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Movement and Spatial Distribution of Mammal Species at wildlife crossings in the Abruzzo region of the Central Apennines, Italy.

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The research presented in this dissertation is original and has been carried out by the undersigned except where otherwise stated

Abstract

This importance of wildlife connectivity in fragmented habitats is widely known. This study aimed to assess the use of wildlife crossings within a wildlife corridor in the Abruzzo region of Italy. Wildlife corridors, along a stretch of state road SS17, maintained in an effort to reduce the impacts of habitat fragmentation, mitigate human-wildlife conflict and reduce biodiversity loss, were monitored with camera traps over a period of three months. The camera traps were used to record and monitor the number of individual animals/species utilising wildlife crossings and the footage was reviewed in order to identify possible trends in the movement of spatial distribution of species in relation to certain factors specifically predator presence, altitude, time. Fourteen wild species and two domestic species were identified utilising the wildlife crossings. Red Deer and Roe Deer were the most frequently observed species. Animals were recorded on the crossing more often at night time than during the day. Possible correlation in Red and Roe Deer numbers in relation to predator presence and altitude were investigated, and though no significant correlation was determined, there appeared to be a trend which could form the hypothesis of a further study. As there is very little current data or research on the efficacy of wildlife corridors, spatial distribution and roadkill numbers for this region, the data collected in the course of this study will be useful in informing current conservation management strategies, will contribute to bridging knowledge gaps currently existing in relation to species distribution and habitat connectivity and help form a basis and give direction to further research.

Acknowledgments

I would like to thank Salviamo l’Orso, especially Mario Cipollone, and the Monte Genzana Alto Gizio Nature Reserve for allowing me to use their camera traps and providing me with knowledge of the research area. Thank you to Kim Townsend-Smyth, all the volunteers who assisted with data collection, my parents for helping fund my time at university and my tutor, Dr. Sandford, for helping me with this dissertation. Thank you to the friends that helped make the last four years enjoyable and keep me motivated, and finally, thank you to myself and PH Premium for getting me through it all.

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1. Introduction

The Central Apennine mountain range in Italy contains the Abruzzo, Lazio and Molise National Park, Majella National Park and Monte Genzana Nature Reserve (Fig 1.). The establishment of these National Parks (NP) began in Italy in 1922 to conserve the habitats of endangered species whose populations rapidly declined after the industrial revolution due to lack of government interest in nature preservation (Lovari and Cassola, 1975). The Abruzzo, Lazio and Molise National Park (PNALM), one of the first national parks in Italy and Europe, was formed in 1923 with the purpose of protecting species such as the Apennine chamois and Marsican brown bear (Rewilding Europe, n.d.).

Figure 1. The Apennine mountain range running through the Italian peninsula, specifically the Abruzzo (ABRUZZI) region, located within the red square (Parotto, Poulsen and Accordi, 2009*)*.

Parcoabruzzo.it (n.d.) states that there are “60 species of mammals, 300 birds and 40 species of reptiles, not to mention the wide variety of insects and invertebrates” found within PNALM, with the key species of local fauna in the Central Apennines listed as “the Marsican brown bear, grey wolf, Apennine chamois, red deer, golden eagle, vultures and an astonishing set of endemics.” (Rewilding Europe, n.d.).

Red deer (*Cervus elaphus*), introduced in the mid-1970s, roe deer (*Capreolus capreolus*) and wild boar (*Sus crofa*) live within the large beech forests that line the hills and valleys of the landscape, and combined with the semi-wild horses and cattle of the area make up the main prey of the main apex predator, umbrella, flagship, keystone and indicator species of the region, the Apennine wolf (*Canis lupus italicus*) (Rewilding Europe, n.d.). This vulnerable species has an estimated population of just 600-1000 individuals (Mattioli, Forconi, Berzi and Perco, 2014), but this is likely to be an underestimation (Galaverni et al., 2015). As an apex predator this species is critical to maintaining the natural order within the ecosystem, its conservation is essential. Although it is possible to observe the Marsican brown bear (*Ursus arctos marsicanus*), extremely low population size (approximately 50, endemic to the central Apennines) means chances of sightings are very low. Reports of sightings, usually made by the general public, are the best method of estimating the locations of bears. Most reports of sightings are at road crossings along regional road SS17, where reports of bear-car collisions are also reported (Edwards, 2016).

Roadkill is the largest single cause of mortality for many vertebrates (Fabrizio et al., 2019) with wildlife-vehicle collisions being amongst the most typical road-related impacts on wildlife populations worldwide (Forman and Alexander, 1998). The Marsican brown bear has an estimated road mortality of 13% of all mortality cases (Life Safe-Crossing, n.d.), a huge percentage considering its tiny population size. Lovari, Sforzi, Scala and Fico (2007) found that of 154 wolf carcasses found within central-eastern Italy, vehicle collisions were the main cause of death. However, as roadkill is easier to detect, this is biased. Data collected assessing the roadkill risk to European badgers shows the increase in risk close to roads compared to areas further from roads within the Abruzzo region (Fig 2.) (Fabrizio et al., 2019).

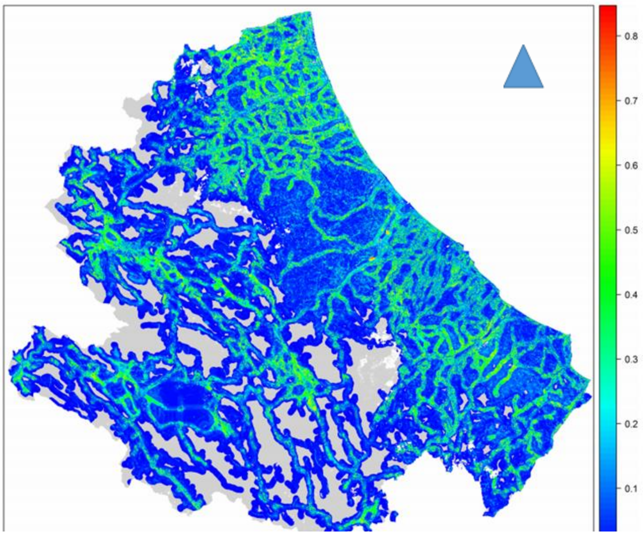

Figure 2. Roadkill risk map of Abruzzo (for European badger). Risk increases towards red and decreases towards blue (Fabrizio et. al. 2009*).*

As no systematic monitoring currently takes place in Abruzzo, the scale of roadkill can only be estimated. For each province in Italy (of which there are currently 103) it is estimated that 15 animals are killed on the roads each year, therefore 1545 nationally (Life.safe-crossing.eu. n.d.). However, as this is purely an estimation, it can be assumed that the actual number is much greater. Applying this estimation system to the rest of Europe, the scale of the problem quickly becomes apparent, especially with two-thirds of all collisions remaining unreported (Snow, Porter and Williams, 2015; Benten, Annighöfer and Vor, 2018).

The development and expansion of roads poses numerous threats to wildlife, including physical dangers, obstruction in migration and movement, as well as habitat fragmentation. Habitat fragmentation poses a massive threat to biodiversity, and more of a specific problem to Italy than direct mortality from roadkill. Goosem (1997) states that roads create barriers to the movement of animals, creating habitat fragmentation and leading to divided populations with reduced genetic diversity, which can further result in extinction. PATOM (Action Plan for the Protection of the Marsican Bear) states SS17 in particular is a major barrier to the migration of the Marsican bear into new areas (Life.safe-crossing.eu. n.d.). Although wolves in Scandinavia have been found to utilize roads, allowing them to move at twice their travel speed

(Zimmermann et al., 2014), Alexander and Waters (2000) found that large roads can act as barriers - limiting distribution and dispersal of populations, as well as increasing human caused mortality such as roadkill. Laurance et al. (2001) suggested that the locations of roads are the single greatest factor creating fragmentation. The density of the road network within Abruzzo can be seen in (Fig.3) highlighting the risk of potential fragmentation.

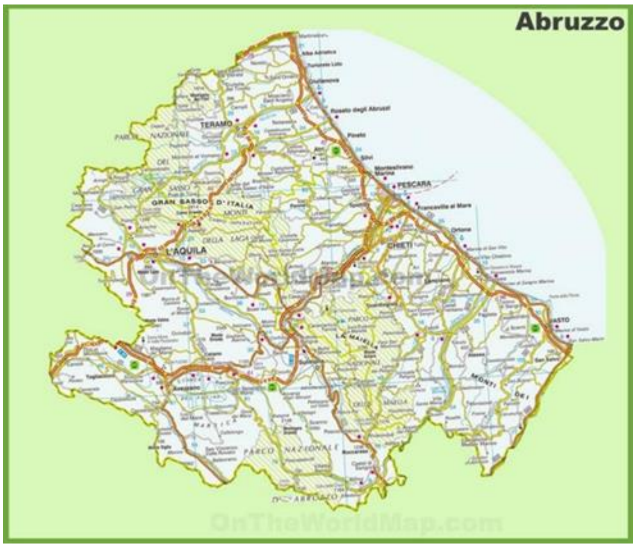

Figure 3. Road map of Abruzzo region, central-eastern Italy (On The World Map, n.d.).

SS17 runs south from Sulmona to Bojano, through a valley that makes up part of a natural wildlife corridor connecting the Monte Genzana Nature Reserve and Abruzzo National Park to the South West and the Majella National Park to the North East (Rewildingeurope.com, 2018). The Abruzzo region contains several Natura 2000 sites (Fig 4.) (part of the “European Commission’s LIFE + funding programme of operating grants for European Environmental Institutions and NGOs”), with the wildlife corridor connecting multiple Habitats Directive Sites, Birds Directive Sites and Birds and Habitats Directive Sites (Natura2000.eea.europa.eu, 2018). Wildlife corridors are links between multiple areas of similar wildlife habitat, made up of native vegetation. They are crucial in allowing the free passage of wildlife from one area to another, maintaining ecological processes and the continuation of populations (Department of Environment and Conservation, 2004). This study was conducted in the area of the wildlife corridor which connects the Abruzzo, Lazio and Molise (PNALM) and Majella National Parks through the Monte Genzana Nature Reserve within the Abruzzo region of central Italy (Fig. 5). Although there is some scepticism towards the overall effectiveness of wildlife corridors, the general consensus is that landscape connectivity enhances population viability for many species (Gilpin and Soule, 1986; Beier and Noss, 1998). Naidoo et al (2018) found that the majority of regional-scale corridors within the Kavango-Zambezi trans frontier conservation area (KAZA TFCA) captured higher levels of connectivity compared to areas without corridors and Gilbert-Norton, Wilson, Stevens and Beard (2010) showed that corridors increased movement of species between fragmented habitat areas by approximately fifty percent compared to areas not connected by corridors and that efforts to maintain and create new corridors are worthwhile.

