rich in grasslands. Forests are still present and well-represented in the territory, where a lot of charismatic species, including the Marsican brown bear (*Ursus arctos marsicanus*), still inhabit. This bear population, usually recognized as a separate subspecies of brown bear (Loy et al. 2008; Colangelo et al. 2012; Guidarelli et al. 2016), is considered the most threatened bear population in the world, with approximately fifty individuals surviving in the Central Apennines of Italy (Ciucci et al. 2015). After years of conservation efforts, the Marsican brown bear remains on the brink of extinction (Rondinini et al. 2013). The only hope of long-term survival is to increase population size through conservation actions aimed at reducing mortality (AA.VV. 2011), with recent evidence suggesting some positive outcomes (Marsican Bear Report 2017, 2018; A. Monaco, pers. com.).

The Central Apennines Rewilding Area surrounds the core area of this endangered species, in particular, known corridors of expansion. This territory has a very strategic position to support the expansion process, either just within this territory or to national and regional protected areas, which include extensive habitat for this species (Ciucci et al. 2016). We can understand the real use of this marginal area by bears through field studies, which validate past spatially explicit models (i.e. Ciucci et al. 2016). These studies can provide new land management indications for the conservation of this focal species in the area of interest, in order to find the suggested balance between biodiversity and human land use.

Camera-trapping is among the most modern methods used to investigate the presence of a species within a determined area, and it is particularly used to provide information about elusive species, such as bears (Wearn and Glover-Kapfer 2017). The actual effectiveness of camera-trapping is supported by comparative studies (Wearn e Glover-Kapfer 2019). Camera traps are either equally effective or superior to other wildlife survey methods (acoustic recording, eDNA, trapping sessions, presence sign surveys, etc.) in terms of generating accurate occupancy data. Particularly, camera-trapping is very suitable for broad-spectrum biodiversity surveys, as it is the best way to detect a large number of species (Wearn e Glover-Kapfer 2019). In addition, camera traps also provide images and videos that can be used as digital museum specimens or powerful visual aids for outreach, lobbying and community engagement.

The purpose of this work is to provide a starting survey on the presence and distribution of habitats and fauna of interest, according to the Rewilding Scale criteria (Table 1). Using the same criteria and methodologies it will be possible to implement a monitoring system that determines if variables of interest will change over time. In this work we will particularly determine:

- Indicators 1.1, 2.1 and 3.1 (Table 1) concerning land use, inferred by land cover databases, acquired with standardized remote sensing techniques developed by European Agencies.
- Indicators 6- and 7.1, and 6- and 7.2 (Table 1) concerning large fauna, acquired by a camera-trapping survey, which was conducted with the aim to acquire data primarily on the Marsican bear.

The survey design which has been described in 2.1.2 has the finality of acquiring data to realize an occupancy model. This result is not included in this report due to the large quantity of images yet to be classified (over 40 000).

Habitat indicators				
Wilder Forests	**1.1** % of the area with spontaneous or native forests	**1.2** % of the forests in which dead wood is a significant proportion of timber volume	**1.3** % of the forest with a natural impact of beetles, storm and fire	**1.4** % of the production forests, changed into non-managed forests
Wilder Mosaics	**2.1** % of the area with natural mosaics and transitions between forests and grasslands	**2.2** % of mosaics/transitions, changed from managed into natural succession	-	-
Wilder Grasslands	**3.1** % of the area with natural grazed open/semi-open habitats	**3.2** % of arable fields, turned into natural grazed habitats	**3.3** % of mown grasslands, turned into natural grazed grasslands	-
Wilder Deltas	**4.1** % of the area with natural marshlands	**4.2** % of the area with natural estuary	**4.3** % of the area with natural coastal waters	**4.4** % of the coastline with natural habitats
Wilder Rivers	**5.1** % of the original floodplain with natural flooding system	**5.2** % of river length without dams	**5.3** % of river length with natural erosion/sedimentation	-
Wildlife indicators				
Herbivory	**6.1** % of indigenous/key large herbivores present	**6.2** % of the area with key large herbivores	**6.3** Density of key large herbivores in the area	**6.4** % of the area without hunting
Carnivory	**7.1** % of indigenous/key large carnivores present	**7.2** % of the area with key large carnivores	**7.3** Density of key large carnivores in the area	**7.4** % of the area without hunting/poaching
Scavenging	**8.1** % of indigenous/key large scavengers present	**8.2** % of the area with dead large animals left in nature	**8.3** Density of key large scavengers in the area	**8.4** % of the area without poisoning
Connectivity indicators				
Terrestrial	**9.1** max. dispersal distance for large mammals without obstacles (roads, fences)	**9.2** max. dispersal distance for large mammals without hunting	-	-
Aquatic	**10.1** % of river length without impassable dams	**10.2** % of migratory fish species present	**10.3** % of the river length without fishing	-

Table 2. Rewilding Europe's Rewilding Scale indicators.

2. Methods

2.1 Camera-trapping

2.1.1 Study area

Camera-traps were deployed in a 61 km^2 area located between the municipalities of Anversa degli Abruzzi, Villalago and Bugnara (province of L'Aquila, Abruzzi; Fig. 1) and identified with the criteria explained below in 2.2.2. In this area, the northern ridges of the Abruzzo, Lazio and Molise National Park (ALMNP) mountains run south to north, and are divided by the Sagittario river which flows northwards parallel to these chains. This is exactly in the middle of the study area, shaping a very deep valley with impressive rocky gorges. Upstream, not so far out of the study area, the river is dammed in an artificial lake. Natural habitat types are based on limestone substrates, and are represented by summit grasslands, broad-leaved woods (hornbeam, oak, beech, pine trees), and varied (Fig. 2). Altitudes range between 550 and 1,850 masl. The average human density in the municipal areas is 11 /km^2 but the highest values of humane presence are in the lowlands, which are 4-5 km out of the study area.

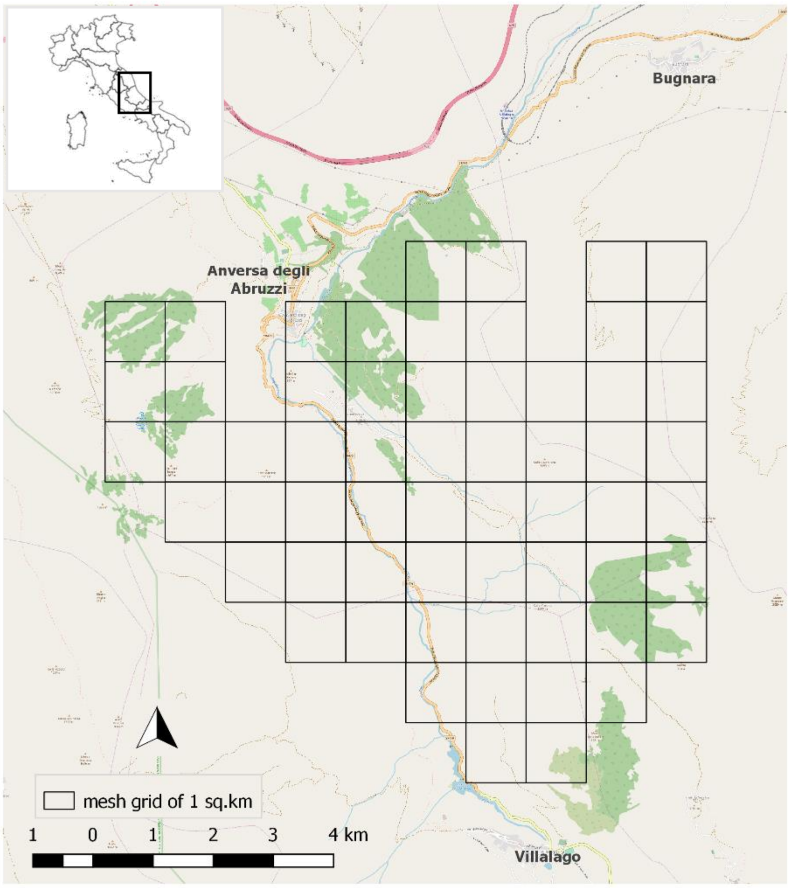


Figure 2. The study area was identified with 61 cells of 1 km-side located in the north-eastern part of the Abruzzo Lazio and Molise National Park's External Protection Zone in Central Apennines.

Approximately 90% of the study area is within the Buffer Zone or External Protection Zone (EPZ) of the ALMNP, while 35% is covered by a Natura 2000 Site of Community Importance (SCI) named "Gole del Sagittario" (IT7110099). This includes two Regional Nature Reserves, the homonym Gole del Sagittario and the St. Domenico Lake and Pio Lake (Fig. 3). A very little portion (about 3%) is within another Natura 2000 SCI, the Monte Genzana SCI (IT7110100). This is managed by the Monte Genzana-Alto Gizio Regional Nature Reserve, which is located on the opposite face of one of the main mountains on which the study was conducted, and where Rewilding Apennines' staff works frequently.

Figure 2. Landscape images of the study area. Up: subsample area 1 (see Fig. 5), full of steep and rocky peaks around Pizzo Marcello (1,437 masl). Down: subsample area 2, represented by the northern ridges of Genzana Mountain (2,170 masl) with the villages of Anversa degli Abruzzi, left in the corner, and the little hamlet of Castovalva set on the rocky ridge.