Several wildlife crossings have been established along SS17 to enable safe movement of animals. These crossing were not initially constructed for wildlife purposes but have been adapted over the years to suit this purpose. Wildlife crossings are passages above or below roadways designed to allow the safe free movement of wildlife across transportation corridors (Donaldson, 2005). Crossings include overpasses (also known as green or eco bridges) and underpasses that can be tunnels, culverts, or viaducts (Carr et al., 2003). Crossings are used to reduce human-wildlife conflict by reducing roadkill and the mortality rate (McCollister and van Manen, 2010). With roads creating habitat loss and fragmentation, and major threats to biodiversity, crossings are a tool to reduce these negative impacts (Department of Environment and Conservation, 2004). Crossings allow the free passage of wildlife from one area to another, maintaining ecological processes and the continuation of populations (Department of Environment and Conservation, 2004; Simpson et al., 2016).

Carr et al (2003) states some of the distinguishable characteristics of wildlife crossings include ‘’grade separation, vegetation to attract animals and provide habitat, fencing and other measures to guide animals to safe crossings, strategic location to enhance habitat connectivity and complement wildlife movement corridors, adjacent land use and zoning that is conducive to long-term habitat protection”. Many findings document the success of wildlife crossings. McCollister and van Manen (2010) observed that within fenced road sections, mortalities were lowest near underpasses and increased with distance away from the underpasses. Simpson et al. (2016) found that wildlife crossings reduced habitat fragmentation and improved movement by allowing safe passage across roads. Beben (2016) found that the wider crossings were used by animals more often, and crossing often are utilized more often at night, possibly due to reduced levels of human activity and disturbance.

Conservation efforts in the study area have focused plans specifically aimed at maintaining the potential for movement of animals through management of wildlife corridors and crossings. **Salviamo L’Orso** (SLO) (Let’s Save the Bear) Project is based in the village of Pettorano sul Gizio within the Monte Genzana Nature Reserve. SLO was established in 2012 with the aim of: “preserving and promoting the expansion of the Marsican brown bear population within the boundaries of its original habitat, namely the Central-Southern Apennines (Abruzzo-Molise-Lazio-Umbria-Marche)” (Salviamo l’Orso, n.d.). SLO achieves its four main priorities of informing, sensitising, overseeing and accomplishing though the activities of: pruning fruit trees, local education, maintenance of fencing and trails to protect livestock, establishment of road signs to prevent roadkill and campaigning to reduce speed limits on sections of road (Salviamo l’Orso, n.d.). The Marsican bear is protected under PATOM, established by the Italian Ministry of the Environment for Protection of the Territory and the Sea. WWF (World Wildlife Fund) is partner of PATOM to “help countries on a national and international level to establish management actions for the conservation of the brown bear” (Swenson, Gerstl, Dahle, and Zedrosser., 2000). The study area is also included and monitored through the **Rewilding Apennines** (part of **Rewilding Europe**) project which, after being set up in 2013, aims to: “establish coexistence corridors by reducing bear mortality and conflict; boost Marsican brown bear numbers by installing road safety measures, removing old fencing, restoring and improving signage, and distributing new mobile electric fences; providing an economic incentive to protect the wildlife” (Rewilding Europe, n.d.). Rewilding Europe’s process, combined with strict protection management and measures established over the previous decades, has had some success due to abandonment of land and a decrease in environmentally damaging traditional activities (Rewilding Europe, n.d.).

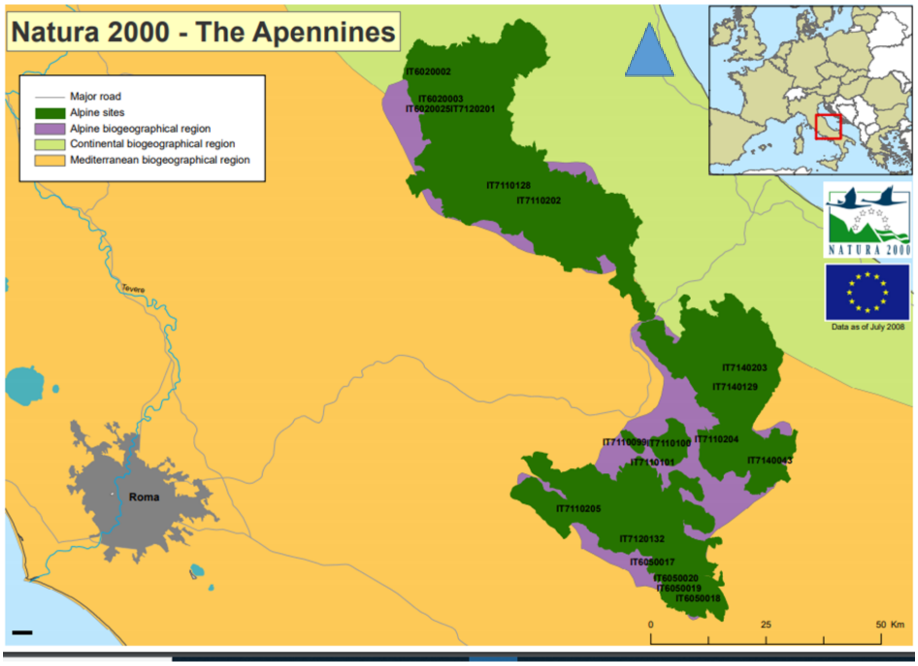

Figure 4. Map of Natura 2000 sites within the central Apennines, central Italy (as of July 2008) (Ec.europa.eu 2020).

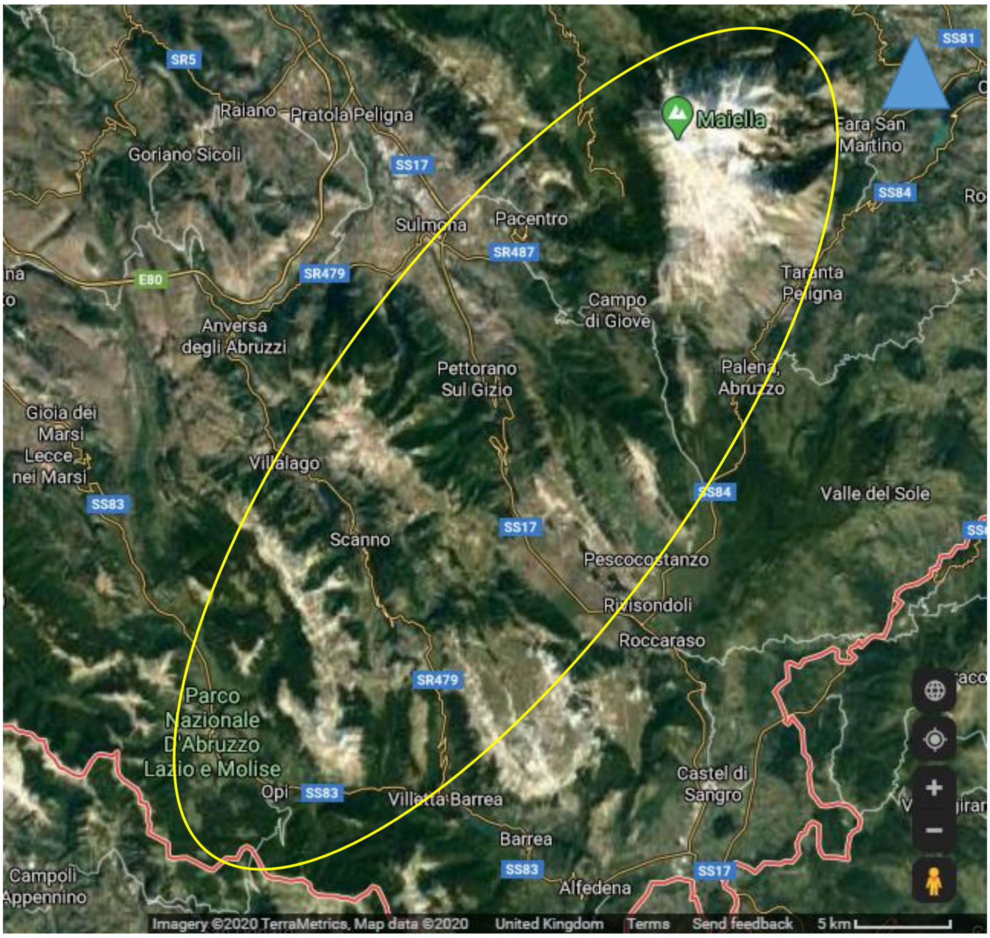

Figure 5. Satellite image showing the wildlife corridor connecting the Abruzzo, Lazio and Molise (PNALM) and Majella National Parks through the Monte Genzana Nature Reserve within the Abruzzo region of central Italy. (Google Maps, 2020).

This study aims to assess the use of seven wildlife crossings, maintained to reduce the impacts of habitat fragmentation, mitigate human wildlife conflict, prevent biodiversity loss and aid in preserving species connectivity, along road SS17 within the Province of L'Aquila of the Abruzzo region between Pettorano sul Gizio and Rocca Pia. These wildlife crossing were monitored with camera traps over a period of three months. The aim of this monitoring is to collate data on the species utilizing these wildlife crossings, which species occur most frequently and in which areas, are the crossings used most at day or night, which crossings are frequented the most and to gain some insight into the effectiveness of the crossings in terms of conservation and allowing for movement and spatial distribution of wildlife in the region. It is expected that the camera traps will record occurrences of most native mammal species know to be in the area and that most activity will occur at night when the chances of human disturbance are low. The data collected may also allow identification of possible trends in the movement of spatial distribution of species in relation to certain factors e.g. predator presence, proximity to road, altitude, and time. Research carried out in the course of this study along with personal communication with contacts at SLO have revealed a huge lack of available information, scientific studies, research, or data relating to wildlife crossings, wildlife corridors or roadkill in Italy. This unfortunately leaves little options for comparable or baseline data but hopefully means this data will contribute to informing management plans in the area regarding the maintenance and improvement of the crossings and aid in the actions being taken to preserve species migration, improve local conservation and to reduce habitat loss, roadkill rates.

2. Materials and Methods

2.1. Study Area

The Abruzzo region (Fig. 6) is situated on the east coast of southern Italy, east of Rome. It encompasses part of the Apennine mountain range. The Apennines are the second largest mountain range in Italy, extending 1200Km along the central ridge of Italy. The landscape encompasses a range of limestone peaks reaching nearly 3,000 metres, canyons, caves and some of Europe’s oldest grasslands and beach woodlands (Rewilding Europe, n.d.). The central Apennines fall within the administrative regions of Abruzzo, Latium and Molise, comprise several peaks exceeding 2000m in altitude and a vast natural area (Rewilding Europe, n.d.).

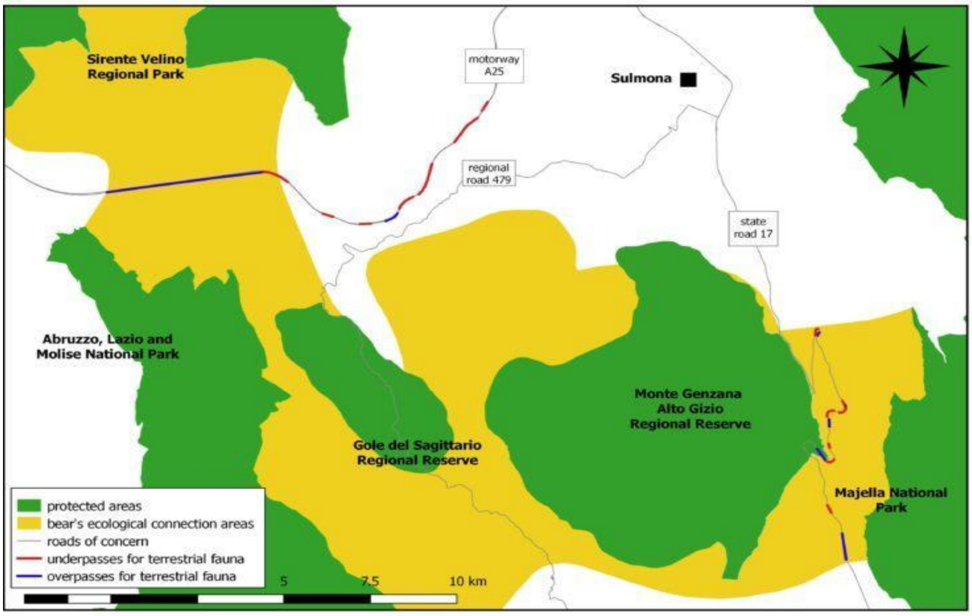

Figure 6. Digital map of the research area showing national parks and reserves, protected areas, Marsican bear ecological connection areas (corridors), and underpasses and overpasses along three main roads within the Abruzzo region (Salviamo l'Orso, n.d.)

The alpine biogeographical region encompasses a grassland valley, mixed broadleaf and coniferous mountainside forests and open scrub and bushland (Fig. 7). This region also contains a number of Natura 2000 sites (Fig. 8)

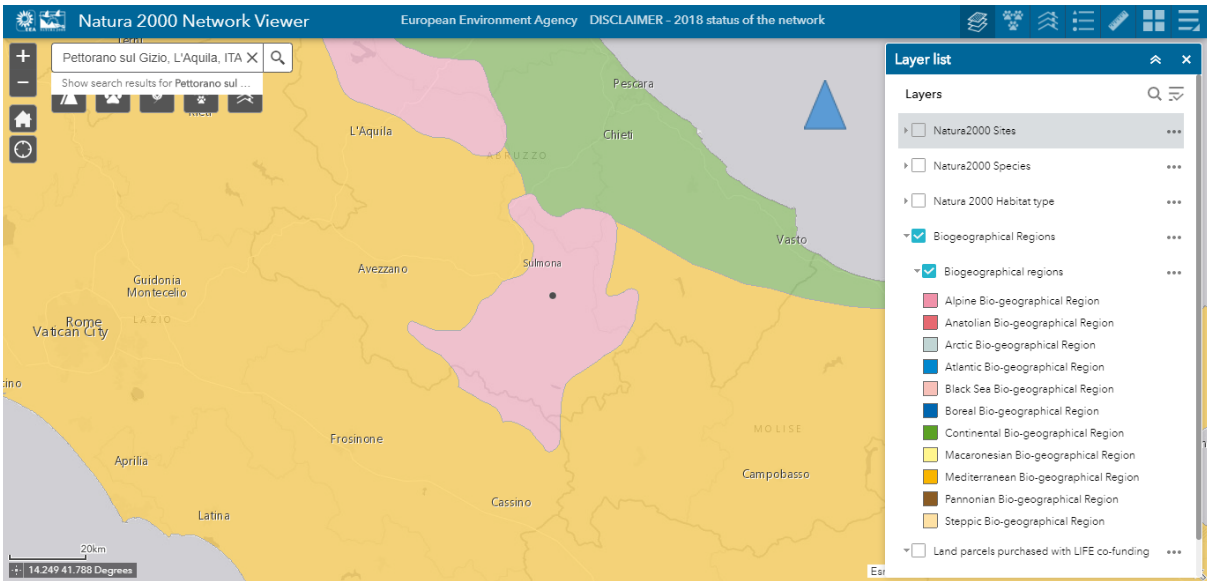

Figure 7. Arcmap GIS map showing the biogeographical regions of central mainland Italy surrounding the research area (Natura2000.eea.europa.eu, 2018)

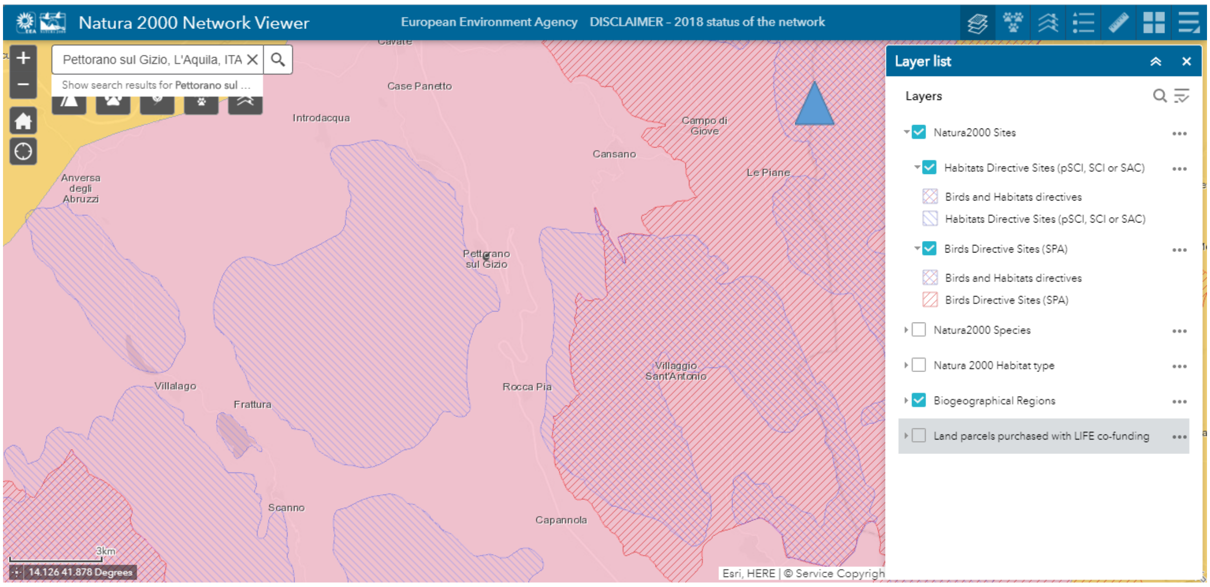

Figure 8. Arcmap GIS map showing the Natura 2000 sites within the Biogeographical Regions of the research and surrounding area (Natura2000.eea.europa.eu, 2018).

The study was conducted along the regional road SS17 (Figs. 10, 11 and 12) (that runs south from Sulmona to Bojano, through a valley that makes up part of a natural wildlife corridor connecting the Monte Genzana Nature Reserve and Abruzzo National Park to the south west and the Majella National Park to the North East (Salviamo l'Orso, n.d.). With the road being built in 1928 and renovated in the 1960s and 70s, none of the crossings were purposely built for wildlife passage. Instead, they were built as viaducts, a bridge over a valley, or as access tunnels for maintenance work or for people to reach their land on the other side of the road (M. Cipollone, 2019, personal communication, 24 October). They, as well as various local pubic footpaths, are maintained as safe crossings for wildlife through various conservation projects carried out by Salviamo l'Orso. Although these crossings are only secondarily used for wildlife, they do however provide a very important conservation tool.

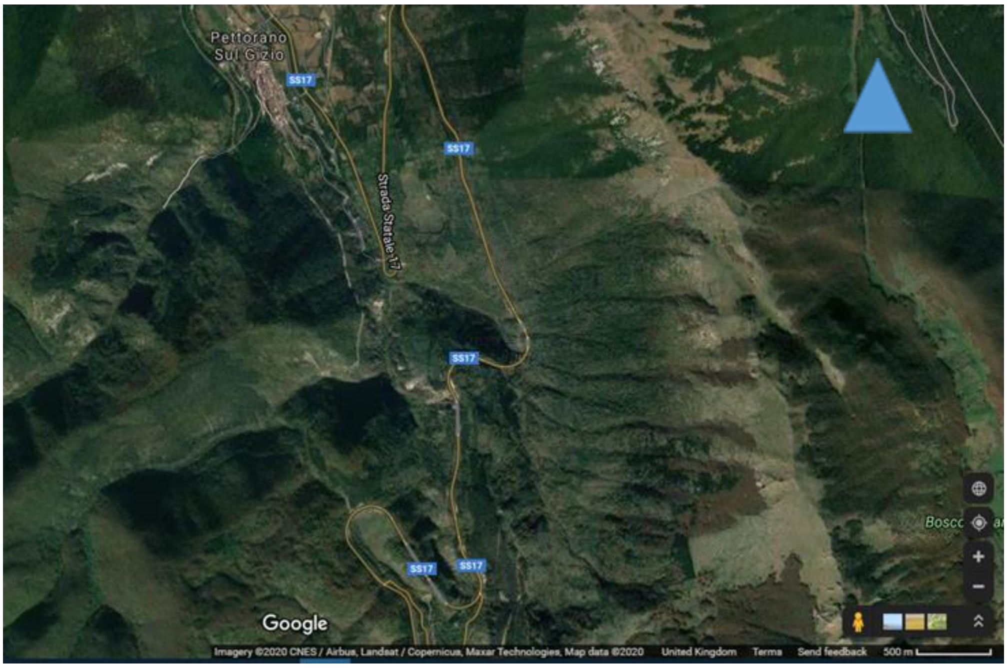

Figure 10. Satellite Image of road SS17 winding southwards between the communes and towns of Pettorano sul Gizio and Rocca Pia, within the research area, within the Abruzzo region, central-eastern Italy (Google Maps, 2020).

Figure 11. Topographical Image of road SS17 winding southwards between the communes and towns of Pettorano sul Gizio and Rocca pia, within the research area, within the Abruzzo region, central-eastern Italy (Google Maps, 2020).

2.2 Monitored Locations

Camera trap (CT) monitoring was undertaken at eight locations along road SS17 within the wildlife corridor, between the villages of Pettorano sul Gizio and Rocca Pia, in the province of

L'Aquila. Seven wildlife crossing were monitored: 4 underpass locations, 3 overpass locations, an additional CT was set up along a track (neither an overpass or underpass) (Fig.12). CT monitoring was carried out from 22.03.19 to 29.06.19. Six cameras were originally set up, 3 at overpass locations and 3 at underpass locations. As mentioned above, these wildlife crossings were not initially established for that purpose but have been adapted to use as a wildlife crossing as a result of conservation efforts in this area. Each of the locations of wildlife crossings have various ecological characteristics, with CTs set up at differing distances from SS17. Table 1. details the landscape features of, and, CT location for each of the monitored wildlife crossings. CT 4 (underpass), CT 5 (overpass) and CT 6 (underpass) were set up on 22.03.19. CT 1 (overpass), CT 2 (overpass), CT 3 (underpass) were set up on the 23.03.19. CT 7a was set up on a track close to SS17 on 14.04.19 and was relocated to a nearby underpass and renamed CT 7b 10.06.19.