2.1.2 Sampling design

As one of the main objectives focusses on the Marsican brown bear (*Ursus arctos marsicanus)*, the study area was identified using a map of areas suitable for the Marsican brown bear (Ciucci et al., 2016). and overlaying a 1 km-side grid of 61 cells containing suitable patches in the area of interest for Rewilding Apennines initiatives (Fig. 3). The study was performed between October and the first weeks of December, before bears start their lethargy and greatly reduce their activity (Tosoni 2010, Ciucci et al. 2012).

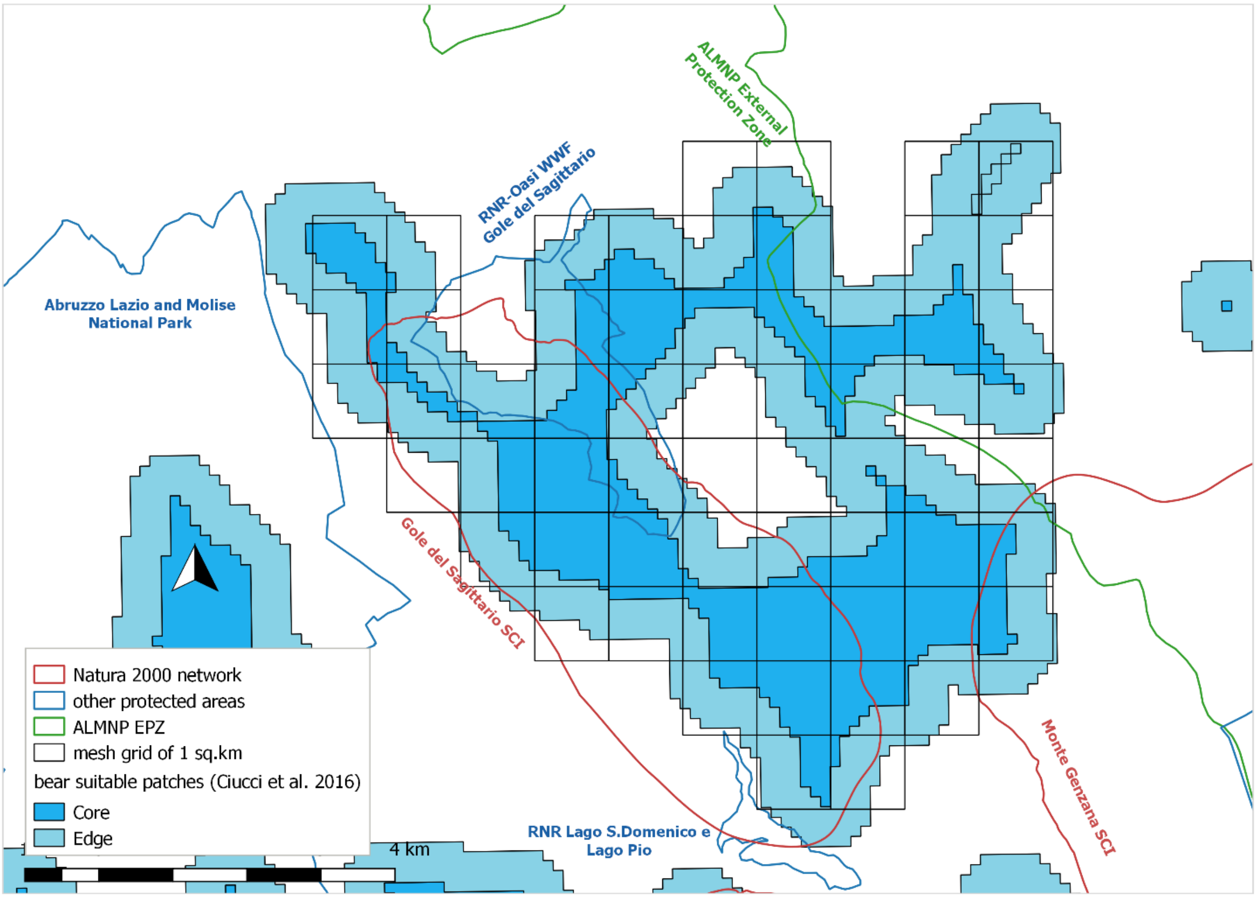


Figure 3. Study area selection process is based on the distribution of bear suitable habitat patches according to the aims of Rewilding Apennines toward this species.

A camera-trap was deployed within every cell. The selection of the camera-trapping sites followed species-specific opportunistic criteria to maximise the likelihood of taking bear pictures, for example, in habitat types known to be preferred by bears in the study period (i.e. beech and oak forests: Tosoni 2010), nearby other natural food sources (i.e. groups of apple trees), along paths crossing saddles and passes between cliffs, on track and path crossroads and junctions. Where this was not possible, we just selected a place where other wildlife was likely to be photographed, e.g. along paths in the forests or where we found signs of presence such as footprints or scats. Camera-traps were fixed mostly to tree trunks at the height of 1 m, with safety cages and Pythons locks, parallel to the ground and perpendicular to the path in order to have the least effect on animal activity

Figure 4. Placing camera-traps followed opportunistic in situ criteria. In the picture, a camouflaged camera-trap taking pictures on a path crossing a saddle.

and habits (so to reduce the disturbance, and to not introduce an avoidance learning bias with camera-traps distribution). Alternatively, they were put on the ground, fixed to a stone and camouflaged (Fig. 4). The area in front of them was cleared of vegetation to prevent empty shots caused by their movements in the wind. When possible, we tried to avoid direct sun light exposure on the camera-trap sensors. After some thefts, the technique of camera-trap deployment changed mostly to fixing them to tree trunks at 3-4 m height without their belts and pointing them at the ground. The quality of the images was reduced, however it prevented loss of scientific data.

In one third of the cells (n=20) each targeted camera-trap was paired with a second camera-trap deployed with random criteria, in order to understand the difference in detection rate (animal photos per day). This was achieved by choosing to deploy cameras randomly within a grid cell versus setting them up where there is the highest chance of detecting animals. Each random location is chosen with QGIS 2.18.28. In random locations we oriented camera-traps toward a path or a track, if present; if not, we oriented those located to lowlands northwards to prevent sunlight exposure, and those located to slopes down shooting the sloping ground.

In total, 81 camera-traps were deployed (Fig. 5) over a total of 1,964 trap-nights, between October 15th 2018 and December 13th 2018. Just 5 camera-traps were removed after the end of this sampling period (on December 30th): these camera-traps were replaced in the last part of the study period due to thefts or multiple false triggers causing the memory card filling in the middle of the study period. We used 40 camera-traps, all camera-traps worked for at least 3 weeks (21 trap-nights) and were deployed in two parts of the study area (Fig. 5; Fig.2) representing two homogeneous (sub)sample areas in space (contiguous areas) and time (same season with no different phenology for the bear).

We used 30 Browning Trail Cameras (trigger speed: 0.3 s; detection range: 25 m) and 10 belonging to other brands (ScoutGuard, BoskonGuard, Acorn, BolyGuard), where we set up 3 rapid fire images. Most of them (95%) used red light flashes. This meant we were unable to distinguish some species that require a coloured photo to be identified, as for those within the *Lepus* and *Martes* genera. Furthermore, camera-trapping techniques we adopted on sites (height, no lures) were not fitted to clearly identify pine martens (*Martes martes*), Italian hares (*Lepus corsicanus*) and wild cats (*Felis silvestris*). Each of these species needs a different and particular camera-trapping technique that would not be efficient for a general mammal survey as we required. Our base techniques were the best trade-off for a starting camera-trap survey, and allowed us to learn important lessons that will help us optimizing follow-up surveys in the coming years.

2.1.3 Herbivore and carnivore presence

Herbivore presence (indicator 6.1) and carnivore presence (indicator 7.1) were estimated respectively as the fraction of the large herbivore and large carnivore species typical of the area which have been observed at least once, as Rewilding Scale defines these indicators (Table 1). Among the species known to occur in the Central Apennine Rewilding Area (Fabrizio 2013) we considered just those mammals belonging to Carnivora and Artiodactyla orders that are typically considered as standard large mammals (Table 2).

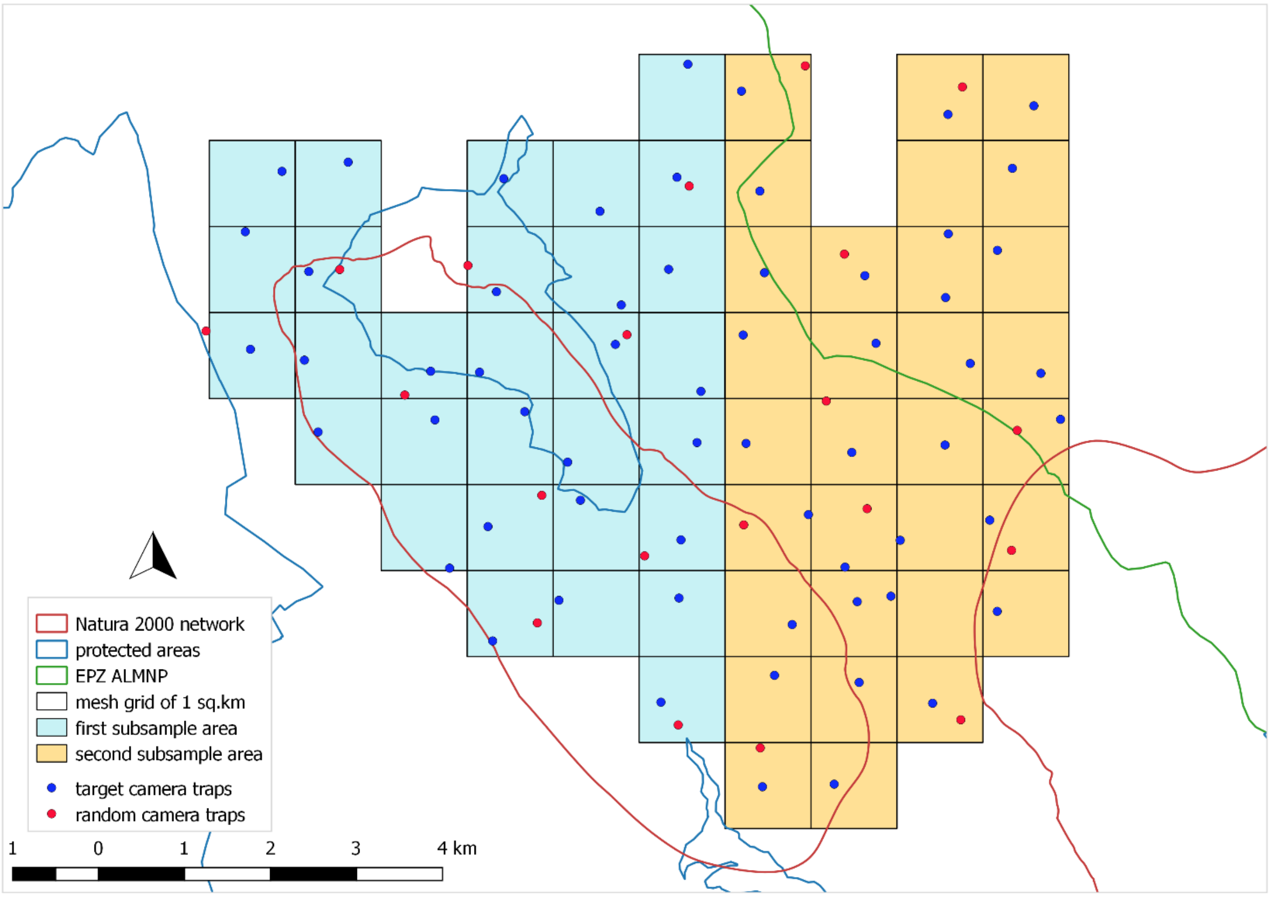


Figure 5. Location of subsample areas and camera-traps in the study area.

To make our results comparable to similar studies performed in other Rewilding Areas (i.e. Marinov 2017) we use the same indicators, which for carnivores, only consider large body-sided ones. However, given the conservation importance of meso-carnivores, we choose to report, separately, also the distribution of smaller body-sized carnivores (see 2.1.5).

Large carnivores	Large herbivores
Apennine wolf (*Canis lupus italicus*)	Wild boar (*Sus scrofa*)
Marsican brown bear (*Ursus arctos marsicanus*)	European roe deer (*Capreolus capreolus*)
	European red deer (*Cervus elaphus*)
	Apennine chamois (*Rupicapra pyrenaica ornata*)

Table 2. Species included in the wildlife indicator for Central Apennines Rewilding Area.

2.1.4 Herbivore and carnivore distribution

Herbivore distribution (indicator 6.2) and carnivore distribution (indicator 7.2) were estimated as the mean of fraction of the grid cells where each species was observed at least once, as Rewilding Scale indicators definition (Table 1). We report values of these Indicators taking into account all the species in Table 2 as a divider number, but we also provide an alternative Indicator taken in order to make comparisons with other Rewilding Areas working with this method (i.e. Marinov 2017).

2.1.5 Other mammals

With this report, we also present an atlas of distribution of some other mammal species to estimate overall species richness across multiple functional groups, and to obtain a baseline survey of their distribution, which is important to allow estimating trends in occupancy over time for several species. This will provide useful information to assess the impact of our conservation interventions in the rewilding areas for a broader set of species. Examples of these species of interest include the crested porcupine (*Hystrix cristata*), the badger (*Meles meles*), the red fox (*Vulpes vulpes*) and the wild cat (*Felis silvestris*).

2.2 Land cover area estimate

To quantify the relative abundance of different habitat types like forests, grasslands and their transition edge areas (indicators 1.1, 3.1 and 2.1: Table 1), we used the last version of CORINE Land Cover released in 2018 by the Copernicus Land Monitoring Service (Copernicus Programme[1]).This uses a Minimum Mapping Unit of 25 hectares for areal phenomena. We have chosen to work with this kind of data because it is available all over the European continent territories, is obtained with the same methods and therefore allows for comparisons between different Rewilding Europe's projects concerning land use (land cover) of the different areas.

CORINE Land Cover classes were grouped into 6 main categories, according to the CORINE Land Cover Technical Guide (EEA 1999): Artificial surfaces, Agriculture areas, Forests and semi-natural areas, Wetlands and Water bodies. We explored better the category of Forests and semi-natural areas, analysing them in more depth at the subcategories level, in order to get the Rewilding Scale indicators (Table 1). Indicator values are therefore the fraction of each habitat type. The analysis was done in QGIS 2.18.28.

[1] https://land.copernicus.eu/pan-european/corine-land-cover/clc2018

3. Results

3.1 Camera-trapping

3.1.1 Herbivore and carnivore presence

We observed with our deployed camera-traps all characteristic large herbivores of the study area (Table 2), resulting in an Indicator 6.1 of 100%.

Of the two large carnivores (Table 2) just one was camera-trapped at least one, the Apennine wolf, while we had an absence of photographic records of Marsican bear. However, all information available to us point to the bear being present in the region and it is most likely that the survey intensity and the deployment of camera traps at the start of the period of reduced activity may have reduced detectability to the point of missing bears despite their presence in the area. Thus, while our reported Indicator 7.1 is 50%, in reality we expect it to be 100%.

3.1.2 Herbivore and carnivore distribution

Among the four large herbivore species typical of the study area, the wild boar is the most widespread during the study period (Table 3), followed by the roe deer and the red deer, each camera-trapped in a slightly lower fraction of grid-cells. Just one camera-trapping event referred to the Apennine chamois (Fig. 6). As a result, the Indicator 6.2 about Herbivore distribution is 48.75%.

Wild boar	**Roe deer**	**Red deer**	**Apennine chamois**
71.67	60	61.67	1.67

Table 3. Percentages of grid cells with herbivore species presence data within the study area.

The distribution of camera-trap photos of wolf (Fig. 7) leads to a large Carnivore distribution value (Indicator 7.2) of 37.70% (23 cells occupied within the 61 of the study are), without considering other carnivore species not captured by camera-traps (*sensu* Marinov 2017). If we include bears in the calculation of Indicator 7.2 its value decreases to 18.85% (23 cells occupied over 122 potential occupied cells across bear and wolf).

3.1.3 Other mammals

The red fox is the most widespread mammal followed by martens and hares (Table 4; Fig. 8 and 9). Domestic dogs are very frequent, often used by humans for hunting, truffle harvesting and shepherding, but in some parts of the study area there are also some feral dogs. European badgers and wild cats have been camera-trapped slightly less, while crested porcupines have been observed only in the western part of the study area. Red squirrel and European polecat are other mammal species reported during the study period. We omitted images of rodent micromammals.

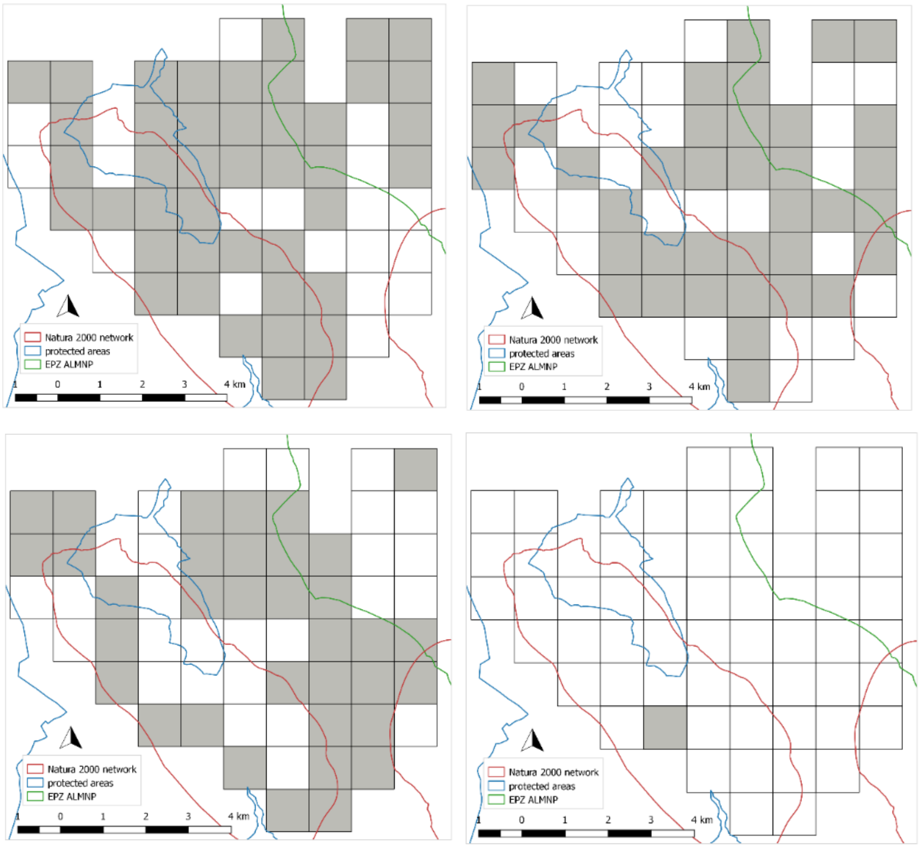


Figure 6. Distribution of four large herbivore species in the study area. From top left to right: distribution of wild boar (Sus scrofa), European roe deer (Capreolus capreolus), European red deer (Cervus elaphus) and Apennine chamois (Rupicapra pyrenaica ornata).