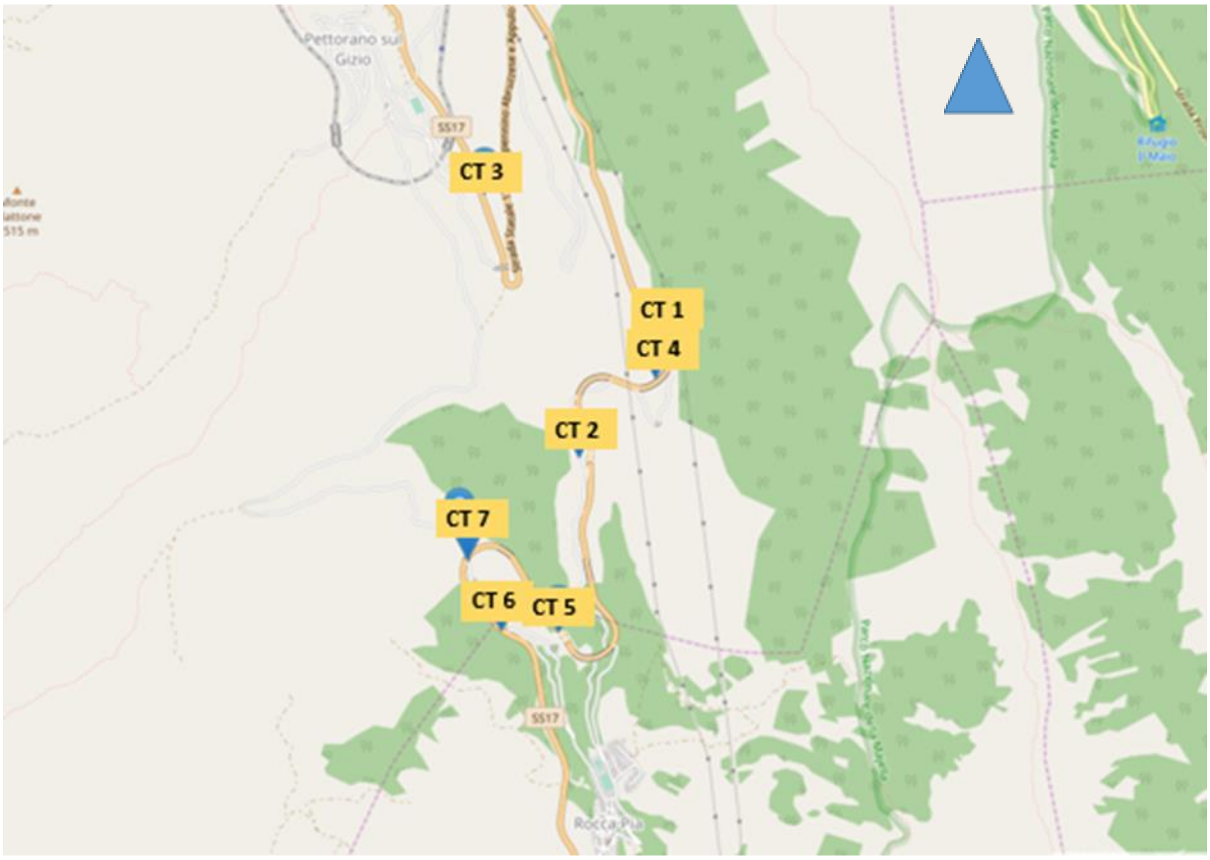

Figure 12. Map showing the locations of the camera traps along road SS17 within the research area, within the Abruzzo region, central-eastern Italy *(Mapcoordinates.net, 2020).*

Table 1. showing the characteristics of the eight camera trap locations

Camera traps							Landscape features			
Set up date	CT Number	UP/OP	CT height (cm)	Elevation (m)	Distance to road (m)	CT direction (N/E/S/W)	Direction North	Direction East	Direction South	Direction West
23-03-19	1	OP	150	913	0	W	Road	Road	Mixed broad leaf and coniforous forest	Open scrub and bushland
23-03-19	2	OP	170	946	43.3	N	Road	Road	Mixed broad leaf and coniforous forest	Mixed broad leaf and coniforous forest
23-03-19	3	UP	190	585	2	NW	Forest/road	Forest	Forest/road	Road
22-03-19	4	UP	180	804	0 (50 below)	NE	Grassland valley	Mountain-side forest	Mountain-side grass land	Grass land valley
22-03-19	5	OP	180	1061	8.1	SW	Forest	Forest	Grass land	Grass land
22-03-19	6	UP	20	1090	3	NE	Grassland	Mixed broad leaf and coniforous forest	Road	Road
12-04-19	7a	(Track)	250	1072	126	E	Forest	Forest	Forest	Forest
10-06-19	7b	UP	50	1080	3	SE	Forest	Road/grass land	Forest	Forest

CT1 was situated on overpass on a grassland overpass above SS17. It faces over the valley and behind it is the steep mountain incline covered in mixed broad leaf and coniferous forest and grassland.

CT2 (Fig. 13) was situated on a wildlife track on an overpass above SS17. It is surrounded by a mixed broad leaf and coniferous forest on a steep hill, and is next to an old, abandoned road which existed prior to the establishment of SS17.

Figure 13. Overpass at Camera Trap 2, along road SS17 Between Pettorano sul Gizio and Rocca Pia, within the Abruzzo region, central-eastern Italy (Google Maps, 2020).

CT3 was positioned in a small, enclosed woodland area, facing an underpass below SS17. On the other side of the underpass to the west there is private gardens/farmland.

CT4 was located at an underpass, approximately 50m directly below road SS17 as it bridges over the valley. To the east is the same grass and mixed broad leaf and coniferous forest covered mountain side that sits behind CT1.

CT5 was located on an overpass at the top of a hillside woodland that falls to the NE/E, directly above the tunnel that SS17 passes through, facing uphill to wildlife path.

CT6 (Fig 14.) was situated in a mixed broad leaf and coniferous forest next to a natural stream that runs NE through the underpass below SS17.

CT7a was positioned higher than the other CTs (due to it being on a short but steep slope), on the edge of a woodland facing a gravel track that runs perpendicular.

CT7b was positioned facing an underpass below SS17. It was camouflaged in a bush (due to it being so low down and accessible by humans that pass through the underpass). Running parallel to this underpass is the same track that CT7a was positioned on and running perpendicular above it is road SS17.

Figure 14. The underpass at Camera Trap 6 being maintained by a member and volunteer of Salviamo l'Orso (Salviamo l'Orso, n.d.).

2.3 Camera Traps

The cameras (Bushnell model: 119447C, 8MP Trophy CAM HD Trail camera) used in this study run on an infrared transmitter and receiver. When the transmitter is interrupted by an object with a higher surface temperature than that of the background the camera is triggered (Apps and McNutt., 2018). A light is also emitted for night-time recording. The settings allow the type of recording (photo, video, or both), the length of recording and the interval time between each recording, as well as other settings.

The camera traps were set in places where there was obvious animal presence (Fig.15), shown by naturally formed animal paths or the presence of animal tracks or scat (Fig, 16), to increase the chances of catching more videos and therefore more data. Where possible, the cameras were set to a high detection level, and given a 5 second recording interval.

Figure 15. A camera trap being installed/checked in the Abruzzo region, central-eastern Italy (Salviamo l'Orso, n.d.).

Figure 16. Bear scat next to measure tape to show scale (Salviamo l'Orso, n.d.).

Due to a lack of options, the cameras had to be set up at different heights according to what was possible at each location. Therefore, the range of heights is 20-250cm, with the mean average being 146.25cm and the recommended average for large deer being 150cm (chest height (Reconyxn inc., 2017), but 20-50cm for the best range of small-large animals (Wearn and Glover-Kapfer, 2020).

Meek, Ballard and Falzon (2016) state that the recommended height provided by several camera trap manufacturers ranges from 20-300cm, but evidence to support the success of a certain height is rare.

2.4 Data Collection

CTs were checked every 1-2 weeks, the accessibility of locations, weather conditions and project scheduling influenced CT checking frequency. The SD cards were removed and replaced with empty ones, and the battery level was checked and replaced if the charge dropped below 40%. The settings were checked to make sure everything was correct.

Once SD cards had been collected all video footage was reviewed. Data relating to species ID, number of individuals and time of day was recorded and entered into an Excel database. The decision on whether the video was recorded at day or night is decided by light/colour seen on videos. On footage where there was an error with the colours/videos are black and white (grey) the time is used to decide on whether the video is day or night using knowledge of sunrise and sunset times at that particular time of the season. Videos set off by foliage moving in the wind were deleted. Error videos were not recorded, and video's where exact species identification was not possible were not used in the final data. Where it is clear from the footage that one individual is recorded over a number of consecutive videos, it is recorded as one individual. Where it is not clear, even though it is highly likely to be one individual, it is counted as separate animals. The final CT checks were carried out on 29.06.19.

CTs 4, 5 and 6 were set up for 99 days, 1,2 and 3 for 98 days, 7a for 59 days and 7b for 19 days. The camera trapping period ran from 22.03.19 – 29.06.19.

2.5 Health & Safety

A risk assessment as carried out prior to the commencement of this research (Appendix 1). Health and safety briefings were also held at the research area coordinated by Salviamo l'Orso prior to data collection.

3. Results

3.1 Overview of CT Data

A total of 1170 videos were reviewed; 521 individual animals were positively identified across all sites. In total 17 species (14 wild species, 3 domestic species) were recorded across all sites. Species recorded and positively identified include: Marsican Brown Bear (*Ursus arctos marsicanus*) (Plate. 4), Italian Wolf (*Canis lupus italicus*) (Plate. 3), Red Deer (*Cervus elaphus*) (Plate. 2), Roe Deer (*Capreolus caprelous*) (Plate. 1), Wild Boar (*Sus scrofa*), Crested Porcupine (*Hystrix cristata*), Wild Cat (*Felis silvestris silvestris*), Corsican Hare (*Lepus corsicanus*), European Badger (*Meles meles*), European Hedgehog (*Erinaceus europaeus*), Domesticated Horse (*Equus ferus caballus*), Red Squirrel (*Sciurus vulgaris*), Domestic Cat (*Felis catus*), Bank Vole (*Myodes glareolus*), Marten (*Martes spp*.) and Red fox (*Vulpes

vulpes) (See Appendix 2). The total number of individuals recorded for each species across each of the CT sites, broken down into day and night observations, are detailed in Table 2.