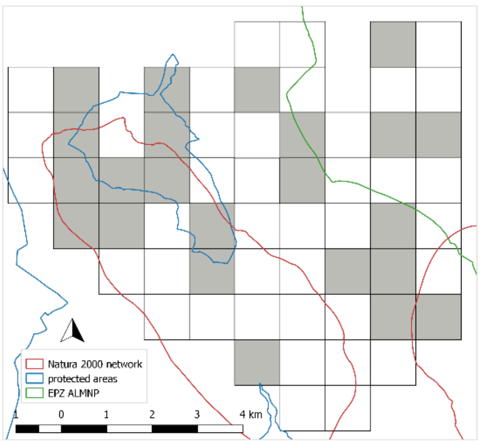


Figure 7. Apennine wolf (Canis lupus italicus) distribution in the study area as camera-trapping data acquired in the study period.

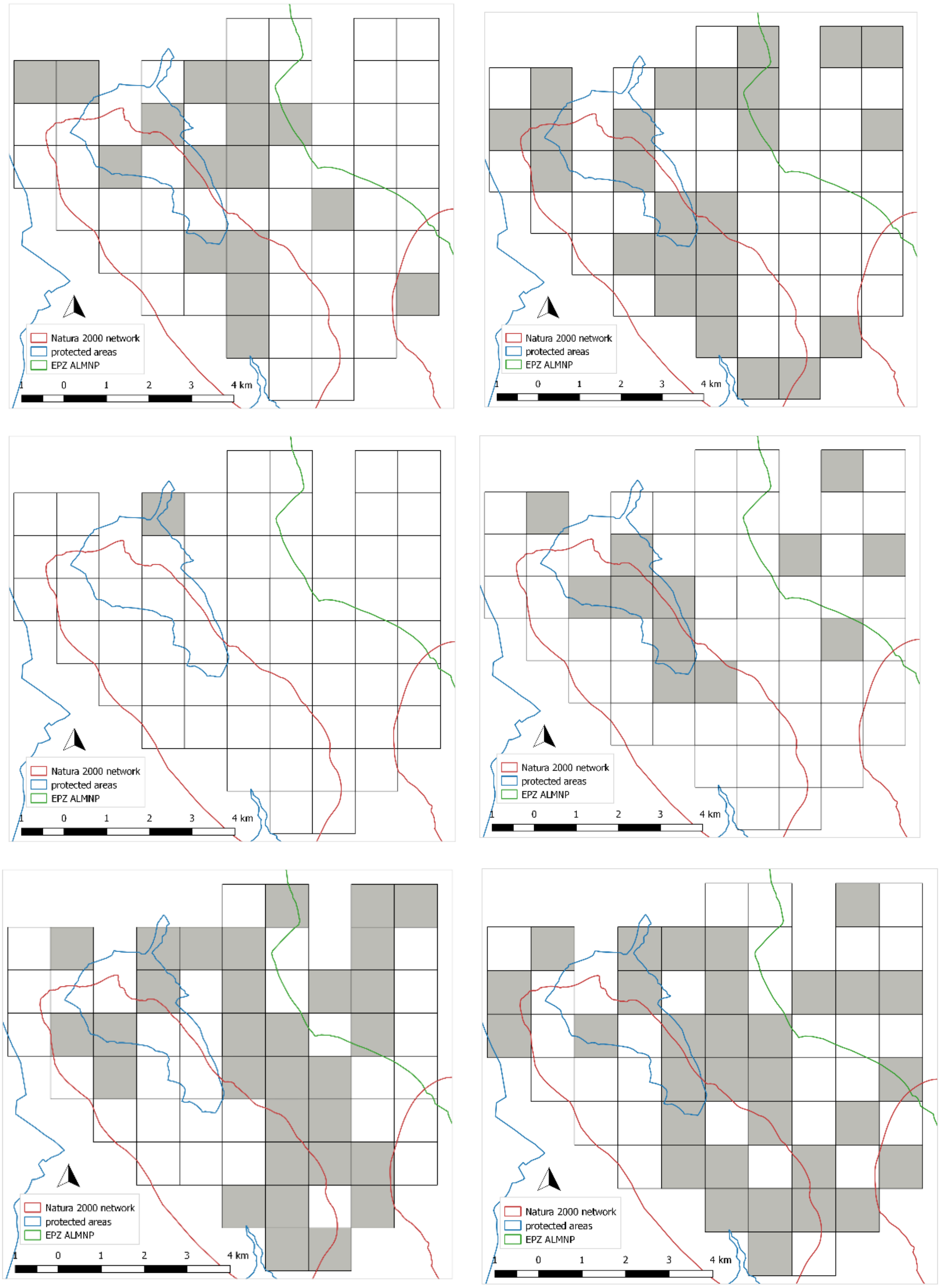
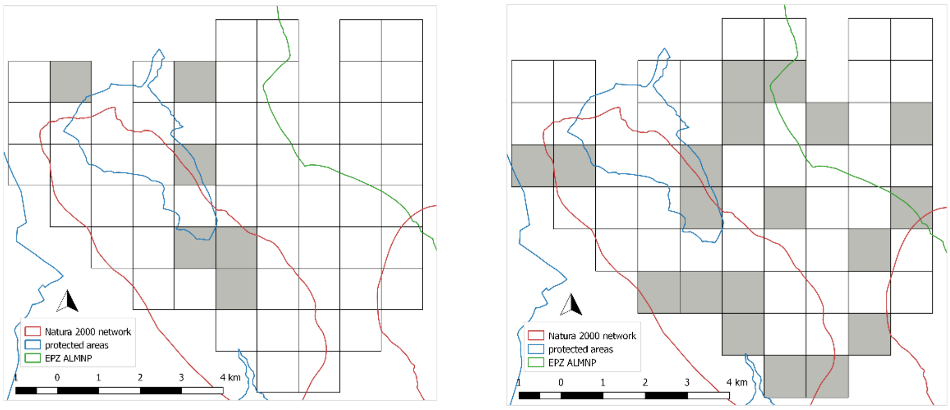


Figure 8. Beginning from top left to right: distribution of Carnivore acquired pictures of badger (Meles meles), pine/beech marten (Martes martes/Martes foina), polecat (Mustela putorius), wild cat (Felis silvestris), domestic dog (Canis familiaris) and red fox (Vulpes vulpes).



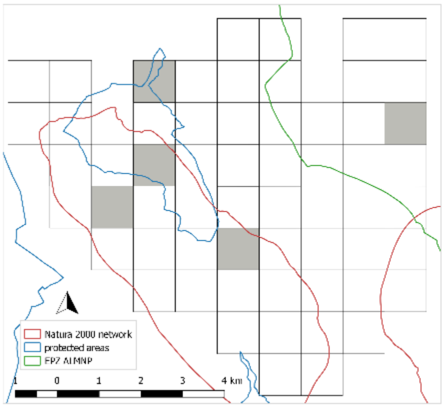


Figure 9. Distribution of Rodent and Lagomorph acquired pictures of crested porcupine (Histrix cristata), Italian/European hare (Lepus corsicanus/Lepus europaeus), red squirrel (Sciurus vulgaris).

Species	**n° of grid cells with occurrences**	**% of grid cells**
Carnivores		
European badger (*Meles meles*)	17	28.33
Pine/beech marten (*Martes martes/Martes foina*)	25	41.67
European polecat (*Mustela putorius*)	1	1.67
Wild cat (*Felis silvestris*)	12	20.00
Domestic dog (*Canis familaris*)	31	51.67
Red fox (*Vulpes vulpes*)	33	55.00
Rodents		
Crested porcupine (*Hystrix cristata*)	6	10.00
Red squirrel (*Sciurus vulgaris*)	5	8.33
Lagomorphs		
Italian/European hare (*Lepus corsicanus/Lepus europaeus*)	19	31.67

Table 4. Observations of other mammals not considered as large fauna acquired during the study period with camera-trapping techniques.

3.2 Land cover area estimation

Seven CORINE Land Cover categories were located in the study area, showing a greater abundance of broad-leaved forests (Table 5), primarily located on mountain slopes (Fig. 10). Grasslands and mosaic patches are very similar in their extension and have a secondary importance. We can also note habitat types of interest represent the totality of the study area surface, reaching the 99.97% of extension.

Indicator 1.1 is 62.5%, Indicator 2.1 is 17.7%, Indicator 3.1 is 19.47% (Table 5).

Rewilding class	Area (ha)	Area (%)	CORINE Land Cover Class	Area (ha)	Area (%)
Agriculture	19	0.03	242 Complex cultivation patterns	19	0.03
Forest	4 072	62.5	311 Broad leaved forest	3 679	56.5
			312 Coniferous forest	224	0.34
			313 Mixed forest	169	0.26
Grassland	1 154	17.7	321 Natural grasslands	1 154	17.7
Mosaic	1 268	19.5	324 Transitional woodland/shrub	928	15.1
			333 Sparsely vegetated areas	340	0.52

Table 5. Land cover categories grouped in order to understand Rewilding Scale habitat types.

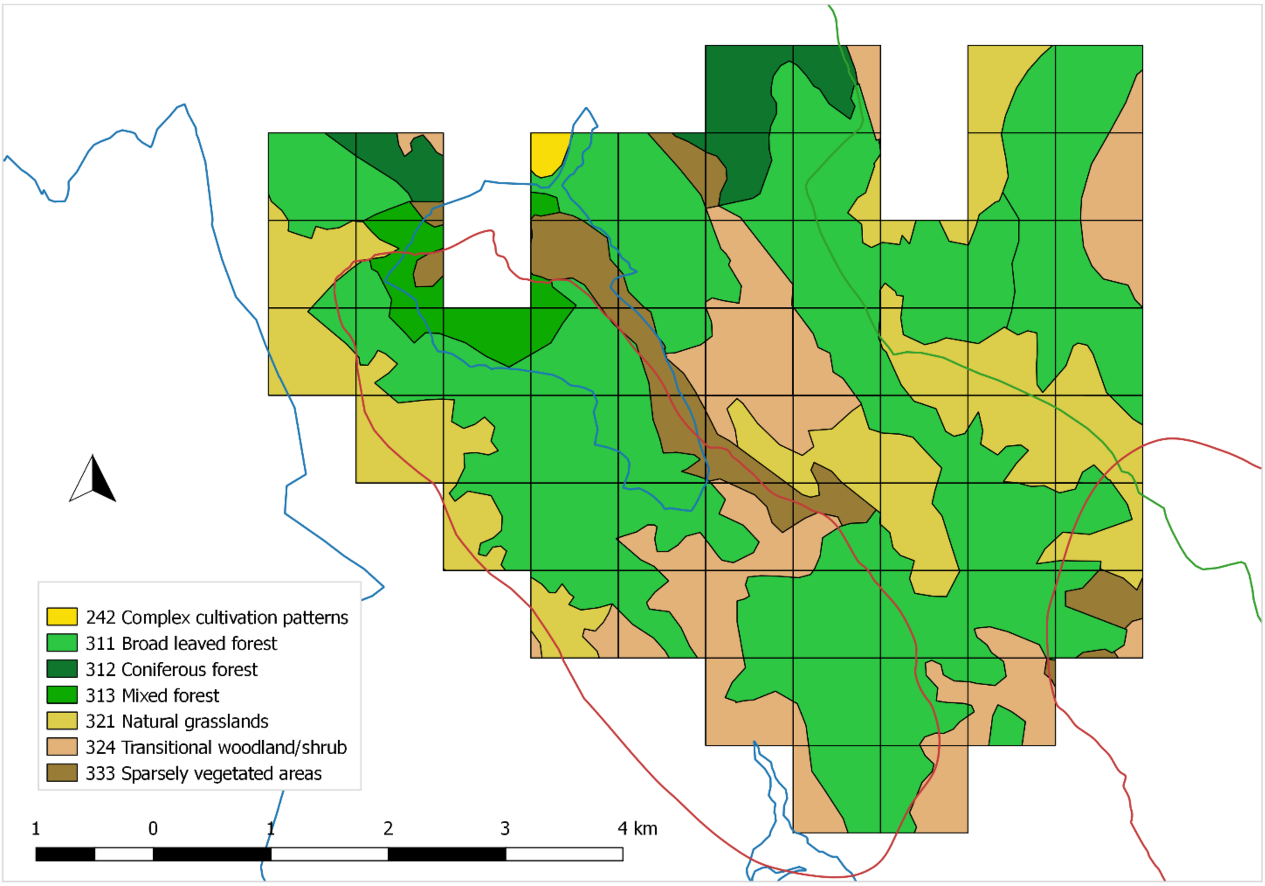


Figure 10. Distribution of habitat type patches within the study area.

4. Discussion

4.1 Camera-trapping

Camera-trapping results show a notable number of species known to occur in the study area (and in the nearby ALMNP (Fabrizio 2013), with distributional patterns that reflects anecdotal evidence from local conservation management authorities (S. Inzaghi, pers. com.).
A general recommendation for biodiversity studies and species checklists is to work with at least 1,000 trap-nights (Wearn and Glover-Kapfer 2017) representing more or less the average of the range of recommendations that have been made across specific camera-trapping studies (Tobler et al. 2008; Wearn et al. 2013; Si et al. 2014). Our analyses were based on a total of 1,964 trap-nights. We have also complied with the recommended length of study less than 3-6 months. Within this range the medium and large-sized mammal community is typically considered to be closed to changes in species composition and abundance and this allows to make reliable estimates of richness and diversity. These aspects and the fact that most species were first captured on camera well before it was retrieved, gives us confidence that the camera trap effort was sufficient and the results reliable, except for the lack of detection of bears, see further below.

Herbivores show a more extensive distribution, as expected from the ease with which they are sighted in the study area. This could also be partially influenced by the great vagility of these species or it could be related to their organisation in large herds and therefore an increased detection probability.

In the nearby ALMNP, red and roe deer average densities are estimated by pellet group counts respectively to 2.4 ind/km^2 (CI: 2.2-2.5: Latini et al. 2015) and 0.21 ind/km^2 (CI: 0.19-0.24: Latini et al. 2015), varying only slightly from data collected in the past decade (2.7 and 1: Latini et al. 2003; 2.3 and 1: Latini 2008). For red deer, similar values have been found in the nearby Genzana Mountain Reserve (1.3-2.5 ind/km^2: Fabrizio et al. 2012) through a camera-trapping study based on individual identification by antlers' shape with a minimum number of 41 individuals and a potential of 79 within the Reserve territory. Assuming these densities apply to our study area, one could infer a potential population of 146 (134-153) red deer and 13 (12-15) roe deer. However, this is most likely a very inaccurate estimate for both these species. First of all, because extrapolating from density values of different areas (even if very close) relies on often invalid assumptions of comparability. For example, the ALMNP average ungulate density reported above was based on three different subsample areas of the National Park, having a very high heterogeneity in red deer densities. These densities are plausibly a reflection of the distance from the release sites in the 70s in the south-east part of the park. The observed densities are respectively 0.5, 1.4 and 8.3 for the northern, the south-central and the eastern section of ALMNP surveyed (Latini et al. 2015). Field observations in the Sagittario valley during the study period revealed the presence several red deer leks, especially on the Genzana Mountain sides. Even in the absence of independent quantitative data, we believe densities here are not as low as in the closest subsample areas of the National Park (i.e. 0.5 and 1.4 ind/ km^2) because the habitat selection and behavioural ecology of the herds suggest that the study area is more suitable to red deers than closest subsample areas of the ALMNP surveyed. In addition, the roe deer estimate from extrapolating densities from other areas (12 individuals) is likely an underestimate, according to sightings in the fields (pers. obs.).

It seems that red deer in our study area are more confined and less spread than roe deer, with an apparent red deer absence on the steep slopes of the Sagittario gorges (Fig. 6). However, direct observations reported the presence of red deer herds and loners in cells where no pictures have been taken, probably due to the camera site selection. During foraging activities, roe deer would be more selective, while red deer would be a better grazer on grasslands (Boitani et al. 2003; Stoms et al. 2008). Therefore, it's probable that the lower number of red deer photographic acquisitions may be due to a systematic underrepresentation of grassland ecosystems. This was determined by, for example, 1) the sampling strategy (see 2.1.2) which systematically aimed to place camera-traps in wooded environments, 2) troubles of positioning camera-traps in open environments without trees (we would have to fix the camera directly to iron rods) or with a few trees that would have facilitated the detection of our tools by potential thieves, 3) it is also probable that denser thickets are less frequented by large herds due to hard movements of some of them having antlers.

It is interesting to note that parameter 6.2 (Herbivory distribution) increases from a value of 48.75% to 64.63% if the average is computed just on three species, excluding the Apennine chamois. This species is not typical of our study area and not present permanently, so we didn't expect this result. Large herds are frequent on high peaks in central and southern areas of the ALMNP. However, the distribution of presence data within the ALMNP and its External Protection Zone shows that the northern-most occurrence of chamois is just a few kilometres south of the study area (Fabrizio 2013). This is precisely on the mountain range that shapes the western ridges of the whole Sagittario gorge and which also crosses the study area. This population in the last 25 years has remained stable, with natural fluctuations in size, between 400 and 600 individuals (Asprea and Pagliaroli 2015). It is probable that the only individual seen by the camera-traps is a juvenile showing dispersal behaviour starting from these northern areas of the ALMNP placed immediately nearby the study site, and it is not unlikely that it may be the same individual observed in the Sagittario Gorges area in recent years (S. Inzaghi, pers. com.). Similar dispersal behaviours of this species were already reported by other wildlife biologists far away from the respective source population (A. Antonucci and A. Monaco, pers.com.).