Plate 1. Roe deer *(Capreolus caprelous)* CT5.

Plate 2. Red deer *(Cervus elaphus) CT1.*

Plate 3. Italian Wolf *(Canis lupus italicus)* CT1.

Plate 4. Marsican Brown Bear *(Ursus arctos marsicanus)* CT7a.

Of all the species present, the highest numbers of individuals were recorded for each Red and Roe Deer compared with other species (Fig 17). Deer species accounted for 50.1% of all individuals recorded. As expected, the Marsican Bear was the wild species with the lowest number of individuals recorded, with only 1 individual recorded accounting for 0.19% of number of individual animals recorded. As expected, more species and individuals were recorded at night, 64.3% of all individuals recorded were recorded at night, with the exception of the Roe Deer and Red Squirrels, of which 68.4% and 71.4% respectively of total numbers of each of these species were recorded during the day (Fig 18).

Table 2. Total numbers of individuals recorded for each species identified including breakdown of day and night observations

CT	Time	Fox	Wolf	Boar	Badger	Hedgehog	Roe Deer	Red Deer	Red Squirrel	Bear	Porcupine	Wild Cat	Hare	Vole	Marten sp.	Dom. Horse	Dom. Cat	Dom. Dog	CT D/N Total	Total Ind.
CT1	Day	4	3	0	0	0	4	7	0	0	0	0	2	0	0	0	0	0	20	
	Night	12	20	8	8	0	4	13	0	0	8	0	6	0	1	0	0	0	80	100
CT 2	Day	0	0	0	1	0	15	9	3	0	0	2	0	0	0	0	0	0	30	
	Night	1	1	4	15	0	9	10	1	0	0	16	0	0	3	0	0	0	60	90
CT 3	Day	0	0	2	0	0	10	17	0	0	0	0	0	0	0	0	0	0	29	
	Night	7	0	0	2	2	1	14	0	0	16	0	0	0	8	0	5	0	55	84
CT 4	Day	2	0	0	0	0	19	12	2	0	0	0	0	0	0	0	0	0	35	
	Night	3	0	0	0	0	4	20	1	0	1	0	0	0	0	0	0	0	29	64
CT 5	Day	0	0	0	0	0	16	7	0	0	0	0	0	1	1	0	0	0	25	
	Night	4	0	1	0	0	14	5	0	0	0	2	1	9	4	0	0	0	40	65
CT 6	Day	0	1	0	0	0	16	1	0	0	0	0	3	0	2	0	0	0	23	
	Night	1	7	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	9	32
CT 7a	Day	0	0	0	0	0	0	6	0	1	0	0	3	0	1	1	1	0	13	
	Night	10	0	3	7	1	3	20	0	0	0	0	4	1	0	0	6	0	55	68
CT 7b	Day	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	9	0	11	
	Night	1	0	0	0	0	2	2	0	0	0	0	0	0	0	0	2	0	7	18
	Sp. Total	45	32	18	33	3	117	144	7	1	25	20	21	11	20	1	23	0	521	521

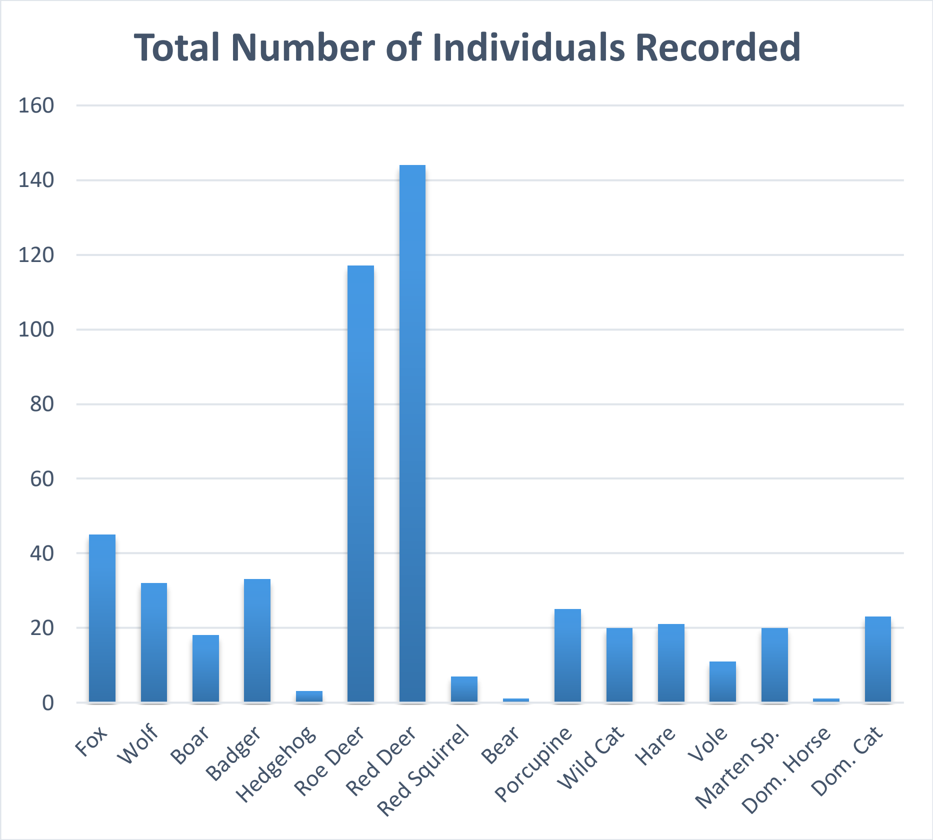

Figure 17. Graph showing number of individuals of species recorded.

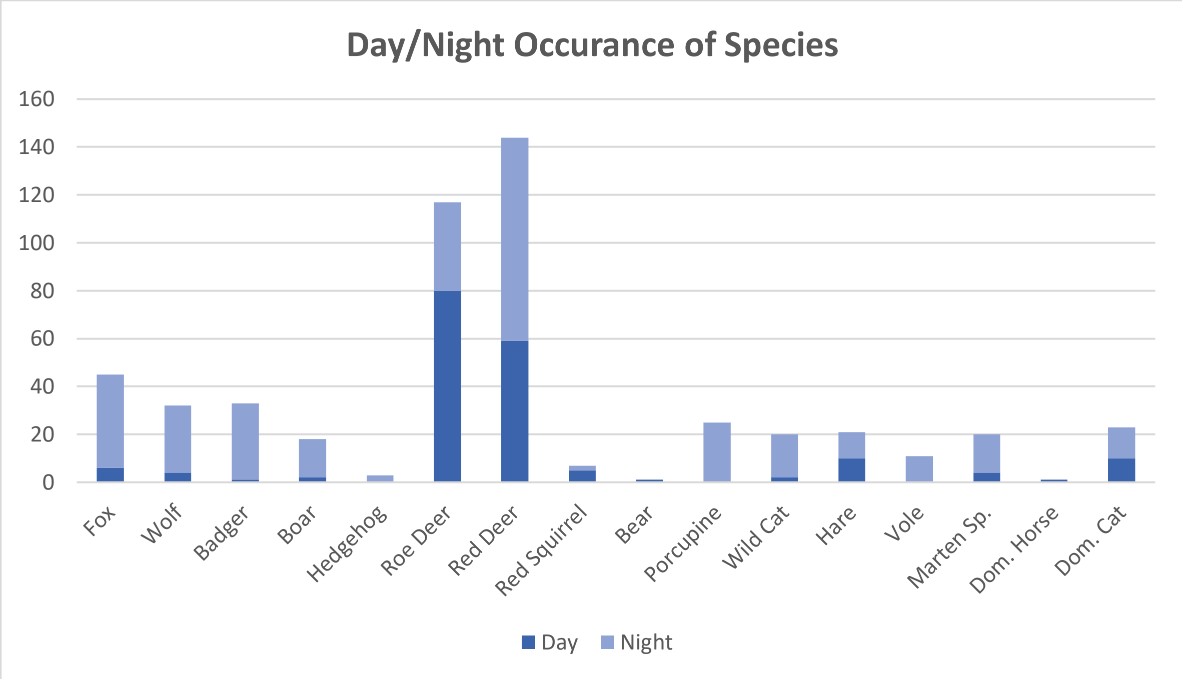

Figure 18. Graph showing ratio of individual species recorded over day and night.

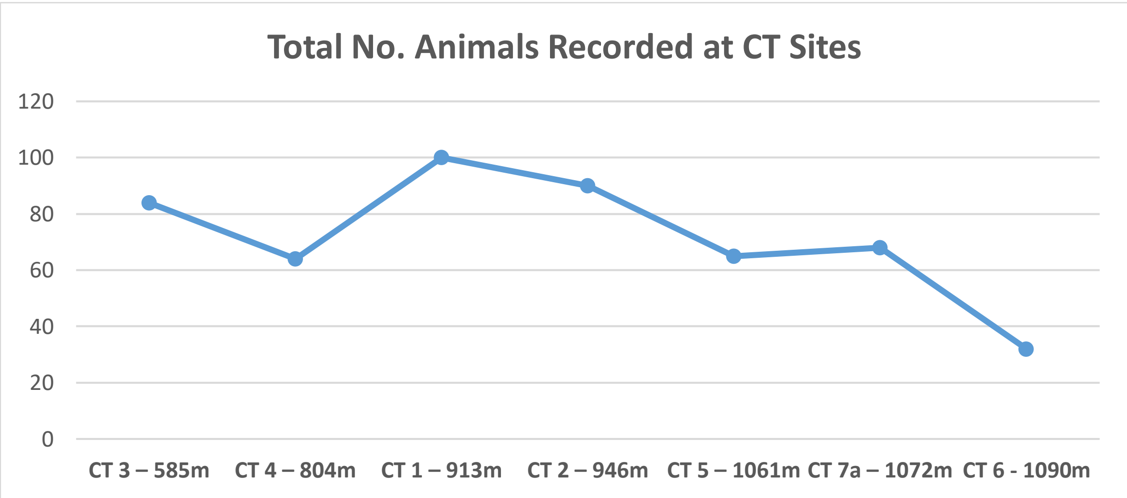

Figure 19. Total no. of animals recorded at each CT site in relation to altitude.

The highest number of individual animals were recorded at CT1 (Fig. 19). The CT was located directly above road SS17. This result may be due to this crossing providing the main route connecting higher ground to the open valley. This area was also open with less vegetation resulting in the CT having a wider field of view to detect movement. A potential negative trend between altitude and number of individuals may be inferred from this graph but would require further study and a monitoring method designed specifically to assess the relationship between altitude and animal presence.

In terms of utilization of wildlife crossing type, 48.95% of animals were recorded on overpasses, 38% at underpasses and 13.05% at the track site.

As the data shows that deer species were recorded most frequently, further analysis was carried out to investigate potential correlations between the number of deer recorded at a particular site and predator presence and altitude.