The wild boar is distributed throughout the territory of the ALMNP (Bernoni et al.) and it is widespread in all Italian Apennines (Boitani et al. 2003) but currently there are no data on density or population estimates in the nearby areas.

When considering additional source of data to map carnivore distribution the indicators increase. During the survey period some Marsican bear presence data were discovered, mainly during the field activities, in 8 grid cells (Fig. 11). Data include footprints, scats, very big and heavy flipped stones (> 30 cm of minimum diameter), couches and direct sightings from local citizens matched with clear evidence (Abruzzo and Molise Bear Monitoring Network, unpublished data). Using these methods, Indicator 6.2 about Carnivore presence would grow to 100%, and Indicator 7.2 about Carnivore distribution would be 25.83%. This is an approximation, provided only to give a general understanding of the number of large carnivores present in this area. This value is by no means an accurate estimate of bear

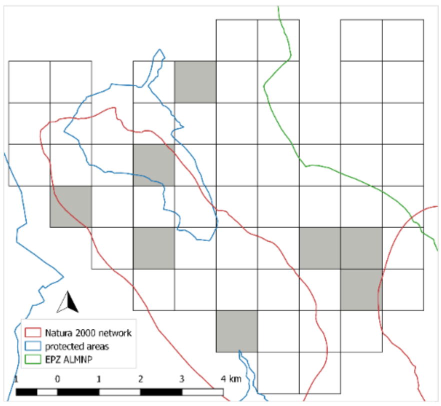


Figure 11. Distribution of bear presence signs detected from September to December 2018 in the study area.

distribution. We are only able to assert that Marsican bears are present in the study area and that, possibly bears are only present during some parts of the year. Notable examples of bear sightings include a young female documented in the northern part in late summer 2018 (Bear Marsican Report 2018) and the female with three cubs reported during the study period (Abruzzo and Molise Bear Monitoring Network, unpublished data). Therefore, despite the study area is formally considered as part of the bear core area (Ciucci et al. 2017) it is possible that the absence of bears' camera-trap data here is due to a low density of individuals, or inappropriate techniques for wide roaming animals (i.e. absence of baits or a too short study period). This hypothesis of low presence of bears is particularly likely in the north of the study area. The southern part is probably used more for movements between the ALMNP and the Genzana Mountain Reserve, providing just some components of the bear habitat, like winter dens in impervious and not disturbed cliffs or some seasonal foods (S. Inzaghi and E. Tosoni, pers.com.).

In the nearby ALMNP, resident wolves home ranges are 104 ± 24 km^2, whereas floaters used two to fourfold larger areas (293-408 km^2), with core areas preferentially established at greater elevation and in the more forested and inaccessible portions of the home range (Mancinelli et al. 2018). We do not know how many wolves are in the study area, but it is clear they are common, and the study area is suitable thanks to its imperviousness and inaccessibility, that reduces human disturbance. Our camera-trapping techniques rarely permit to us to assess where/when we found a floater or a pack (because repeated pictures have 10 seconds delay, see 2.1.2), and so to establish the average size of a pack. Nevertheless, following wild prey reintroductions in the ALMNP since the mid '70s (Apollonio and Lovari 2001), local prey availability and diversity here are amongst the highest in the Central Apennines, corresponding to a relatively high density of wolves in the area (Mancinelli et al. 2018).

Among other mammals, it is remarkable the number and geographic distribution camera-traps pictures of wild cats, suggesting the area is highly suitable for the species and can host many individuals. Unfortunately, using scientific identification criteria (Ragni and Possenti 1996; Lapini 2011) based on morphological classification (e.g. Matteucci et al. 2013), we are not able to accurately assess whether they all belong to wild cats versus feral domestic cats. To reliably judge the differences between wild and domestic cats and their hybrids, a special technique of camera-trapping is required to capture the dorsal coat pattern, possibly with a white flash, high definition and a lure. For the distribution map in this report we have assumed all unclear images of wild cat in forest habitats far from villages or at high altitudes, to be wild cats (Fig. 7). We estimate a minimum number of 6 different individuals, and a maximum of 23 (17 other camera-trapping events on 7 different grid cells considered impossible to identify as single individuals). Population density in other Italian regions reached with different methods ranges between 0.18-0.43 ind/km^2 (Ragni 2006; Anile et al. 2012, 2014), so the study area can potentially host from 11 to 26 individuals. Because many of these studies in Sicily island where cats have no competitors (e.g. badger, wolf) it is more reliable to use densities reached on the peninsula, which reduces the range between 11-19 animals.

Foxes and martens are widespread all across the study area as expected by the ecology of those species. Unfortunately, we are not able to distinguish pine and beech marten locations, so we cannot estimate reliably their distribution and density.

Badgers and crested porcupines seem to use medium altitudes, in line with what is known for the species in Italy (Boitani et al. 2003; Amori et al. 2008), with some differences between the two species. Crested porcupines have a more frequent presence in the main valley, badgers are more widespread, and also use higher elevations. We obtained just one good camera-trap photo attributable to polecat in the Sagittario valley, near the stream, as expected for the known ecology of this elusive mammal in the peninsula, which is very often linked to riparian habitats (Boitani et al. 2003; Rondinini et al. 2006; Russo et al. 2017). However, in the study area, it has been observed also far from the river in 2009 by means of camera traps at an altitude of about 1,200 masl (while the main stream in the area flows at an average of 600 masl) in an area without riparian habitats nearby (R. Fusillo, pers. com.). This maybe represents a suboptimal habitat, since polecat are seen also in pastures and grasslands far away from river networks (E. Manzo, pers.com.). The study area is still lacking in polecat data except two presence data and the inclusion in the wildlife checklist of the Genzana Mountain Reserve.

Red squirrels seem to have a very fragmented distribution. This patchy distribution is most likely due to poor detection rate, rather than a true reflection of their occurrence in the area. This may be due to an incongruence between camera-trapping techniques and the species behaviour, considering the absence of baits (Di Cerbo and Biancardi 2012) and, probably, its lower presence on the ground.

The high presence of domestic dogs, used for hunting, truffle harvesting and sheep farming can affect biodiversity, including disturbance and disease transmission to species under risk of extinction like the Marsican bear. Feral dogs, present in the area albeit in low numbers, may prey on herbivores and hybridise with wolves (Hughes and Macdonald 2013). We observed the largest number of dogs in areas with easiest access, like those with a minor difference of altitude or where dirt roads lead up into the mountain. Vaccination campaigns or (better) vaccination control by local health agencies should be implemented with stakeholders (hunters, truffle hunters, sheep farmers).

The hare is one of the most camera-trapped animals. As in the case of martens, without particular techniques of camera-trap deployment (i.e. lower height from the ground, higher definition, white flash) we are not able to distinguish the Italian hare (*Lepus corsicanus*) from the European one (*Lepus europaeus*). Despite this, some images have recorded the part of the body of interest to understand what hare species are camera-trapped (Trocchi and Riga 2005), and provide understanding of the presence of Italian hares in our area, even if it is not advisable to use black and white images for determinations (F. Riga, pers.com.). This is not so unexpected considering that in the ALMNP the presence of Italian hares has been ascertained also in the northern part, west of our study area (Asprea 2016). Other camera-trapping images have also been acquired in the study area, and some direct sightings and pellet determinations were at the low altitudes in very rich ecotonal habitats at the boundaries of the northern part of the study area (Ricci et al. 2007). All of these sources of evidence confirm that the Italian hare occurs in our study area. What we do not know is its distribution, and new studies investigating this species would be extremely valuable, to understand its occurrence, density, habitat preference and other life-history parameters, as well as to monitor its conservation status in Italy.

4.2 Land cover area estimation

We were able to estimate the percentage of land cover area for indicator 1.1,2.1 and 3.1 (Table 1). For indicator of transitions in land-use (as for indicator 3.3 - % of mown grasslands changed into natural grazed habitats) we would need cadastral data or time-series in land-use maps, which we don't have access to at the moment. For indicators of habitat condition, (e.g. indicator 1.2 - % of forests in which dead wood is a significant proportion of timber volume), we would need specific field surveys with dedicated professionals or other specific informative layers of the Copernicus Land Monitoring Service, like Grassland with ploughing indicator (PLOUGH) for the indicator 3.2 (% of arable fields changed into natural grazed habitats). The latter is a high-resolution layer specifically available for experts, but, as we have seen preliminary in the study area, there is a small percentage of land not ploughed for 2 to 4 years in 2015 (Ploughing Indicator 2015[2]).

In order to do a first survey, which will be helpful for future monitoring on land cover and land use dynamics in the study area, we have used the European land cover with MMU[3] 25 hectares. This was used due to its strengths of high availability and easy use, as well as it frequently updating. So, the use of this CORINE can be considered acceptable (Gallego and Bamps 2008) and a sustainable trade-off, and the use of the same database among different Rewilding Areas can facilitate the comparability of indicators. Apart from these positives aspects, the used land cover map definition might not fit optimally to the study area scale. In this sense, we had to abandon the idea to use a better informative layer like the CORINE Land Cover with a 1-hectar MMU provided by the Abruzzo Region in 2000. Because it has never been updated after its first release, we do not know if there will be another release in the future to compare with, and the layer may no longer reflect actual land-use and land-cover.

Moreover, we tried to assess if some habitat patches in the study area changed between 2012 and 2018, and no changes were detected by the Land Cover Changes inventory. We did not include this analysis as a study method because it did not provide any information on changes starting from the moment when Rewilding Apennines was officially in charge of this area. Nevertheless, this method can be used in the future, but it is important to notice changes may not be detectable due to the resolution of the CORINE inventory (i.e. MMU 25 ha). Clearings developing into woodlands are conceivably underrepresented, and this attempt to very basically infer the indicator 2.2 (% of mosaics/transitions, changed from managed into natural succession) failed, also from 2006 to 2012 (cover period 2006-2018). A different method should be found and tested, for example trying to update independently a land cover classification at 1-hectar MMU.

Moreover, except artificial plantings, it is difficult to notice a change in vegetation cover over few years, and maybe, if the objective of the Rewilding Scale is to record enhancements in the local environment conditions, it is better to report just those progress steps in agreements that allow the change in land use toward the recovery goals.

With regards to the indicators 1.1, 2.1 and 3.1 (i.e. percentage of spontaneous, native or natural cover; Table 1), the satellite imagery data required supplementary on the ground surveys and field

[2] https://land.copernicus.eu/pan-european/high-resolution-layers/grassland/expert-products/ploughing-indicator/2015

[3] Minimum Mapping Unit

observations, made especially on tree species composition to confirm the presence of native vegetation. The only species known to be planted during the last decades is the Austrian pine (*Pinus nigra*) that is left under conspicuous populations in order to fight landslides.

Unmanaged forests are difficult to estimate without reliable data or without consulting the forestry plans (how often cuts are made and what is their intensity, distribution, species/size selection and technique adopted). However, we think coppicing is contemplated by local communities, (as generally happens in Italy), except maybe in the Sagittario Gorges area, due to imperviousness and high slopes of mountain sides. Forest management is unlikely to have occurred in the past in the highest parts of the study area near the Genzana Mountain, since we have found outside all the protected areas some nuclei of common yew (*Taxus baccata*), a very rare tree in the Italian peninsula and protected by the European Habitat Directive (Annex I – Habitat 9210: Apennine beech forests with *Taxus* and *Ilex*). These nuclei have survived despite the areas are not formally protected (even though the presence of an Annex I habitat should warrant the designation of a SCI site), and suggests that minimal or no forest management was present in these beech forests, otherwise the yew would have been eliminated.

Grasslands and sparsely vegetated areas are frequented by sheep and goats by local pastoralists, especially those located at medium-low altitudes. At higher altitudes, grazing is provided by deer, small flocks of sheep and goats, cows in the southern part of the study area, and horses in the north-western one. Despite this, it is possible that in the future grassland habitats located at the top of the mountains will be threatened by an advance of the tree line caused by climate changes, unless this advance is contained by herbivory pressure or other factors (Harsch et al. 2009), with a consequent loss of this habitat type which is so important for a set of species, ecologically linked to it.

Acknowledgments

We are grateful for the collaboration to WWF Abruzzo and Ambiente e/è Vita, respectively managing bodies of two Regional Nature Reserves: Gole del Sagittario, and Lago San Domenico and Lago Pio.

Many thanks also to Sefora Inzaghi to have shared fundamental materials for field surveys.

We desire to express special thanks to Oliver R. Wearn for the fundamental consultancy on planning the sampling design, and a special mention to all volunteers involved in this work: Maarja Jagomagi, Clare Alley, Katie Harris, Jamie Tyghe, Vickie Glennon, Charlotte Almond, Mike Cox for camera-trapping field work, Ennio Ciccotti for having shared remarkable field observations, Eleanor Arthur for a first language review.

References

AA.VV. (2011). Piano d'Azione per la Tutela dell'Orso bruno Marsicano. Quad. Cons. Natura, 37, ISPRA [in Italian].

Ahumada, J. A., Silva, C. E., Gajapersad, K., Hallam, C., Hurtado, J., Martin, E., McWilliam, A., Mugerwa, B., O'Brien, T., Rovero, F., Sheil, D., Spironello, W.R., Winarni, N., Andelman, S.J. (2011). Community structure and diversity of tropical forest mammals: data from a global camera-trap network. Philosophical Transactions of the Royal Society B: Biological Sciences, 366(1578), 2703-2711.

Amori, G., Contoli, L., Nappi, A. (2008). Mammalia II: Erinaceomorpha, Soricomorpha, Lagomorpha, Rodentia. Calderini.

Anile, S., Ragni, B., Randi, E., Mattucci, F., Rovero, F. (2014). Wildcat population density on the Etna volcano, Italy: a comparison of density estimation methods. Journal of Zoology, 293(4), 252-261.

Apollonio, M., Lovari, S. (2001). Reintroduzioni di cervi e caprioli nei parchi nazionali, con note sulle immigrazioni naturali. In Progetto di monitoraggio dello stato di conservazione di alcuni mammiferi particolarmente a rischio della fauna Italiana. Edited by S. Lovari and A. Sforzi. Ministero dell'Ambiente, Roma. pp 462-475 [in Italian].

Asprea, A., Pagliaroli, D. (2015). Struttura e dinamica di popolazione del camoscio appenninico (Rupicapra pyrenaica ornata) nel Parco Nazionale d'Abruzzo, Lazio e Molise. Relazione interna all'Ente [in Italian].

Asprea, A. (2016). Progetto di sistema dei Parchi Nazionali per la conservazione della lepre italica (Lepus corsicanus). Relazione finale [in Italian].

Bernoni, M., Gentile, C., Gentile, L., Migliaccio, E., Sulli, C. La fauna del Parco Nazionale d'Abruzzo [in Italian].

Boitani, L., Lovari, S., Vigna Taglianti, A. (2003). Fauna d'Italia. Mammalia III: Carnivora - Artiodactyla. Edizioni Calderini, Bologna, 434 [in Italian].

Buskirk, S.W. (1999). Mesocarnivores of Yellowstone. In: Clark, T.W.; Curlee, A.P.; Minta, S.C.; Kareiva, P.M., editors. Carnivores in ecosystems: The Yellowstone experience. New Haven, CT: Yale University Press; 167-187.

Chivian, E., Bernstein, A. (Eds.). (2008). Sustaining life: how human health depends on biodiversity. Oxford University Press.

Ciucci, P., Tosoni, E., Maiorano, L., Gentile, L., Sulli, C., Boitani, L. (2012). Denning in the Apennine brown bear (Ursus arctos marsicanus) and potential conflict areas: toward pro-active measures. Scientific contribution at the VIII Italian Association of Theriology Congress, Fabriano, Italia.

Ciucci, P., Gervasi, V., Boulanger, J., Altea, T., Boitani, L., Gentile, D., Paetkau, D., Sulli, C., Tosoni, E. (2015). Ex post non-invasive survey of the core Apennine bear population (Ursus arctos marsicanus) in 2014. Annual report for Project LifeNAT/IT/000160 "Arctos"-action E3 non-invasive survey of the core Apennine bear population. Department of Animal and Human Biology, University of Rome La Sapienza, Rome.

Ciucci, P., Maiorano, L., Chiaverini, L., Falco, M. (2016). Aggiornamento della cartografia di riferimento del PATOM su presenza e distribuzione potenziale dell'orso bruno marsicano nell'Appennino centrale. Azione A2: Relazione tecnica finale [in Italian].

Ciucci, P., Altea, T., Antonucci, A., Chiaverini, L., Di Croce, A., Fabrizio, M. Forconi, P., Latini, R., Maiorano, L., Monaco, A., Morini, P., Ricci, F., Sammarone, L., Tosoni, E., Regione Lazio Bear Monitoring Network (2017). Distribution of the brown bear (Ursus arctos marsicanus) in the Central Apennines, Italy, 2005-2014. Hystrix, the Italian Journal of Mammalogy, 28(1), 86-91.

Colangelo, P., Loy, A., Huber, D., Gomerčić, T., Vigna Taglianti, A., Ciucci, P. (2012). Cranial distinctiveness in the Apennine brown bear: genetic drift effect or ecophenotypic adaptation? Biological journal of the Linnean society, 107(1), 15-26.

Di Cerbo, A. R., & Biancardi, C. M. (2012). Monitoring small and arboreal mammals by camera-traps: effectiveness and applications. Acta Theriologica, 58(3), 279–283.

EEA (1999). CORINE Land Cover - Technical guide. European Environmental Agency – European Commission, Joint Research Centre, Space Applications Institute, Agriculture and Regional Information Systems Unit.

Elzinga, C. L., Salzer, D. W., Willoughby, J. W., & James, P. Gibbs. (2001). Monitoring plant and animal populations. Blacwell Science.

Fabrizio, M., Monaco, A., Nonni, F. (2012). Stima numerica della popolazione maschile di Cervus elaphus mediante identificazione individuale da fototrappolaggio. Atti del Convegno "Il foto-video trappolaggio in Italia: primi risultati di una nuova tecnica di ricerca scientifica per la fauna selvatica" 9 luglio 2011-Pettorano sul Gizio (AQ), 18 [in Italian].