3.2. Wolf-Deer-Altitude Analysis

Data relating to the number of deer and wolves was plotted on a graph in order to investigate potential drivers influencing distribution of deer species at each research location. Fig.20 represents the number of roe deer, red deer and wolves present in relation to altitude. The graph illustrates that wolf numbers peaked at the site monitored at CT 1 at an altitude of 913m with 71.9% of all wolves recorded in this study occurring at this location. This could possibly be due to human avoidance (Capitani et al., 2006), or lower summer temperature for pups, with Bassi et al (2015)'s research showing that wolves preferred altitudes between 800 and 1200m where there is no settlements and the temperature is lower. CT1 is one of the furthest sites from any settlements. However, as the other CTs were also located within this altitude range, the results are more likely due to other factors, such as the surrounding habitat and the location of the overpass, as well as the areas this crossing enables access to, such as access to the open valley floor from higher ground. The highest number of red deer occurred at CT4, at an altitude of 804m with a secondary peak of numbers at 585m. There appears to be a decline in red deer numbers as wolf numbers increase followed by an increase as wolf numbers decrease. The highest number of roe deer were recorded at CT5 at an altitude of 1061m. Roe deer numbers also appear to decline at the site where the highest number of wolves are recorded and increase to their highest point where wolf numbers are at zero.

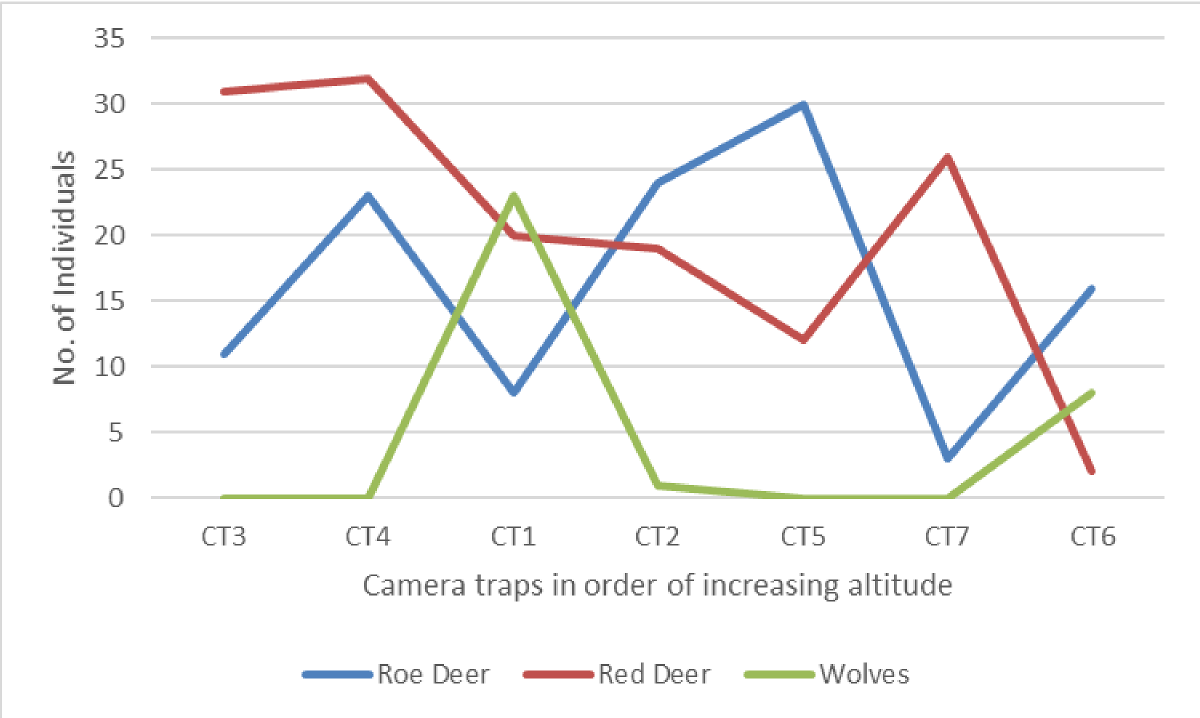

Figure 20. Graph showing the relationship between individual species number and increasing altitude for Roe deer, Red deer, and Wolves.

This graph indicates a potential relationship between the number of deer present in relation to wolf presence and/or altitude. Correlation tests were carried out to establish if there is any definitive link or correlation between the number roe and red deer recorded at each site in relation to the number of wolves recorded and altitude. The tests imply that there is not a strong correlation however there is a trend, further study into other drivers and factors, such as habitat type and migration patterns, that can affect animal numbers recorded at a given site is required. Wolf/altitude and roe deer/altitude both showed no correlation between the number of individuals recorded in relation to altitude. Red deer/altitude showed strong negative correlation (-0.7176), showing that as altitude increases the number of red deer decreases. This could possibly be due to red deer feeding at lower altitudes with their offspring. T-tests carried out for all three gave a p-value above 0.05, therefore the data is not statistically significant.

3.3. Predator – Prey Analysis

Analysis carried out (Fig. 21) shows that total deer and total wolf numbers across the camera traps almost mirror one another, with an obvious decrease for deer numbers at CT6 where wolf numbers increase. Deer recordings are higher than wolf recordings at every camera trap.

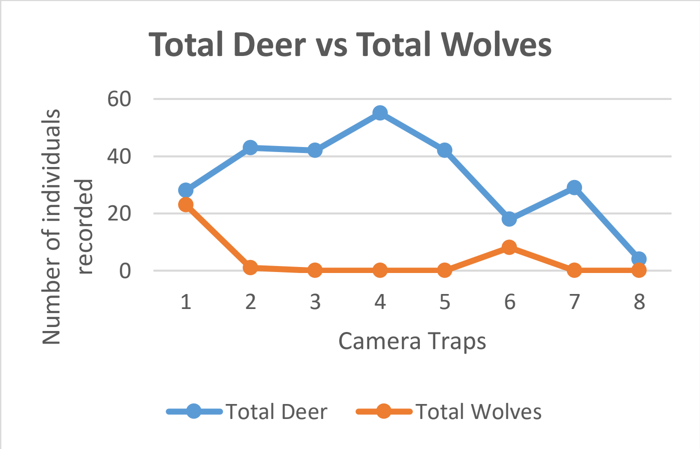

Figure 21. Graph showing Total Deer spp. vs Total Wolves.

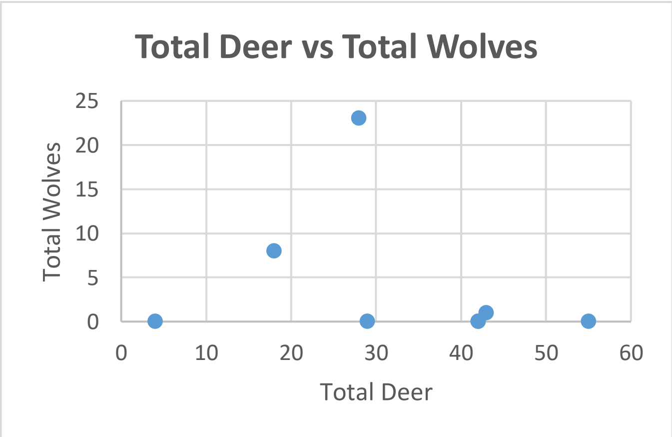

Figure 22. Graph showing Total Deer against Total Wolves.

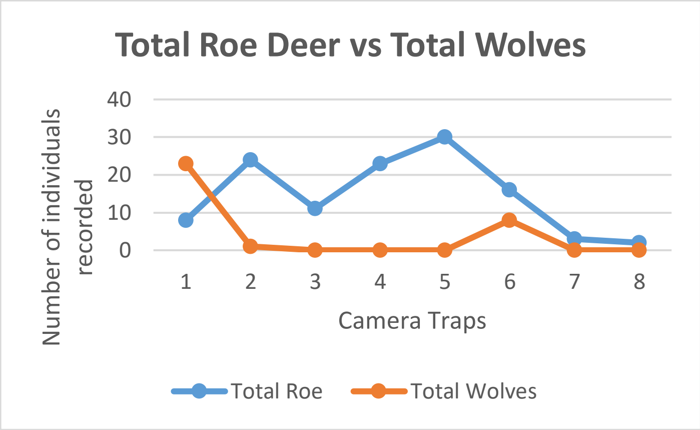

Figure 23. Graph showing Total Roe Deer vs Total Wolves.

Fig. 23 shows that between CTs 1 and 2, deer and wolf numbers almost mirror each other. CT1 is the only location where wolf recordings exceed those of roe deer.

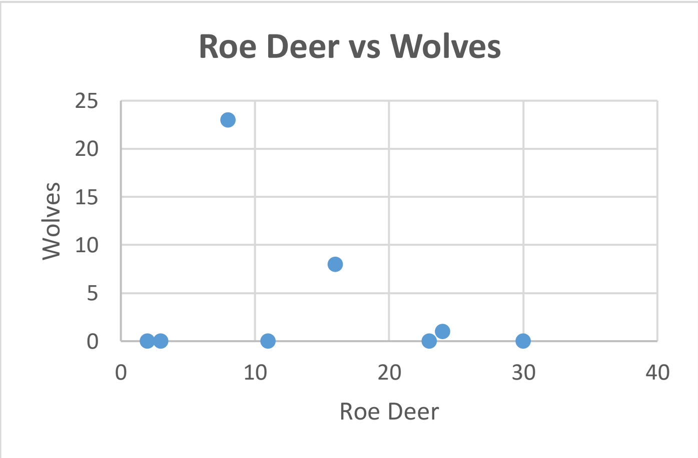

Figure 24. Graph showing Roe Deer against Wolves.

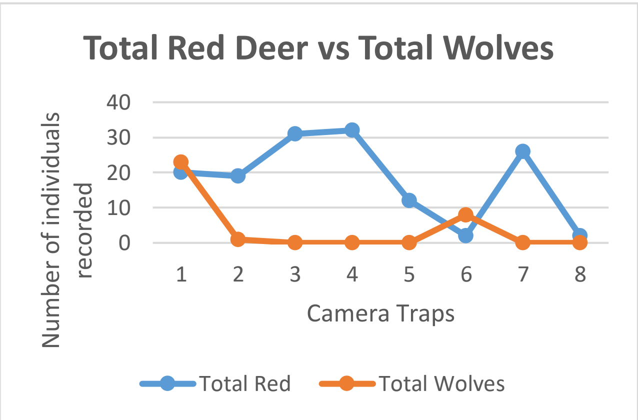

Figure 25. Graph showing Total Red Deer vs Total Wolves.

Figure. 25 shows that red deer and wolf numbers across the camera traps almost mirror one another with an obvious decrease for deer numbers at CT6 where wolf numbers increase and pass that of the red deer. CTs 1 and 6 are the only location where wolf recordings exceed those of roe deer.

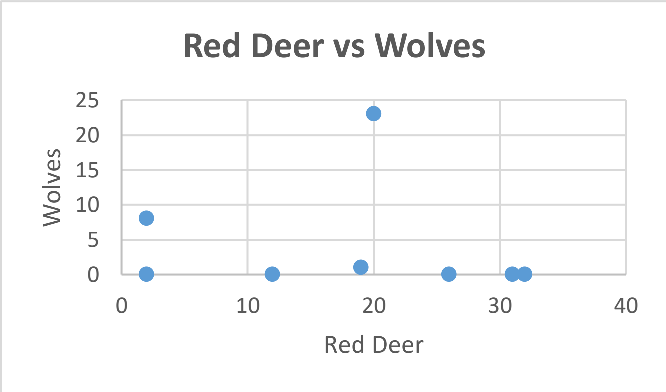

Figure 26. Graph showing Red Deer against Wolves.

Predator-prey correlation tests all showed very weak negative correlation, showing that there is no relationship between wolf and deer numbers at any of the crossings. T-tests carried out for all three gave a p-value above 0.05, therefore the data is not statistically significant.

Wolf numbers are generally lower than deer across all three graphs, due to their much lower populations, because they are a predator and so naturally much lower in population size, and also because of their historic persecution from Humans across the region.

4. Discussion

It was expected that the CTs would record occurrences of most native mammal species known to be in the area and that most activity would occur at night when the chances of human disturbance are low. Fourteen wild species were recorded over the research period. The low number of Marsican Bear observed is to be expected due to their vast home ranges and low population numbers, however in 2019 twelve different individuals were genetically identified in the area (http://www.parcoabruzzo.it/pdf/NaturaProtetta_RapportoOrso2019.pdf, pages 70-73). More activity was recorded at night (with the exception of Roe Deer) possibly due to reduced human activity and increased cover for prey species and was expected in nocturnal species such as hedgehog and porcupine and Deer sp. Which move mostly at dawn and dusk. The data collected pointed to possible trends in the movement of spatial distribution of species in relation to certain factors e.g. predator presence, proximity to road, altitude, and time. Deer sp. appeared to avoid locations where wolves are recorded frequently. Further analysis to investigate this hypothesis showed no significant correlation, however there is a trend which could form the basis of a focused study. Analysis showed no correlation between either species presence and altitude or between predator and prey numbers. No statistical significance was found, but there are obvious trends in the data that, again, could be pursued in further studies. The data does not inform fully if corridors and crossings are ‘working’. This data is useful in terms of identifying the numbers of wildlife and variety of species present in the study area, may be used to inform conservation management and to form a database of wildlife use of corridors and crossings, to assess the impact of these crossings in reducing wildlife mortality and human-wildlife collisions/conflict. The research area is an area of ecological importance, the location of Natura 2000 sites, and home to a critically endangered species, structured monitoring, reporting and robust data collection and surveys regarding species movement and roadkill numbers are crucial to conservation efforts.

5. Limitations of study

There were a number of limitations to this study that future research should address to achieve a more robust data set and comprehensive results. Unfortunately, due to project constraints and adverse weather conditions it was not possible to check CTs at designated intervals. This effected the comparability of the data somewhat, same say set up and same day checks across all monitored sites would allow a more for a more standardised dataset. It was not possible to access control data due to project constraints and the involvement of a number of third-party researchers. Control data is crucial in understanding the efficacy of these crossings. There is very little research or peer reviewed sources relating to the area, as well as a complete lack of roadkill data. Access to roadkill data would help to estimate the impact the crossings are having in reducing human-wildlife conflict and vehicle/wildlife collisions. No roadkill data was available from either before or after the crossings were adapted to wildlife use. A more robust study with definitive conclusions requires a greater number of CT locations including those acting as a control, over a greater time period, combined with data collected on roadkill, species numbers etc. prior to conservation activities.

5. Conclusion

This study aimed to assess the use of seven wildlife crossings, maintained to reduce the impacts of habitat fragmentation, mitigate human wildlife conflict, prevent biodiversity loss and aid in preserving species connectivity, along road SS17 within the Province of L'Aquila of the Abruzzo region between Pettorano sul Gizio and Rocca Pia. These wildlife crossings, while not originally constructed for the purpose of wildlife connectivity, are crucial bridges for species movement within the Abruzzo region. Much further study is required in the area as very little data and very few peer reviewed publications exist concerning the region, the threats to biodiversity in Abruzzo, the conservation work being undertaken, roadkill records etc. This study aimed to collate data which could be used to inform management strategies with regards to wildlife crossings. While the data collected through this study does not comprise a complex data set, it contributes to the beginnings of data collection which will have to build a picture of the species utilizing these wildlife crossings, which species occur most frequently and in which areas, which crossings are most utilized and will allow some insight into the effectiveness of the crossings in allowing for movement and spatial distribution of wildlife in the region. Research carried out in the course of this study along with personal communication with contacts at SLO have revealed a huge lack of available information, scientific studies, research, or data relating to wildlife crossings, wildlife corridors or roadkill in Italy. This unfortunately leaves little options for comparable or baseline data but hopefully means the data collected in this study will contribute to informing management plans in the area regarding the maintenance and improvement of the crossings and aid in the actions being taken to preserve species migration, improve local conservation efforts and to reduce habitat loss and roadkill rates.

7. Future work

As so little data exists for this area there is a huge potential for a number of studies to be undertaken with real benefits to conservation. As mentioned in the section above relating to limitations of this study, further research should aim to collate more robust and comprehensive data on the species present in Abruzzo, their movements and the impacts of the road networks. Further data analysis is necessary to establish if any correlation exists between wildlife numbers and variables such as seasons, habitat type, proximity of roads etc.

References

Alexander, S. and Waters, N., 2000. The effects of highway transportation corridors on wildlife: a case study of Banff National Park. *Transportation Research Part C: Emerging Technologies*, [online] 8(1-6), pp.307-320.

Anile, S., Bizzarri, L. and Ragni, B. 2010. Estimation of European wildcat population size in Sicily (Italy) using camera trapping and capture–recapture analyses. *Italian Journal of Zoology*, [online] 77(2), pp.241-246.

Apps, P. and McNutt, J., 2018. How camera traps work and how to work them. *African Journal of Ecology*, [online] 56(4), pp.702-709.

Bassi, E., Willis, S., Passilongo, D., Mattioli, L. and Apollonio, M., 2015. Predicting the Spatial Distribution of Wolf (Canis lupus) Breeding Areas in a Mountainous Region of Central Italy. *PLOS ONE*, 10(6), p.e0124698.

Beben, D. 2016. Crossings Construction as a Method of Animal Conservation. *Transportation Research Procedia*, [online] 14, pp.474-483.

Beier, P. and Noss, R., 1998. Do Habitat Corridors Provide Connectivity? *Conservation Biology*, [online] 12(6), pp.1241-1252.

Benten, A., Annighöfer, P. and Vor, T., 2018. Wildlife Warning Reflectors' Potential to Mitigate Wildlife-Vehicle Collisions—A Review on the Evaluation Methods. *Frontiers in Ecology and Evolution*, [online] 6.

Capitani C, Mattioli L, Avanzinelli E, Gazzola A, Lamberti P, Mauri L., 2006. Selection of rendezvous sites and reuse of pup raising areas among wolves *Canis lupus* of north-eastern Apennines, Italy. Acta Theriologica; 51: 395–404

Carr, T., Dacanay, R., Drake, K., Everson, C., Sperry, A. and Sullivan, K., 2003. Wildlife Crossings: Rethinking Road Design To Improve Safety And Reconnect Habitat. *Master of Urban and Regional Planning Workshop Projects*. Paper 142. [online] Portland, OR.: Portland State University, p.2.

Department of Environment and Conservation 2004. *Wildlife Corridors. Natural Resource Management Advisory Series*. [online] Coffs Harbour: Environment Protection and Regulation Division North East Branch Department of Environment and Conservation, pp.1-4. Available at: https://www.environment.nsw.gov.au/resources/nature/landholderNotes15WildlifeCorridors.pdf [Accessed 5 Feb. 2020].

Donaldson, B. 2005. The use of highway underpasses by large mammals in virginia and factors influencing their effectiveness. [online] Charlottesville: Virginia Transportation Research Council, p.2.

Ec.europa.eu. 2020. Natura 2000 - Environment - European Commission. [online] Available at: https://ec.europa.eu/environment/nature/natura2000/index_en.htm [Accessed 22 Feb. 2020].Ec.europa.eu. 2020. Natura 2000 - The Apennines. [image]. [online] Available at: https://ec.europa.eu/environment/nature/natura2000/biogeog_regions/maps/apennines.pdf [Accessed 22 Feb. 2020].

Edwards, C., 2016. Endangered Italian Bear Killed In Suspected Hit-And-Run. [online] Thelocal.it. Available at: https://www.thelocal.it/20161019/endangered-bear-killed-in-hit-and-run-in-italy [Accessed 29 March 2020].

Fabrizio, M., Di Febbraro, M., D'Amico, M., Frate, L., Roscioni, F. and Loy, A., 2019. Habitat suitability vs landscape connectivity determining roadkill risk at a regional scale: a case study on European badger (Meles meles). *European Journal of Wildlife Research*, [online] 65(1).

Fabrizio, M., Di Febbraro, M., D'Amico, M., Frate, L., Roscioni, F. and Loy, A., 2019. Roadkill Risk Map. [image] Available at: https://www.researchgate.net/publication/330104923_Habitat_suitability_vs_landscape_connectivity_determining_roadkill_risk_at_a_regional_scale_a_case_study_on_European_badger_Meles_meles [Accessed 26 April 2020].

Forman, R. and Alexander, L., 1998. Roads and their major ecological effects. *Annual Review of Ecology and Systematics*, [online] 29(1), pp.207-231.

Galaverni, M., Caniglia, R., Fabbri, E., Milanesi, P. and Randi, E., 2015. One, no one, or one hundred thousand: how many wolves are there currently in Italy?. *Mammal Research*, [online] 61(1), pp.13-24.

Gilbert-Norton, L., Wilson, R., Stevens, J. and Beard, K., 2010. A Meta-Analytic Review of Corridor Effectiveness. *Conservation Biology*, [online] 24(3), pp.660-668.

Gilpin, M. and Soule, M., 1986. Minimum viable populations: *Processes of species extinction*.

Google Maps, 2020. Abruzzo Satellite. Google Maps [online] Available at: https://www.google.com/maps/place/Abruzzo,+Italy/@41.9441757,13.7518133,37311m/data=!3m1!1e3!4m5!3m4!1s0x13303577b894aa23:0x1094f9ab2387cf0!8m2!3d42.1920119!4d13.7289167 [Accessed 12 May. 2020].