Fabrizio, M. (ed.) (2013). Piano di Gestione dei Siti Natura 2000 del Parco Nazionale d'Abruzzo, Lazio e Molise ZPS IT7120132 "Parco Nazionale d'Abruzzo Lazio e Molise" SIC IT7110205 "Parco Nazionale d'Abruzzo" D. G. R. n. 1026 del 29.12.2012 Misura 3.2.3. "Tutela e riqualificazione del patrimonio rurale" Piano di Sviluppo Rurale 2007-2013 della Regione Abruzzo [in Italian].

Gallego, J., Bamps, C. (2008). Using CORINE land cover and the point survey LUCAS for area estimation. International Journal of Applied Earth Observation and Geoinformation, 10(4), 467-475.

Guidarelli, G., Colangelo, P., Ciucci, P., Loy, A., & Meloro, C. (2016). The marsican bear (Ursus arctos marsicanus): morphological evidences of taxonomic and ecological distinctiveness. *Hystrix, It. J. Mamm.* 27 (supplement) – X Congresso Italiano di Teriologia.

Harsch, M. A., Hulme, P. E., McGlone, M. S., Duncan, R. P. (2009). Are treelines advancing? A global meta-analysis of treeline response to climate warming. Ecology letters, 12(10), 1040-1049.

Hayward, M. W., Kerley, G. I., Adendorff, J., Moolman, L. C., O'brien, J., Sholto-Douglas, A., Bissett, C., Bean, P.M., Fogarty, A.W., Howan, D., Slater, R.D. (2007). The reintroduction of large carnivores to the Eastern Cape, South Africa: an assessment. *Oryx*, *41*(2), 205-214.

Hughes, J., Macdonald, D. W. (2013). A review of the interactions between free-roaming domestic dogs and wildlife. Biological Conservation, 157, 341-351.

IPBES (2019). Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (Paris, France, 2019).

IUCN (2004). 2004 IUCN Red List of Threatened Species.

Lapini, L. (2011). Il gatto selvatico (Felis s. silvestris) nell'Italia nord-orientale. Conferenza organizzata Da As. St. O. R. E., Palmanova, Udine, 11 novembre 2011 [in Italian].

Latini, R. (2008). Monitoraggio ungulate selvatici – Anno 2007 [in Italian].

Latini, R., Pizzol, I., Ferrera, G., Kleuser, H. (2003). Selezione invernale dell'habitat e densità del cervo (Cervus elaphus) e del capriolo (Capreolus capreolus) nel Parco Nazionale d'Abruzzo. Hystrix, the Italian Journal of Mammalogy, 14(Supplement) [in Italian].

Latini, R., Asprea, A., Pagliaroli, D. (2016). Stima della densità della popolazione di cervo e di capriolo nel parco nazionale d'Abruzzo, Lazio e Molise [in Italian].

Loy, A., Genov, P., Galfo, M., Jacobone, M. G., Vigna Taglianti, A. (2008). Cranial morphometrics of the Apennine brown bear (Ursus arctos marsicanus) and preliminary notes on the relationships with other southern European populations. Italian Journal of Zoology, 75(1), 67-75.

Massei, G., Genov, P. V., Staines, B. W., Gorman, M. L. (1997). Mortality of wild boar, Sus scrofa, in a Mediterranean area in relation to sex and age. Journal of Zoology, 242(2), 394-400.

Mattucci, F., Oliveira, R., Bizzarri, L., Vercillo, F., Anile, S., Ragni, B., Lapini, L., Sforzi, A., Alves, P.C., Lyons, L.A. & Randi, E. (2013). Genetic structure of wildcat (Felis silvestris) populations in Italy. Ecol. Evol. 3, 2443–2458.

Melis, C., Szafrańska, P. A., Jędrzejewska, B., Bartoń, K. (2006). Biogeographical variation in the population density of wild boar (Sus scrofa) in western Eurasia. Journal of biogeography, 33(5), 803-811.

McComb, B. C., Zuckerberg, B., Vesely, D., Jordan, C. (2010). Monitoring animal populations and their habitats: a practitioner's guide. CRC Press.

Mancinelli, S., Boitani, L., & Ciucci, P. (2018). Determinants of home range size and space use patterns in a protected wolf (Canis lupus) population in the central Apennines, Italy. Canadian Journal of Zoology, 96(8), 828-838.

Marinov, F. (2017). Implementing the Rewilding Scale in the Eastern Rodophes Rewilding Area. Rewilding Europe – Wageningen University and Research.

Marsican Bear Report 2017 [Rapporto Orso Marsicano 2017]. Natura Protetta - Notiziario del Parco Nazionale d'Abruzzo, Lazio e Molise, n.21. Estate 2018, Speciale Orso [in Italian].

Marsican Bear Report 2018 [Rapporto Orso Marsicano 2018]. Natura Protetta - Notiziario del Parco Nazionale d'Abruzzo, Lazio e Molise, n.22. Primavera 2019, Speciale Orso [in Italian].

Millennium Ecosystem Assessment (2005). Ecosystems and Human Well-being: Synthesis. Island Press, Washington, DC.

Primack, R. B., Boitani, L., Boitani, C. (2013). Biologia della conservazione. Zanichelli [in Italian].

Ragni, B. 2006. Il gatto selvatico. [The wildcat]. In: Perdisa, A.(Eds.), Salvati dall'arca. [Saved by the ark]. Bologna, pp. 35-36[in Italian].

Ragni, B., Possenti, M. (1996). Variability of coat-colour and markings system in Felis silvestris. Italian Journal of Zoology, 63(3), 285-292.

Ricci, F., Riga, F., Trocchi, V., Pierpaoli, M., Barone, V., Di Giambattista, P. (2007). Ecologia e status di Lepus corsicanus e L. europaeus nella Riserva Naturale Regionale Gole del Sagittario. de Filippo G., De Riso L., Riga F., Trocchi V. e Troisi SR (a cura di) [in Italian].

Rondinini, C., Ercoli, V., Boitani, L. (2006). Habitat use and preference by polecats (Mustela putorius L.) in a Mediterranean agricultural landscape. Journal of Zoology, 269(2), 213-219.

Rondinini, C., Battistoni, A., Peronace, V., Teofili, C. (2013). Lista rossa IUCN dei vertebrati italiani. Comitato Italiano IUCN e Ministero dell'Ambiente e della Tutela del Territorio e del Mare, Roma, 56 [in Italian].

Russo, L.F., Fabrizio, M., Di Febbraro, M., Loy, A. (2017). A road risk map for the European polecat (Mustela putorius, Mammalia, Carnivora, Mustelidae) in Italy. Road ecology experiences: research, planning and design for the ecological sustainability of infrastructures. Pettorano sul Gizio (AQ), Italia. Poster.

Si, X., Kays, R. & Ding, P. (2014). How long is enough to detect terrestrial animals? Estimating the minimum trapping effort on camera traps. PeerJ, 2, e374.

Storms, D., Aubry, P., Hamann, J. L., Saïd, S., Fritz, H., Saint-Andrieux, C., Klein, F. (2008). Seasonal variation in diet composition and similarity of sympatric red deer Cervus elaphus and roe deer Capreolus capreolus. Wildlife Biology, 14(2), 237-251.

Torres, A., Fernández, N., zu Ermgassen, S., Helmer, W., Revilla, E., Saavedra, D., Perino, A., Mimet, A., Jose´, M. Rey-Benayas, J.M., Selva, N., Schepers, F., Svenning, J., Pereira, H.M. (2018). Measuring rewilding progress. Philosophical Transactions of the Royal Society B: Biological Sciences, 373(1761), 20170433.

Tobler, M. W., Carrillo-Percastegui, S. E., Pitman, R. L., Mares, R., Powell, G. (2008). An evaluation of camera-traps for inventorying large-and medium-sized terrestrial rainforest mammals. Animal Conservation, 11(3), 169-178.

Tosoni, E. (2010). Indagini ecologiche relative alla popolazione di orso bruno marsicano (Ursus arctos marsicanus) nel territorio del Parco Nazionale d' Abruzzo, Lazio e Molise. Ph.D. Dissertation, University of Rome ''La Sapienza,'' Rome, Italy [in Italian].

Trocchi, W., Riga, F. (2005). I Lagomorfi in Italia. Linee guida per la conservazione e la gestione. MPAF-INFS, Documenti tecnici, 25, 128 pp [in Italian].

Wallach, A. D., Izhaki, I., Toms, J. D., Ripple, W. J., & Shanas, U. (2015). What is an apex predator? *Oikos*, *124*(11), 1453-1461.

Wearn, O.R., Rowcliffe, J.M., Carbone, C., Bernard, H. & Ewers, R.M. (2013). Assessing the status of wild felids in a highly-disturbed commercial forest reserve in Borneo and the implications for camera trap survey design. PLoS One, 8, e77598.

Wearn, O. R., Glover-Kapfer, P. (2017). Camera-trapping for conservation: A guide to best-practices. WWF Conservation Technology Series 1 (1).

Wearn, O.R., Glover-Kapfer, P. (2019). Snap happy: camera traps are an effective sampling tool when compared with alternative methods. Royal Society open science 6.3: 181748.