Google Maps, 2020. SS17 Satellite. Google Maps [online] Available at: https://www.google.com/maps/place/67033+Villaggio+Sant'Antonio+Province+of+L'Aquila,+Italy/@41.949986,13.9708128,9327m/data=!3m1!1e3!4m5!3m4!1s0x1330693e405e7f25:0x4ecc8c1a358b1b87!8m2!3d41.9399725!4d14.0349913 [Accessed 12 May. 2020].

Google Maps, 2020. SS17 Topographical Image. Google Maps [online] Available at: https://www.google.com/maps/place/67033+Villaggio+Sant'Antonio+Province+of+L'Aquila,+Italy/@41.9506094,13.973618,13.75z/data=!4m5!3m4!1s0x1330693e405e7f25:0x4ecc8c1a358b1b87!8m2!3d41.9399725!4d14.0349913!5m1!1e4 [Accessed 12 May. 2020].

Google Maps. 2020. SS17 Street view. Google Maps. [online] Available at: https://www.google.com/maps/@41.9592569,13.9806007,3a,75y,138.34h,92.98t/data=!3m6!1e1!3m4!1sjTJsAK0MTmD4DRgp9iG1vg!2e0!7i13312!8i6656 [Accessed 22 Feb. 2020].

Goosem, M. 1997. Internal fragmentation: the effects of roads, highways and powerline clearings on movements and mortality of rainforest vertebrates. *Tropical Forest Remnants: ecology, management, and conservation of fragmented communities*, [online] pp.241-255.

Laurance, W., Cochrane, M., Bergen, S., Fearnside, P., Delamonica, P., Barber, C., D'Angelo, S. and Fernandes, T. 2001. Environment: The Future of the Brazilian Amazon. *Science*, [online] 291(5503), pp.438-439.

Life Safe-Crossing, No date. LIFE SAFE-CROSSING - Preventing Animal-Vehicle Collisions – Demonstration Of Best Practices Targeting Priority Species In SE Europe. [online] Firenze: LIFE European Union, p.1. Available at: https://ec.europa.eu/environment/life/project/Projects/index.cfm?fuseaction=search.dspPage&n_proj_id=6860&docType=pdf [Accessed 25 April 2020].

Life.safe-crossing.eu. No date. The impacts of linear infrastructures on biodiversity. [online] Available at: https://life.safe-crossing.eu/the-impacts-of-linear-infrastructures-on-biodiversity [Accessed 25 April 2020].

Lovari, S. and Cassola, F. 1975. Nature conservation in Italy: the existing national parks and other protected areas. *Biological Conservation*, [online] 8(2), pp.127-142.

Lovari, S., Sforzi, A., Scala, C. and Fico, R., 2007. Mortality parameters of the wolf in Italy: does the wolf keep himself from the door? *Journal of Zoology*, [online] 272(2), pp.117-124.

Mapcoordinates.net. 2020. Google Maps - Find GPS coordinates, longitude, latitude, altitude. [online] Available at: https://www.mapcoordinates.net/en [Accessed 24 Feb. 2020].

Mattioli, L., Forconi, P., Berzi, D. and Perco, F., 2014. Wolf population estimate in Italy and monitoring perspectives. *At Hystrix the Italian Journal of Mammalogy*, [online] 25, p.1.

McCollister, M. and van Manen, F. 2010. Effectiveness of Wildlife Underpasses and Fencing to Reduce Wildlife–Vehicle Collisions. *Journal of Wildlife Management*, [online] 74(8), pp.1722-1731.

Meek, P., Ballard, G. and Falzon, G. 2016. The higher you go the less you will know: placing camera traps high to avoid theft will affect detection. *Remote Sensing in Ecology and Conservation*, [online] 2(4), pp.204-211.

Monte Genzana Alto Gizio Regional Nature Reserve, 2020. *Monte Genzana Alto Gizio Riserva Naturale Regionale Logo*. [image] Available at: https://www.riservagenzana.it/ [Accessed 29 March 2020].

Naidoo, R., Kilian, J., Du Preez, P., Beytell, P., Aschenborn, O., Taylor, R. and Stuart-Hill, G., 2018. Evaluating the effectiveness of local- and regional-scale wildlife corridors using quantitative metrics of functional connectivity. *Biological Conservation*, [online] 217, pp.96-103.

Natura2000.eea.europa.eu. 2018. Arcgis Web Application. [online] Available at: https://natura2000.eea.europa.eu/ [Accessed 30 March 2020].

On The World Map, No date. Abruzzo Road Map. [image] Available at: http://ontheworldmap.com/italy/region/abruzzo/abruzzo-road-map.html [Accessed 26 April 2020].

Parcoabruzzo.it., No date. *Fauna | Parco Nazionale D'abruzzo, Lazio E Molise*. [online] Available at: http://www.parcoabruzzo.it/page.php?id=173 [Accessed 9 May 2020].

Pariona, A. 2019. The National Parks of Italy. [online] WorldAtlas. Available at: https://www.worldatlas.com/articles/how-many-national-parks-are-there-in-italy.html [Accessed 22 Feb. 2020].

Parotto, M., Poulsen, T. and Accordi, B. 2009. *Apennine Range | mountains, Italy*. [online] Encyclopaedia Britannica. Available at: https://www.britannica.com/place/Apennine-Range [Accessed 9 Feb. 2020].

PNALM Archive, n.d. *PNALM Logo*. [image] Available at: http://www.parcoabruzzo.it/pagina.php?id=205 [Accessed 6 April 2020].

Reconyxn inc. 2017. HyperFire: High Performance Cameras Instruction Manual. Holmen, W: Author. Available at: http://images.reconyx.com/file/HyperFireManual.pdf [Accessed 28 March. 2020].

Rewilding Europe. No date. Central Apennines | Rewilding Europe. [online] Available at: https://rewildingeurope.com/areas/central-apennines/ [Accessed 22 Feb. 2020].

Rewilding Europe. No date. Central Apennines | Rewilding Europe. [online] Available at: https://rewildingeurope.com/areas/central-apennines/details/ [Accessed 30 March. 2020].

Salviamo l'Orso, No date. *Bear paw print next to a key to show scale*. [image] Available at: https://www.salviamolorso.it/en/portfolio-items/wildlife-corridors/ [Accessed 4 April 2020].

Salviamo l'Orso, No date. *A fruit tree being pruned by members of Salviamo l'Orso*. [image] Available at: https://www.salviamolorso.it/en/portfolio-items/wildlife-corridors/ [Accessed 4 April 2020].

Salviamo l'Orso, No date. *Bear scat next to a key to show scale*. [image] Available at: https://www.salviamolorso.it/en/portfolio-items/wildlife-corridors/ [Accessed 4 April 2020].

Salviamo l'Orso, No date. *Camera Trap Being Installed/Checked*. [image] Available at: https://www.salviamolorso.it/en/portfolio-items/wildlife-corridors/ [Accessed 4 April 2020].

Salviamo l'Orso, No date. *Reflective Warning Road Sign Set Up Along A Stretch Of Road In The Abruzzo Region*. [image] Available at: https://www.salviamolorso.it/en/new-speed-limits-introduced-ss-83-protect-marsican-bear/ [Accessed 5 April 2020].

Salviamo l'Orso, No date. *Salviamo L'orso Logo*. [image] Available at: https://www.salviamolorso.it/en/ [Accessed 31 March 2020].

Salviamo l'Orso, No date. *The underpass at Camera Trap 6 being maintained*. [image] Available at: https://www.salviamolorso.it/en/portfolio-items/wildlife-corridors/ [Accessed 4 April 2020].

Salviamolorso.it. 2020. Charter – Salviamo l'Orso. [online] Available at: http://www.salviamolorso.it/en/about/charter/ [Accessed 22 Feb. 2020].

Salviamolorso.it. 2020. *Wildlife corridors – Salviamo l'Orso*. [online] Available at: http://www.salviamolorso.it/en/portfolio-items/wildlife-corridors/ [Accessed 8 Feb. 2020].

Salviamolorso.it. No date. *Salviamo L'orso – Associazione Per La Conservazione Dell'orso Bruno Marsicano*. [online] Available at: https://www.salviamolorso.it/en/ [Accessed 4 April 2020].

Simberlo, D., 1999. Biodiversity and bears - a conservation paradigm shift. *Ursus*, [online] 11.

Simpson, N., Stewart, K., Schroeder, C., Cox, M., Huebner, K. and Wasley, T. 2016. Overpasses and underpasses: Effectiveness of crossing structures for migratory ungulates. *The Journal of Wildlife Management*, [online] 80(8), pp.1370-1378.

Snow, N., Porter, W. and Williams, D., 2015. Underreporting of wildlife-vehicle collisions does not hinder predictive models for large ungulates. *Biological Conservation*, [online] 181, pp.44-53.

Swenson, J. E., Gerstl, N., Dahle, B., and Zedrosser, A. 2000. Action Plan for the Conservation of the Brown Bear in Europe (Ursus arctos). [114], 1-70. Strasbourg Cedex, Council of Europe. *Nature and environment*.

Wearn, O.R. and Glover-Kapfer, P., 2020. *Camera-Trapping For Conservation: A Guide To Best Practices*. WWF Conservation Technology Series 1(1). [online] Woking: WWF-UK, p.128.

Zimmermann, B., Nelson, L., Wabakken, P., Sand, H. and Liberg, O., 2014. Behavioral responses of wolves to roads: scale-dependent ambivalence. *Behavioral Ecology*, [online] 25(6), pp.1353-1364.

Appendix

Figure 28. Marten *(Martes spp.)* CT5.

Figure 29. Roe deer *(Capreolus caprelous)* CT5.

Figure 30. Red deer (Cervus elaphus) CT1.

Figure 31. Italian Wolf *(Canis lupus italicus)* CT1.

Figure 32. Marsican Brown Bear *(Ursus arctos marsicanus)* CT7a.

Figure 33. Wild boar (Sus scrofa) CT2.

Figure 34. Corsican Hare (Lepus corsicanus) CT4.

Figure 35. Crested Porcupine (Hystrix cristata) CT3.

Figure 36. Red squirrel (Sciurus vulgaris) CT4.

Figure 37. Wild Cat (Felis silvestris silvestris) CT2.

Figure 38. Bank Vole/Vole spp. (Myodes glareolus) CT7a.

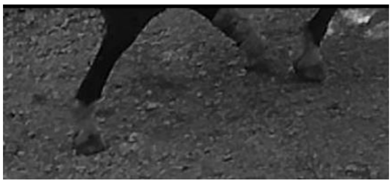

Figure 39. Domesticated Horse (Equus ferus caballus) CT7a.

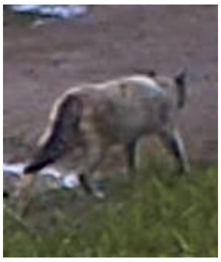

Figure 40. Domestic Cat (Felis catus) CT7b.

Figure 41. Red fox (Vulpes vulpes) CT1.

Figure 42. European Badger (Meles meles) CT2.