Driven by f(l)avor - Marsican brown bear occurrence in correlation to the availability of plant-based foods in different vegetation types: A pilot study

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ASSOCIAZIONE PER LA CONSERVAZIONE DELL'ORSO BRUNO MARSICANO

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Marsican brown bear occurrence in correlation to the availability of plant-based foods in different vegetation types: A pilot study

A pilot study aiming to identify the potential relationship between Marsican brown bear (*Ursus arctos marsicanus*) occurence and the availability of plant-based foods in the present vegetation types in the Riserva Naturale Regionale Monte Genzana Alto Gizio, central Italy.

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SALVIAMO L'ORSO
Associazione per la Conservazione dell'Orso Bruno Marsicano

Preface

This research report is the outcome of my 5-month internship at Salviamo l'Orso in the Riserva Naturale Regionale Monte Genzana Alto Gizio in Italy. The internship was part of my Animal Management study to gain field experiences and to help finding a future career. I executed a research with the aim to identify a possible correlation between Marsican brown bear signs and the availability of plant-based foods in the vegetation types present in the Riserva Naturale Regionale Monte Genzana Alto Gizio.

My special thanks go to Mario Cipollone for giving me the opportunity to execute this study for Salviamo l'Orso, for supervision and support throughout my internship, for sharing his knowledge about the animals and nature and for his work and dedication to save the Marsican brown bear. Also, a big thank you to Jan-Niklas Trei, who was a great help for all smaller and bigger GIS questions, for helping to set up a valuable research, for always sharing his ideas on how to further improve my research and for becoming a very supportive and good friend. Furthermore, I would like to thank the reserve staff, Antonio Di Croce, Antonio Monaco, Mario Colonico, Irene Shivji and Mario Finocchi, for supporting me and sharing data. I am very grateful for everybody that enriched my time in Italy. Lastly, I thank my tutor Berend van Wijk for supervising my internship and Henry Kuipers for helping me with the statistical analysis in SPSS and RStudio.

Alina Martin

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Abstract

The Marsican brown bear (*Ursus arctos marsicanus*), is a critically endangered species with a restricted home range to the Abruzzo region in Italy. This pilot study was aimed at identifying and mapping seasonal plant-based foods of the bears and identifying possible correlations between food availability in vegetation types and bear signs within the Riserva Naturale Regionale Monte Genzana Alto Gizio (RNRMGAG) to eventually gain knowledge of varying food availability and to ultimately protect important foraging areas in the present vegetation types. Within the RNRMGAG, which is mostly covered by deciduous forest, 15 random plots were selected and investigated to identify plant-based foods. To assess possible correlations between available foods, the vegetation types and bear signs the trails in the RNRMGAG were divided into 200m-sections, each having their own 50m-buffer on both sides, including several vegetation types, called fractions, which have been individually accounted for. Apple trees as a food source have been separately analysed, because sufficient data was available. It was found that the RNRMGAG offered 6 plant-based foods in spring, 9 in early summer, 13 in late summer and 14 in autumn. However, data obtained from the vegetation investigation was not sufficient to make a statement about food availability that could be up-scaled to the whole reserve due to the low number of plots. Possible correlations with bear signs could not be further analysed. No correlation between the number of bear signs and vegetation types present was found, but presence of apple trees was significant on the number of bear signs. It was analysed that per hectare with apple tree presence 10 times more bear signs were expected, than per hectare without apple trees. This pilot study was a step forward in identifying possible correlations between Marsican brown bear occurrence and available foods in the RNRMGAG, but data collection methods need to be modified considerably. The abundance of plant-based foods needs to be investigated in all parts of the RNRMGAG far off trail to avoid trail bias.

Keywords: Food source mapping, negative binomial generalized linear model, plots, Abruzzo, dietary season, spatial data

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Introduction

The Marsican brown bear (*Ursus arctos marsicanus*), a subspecies (Altobello, 1921) of the Eurasian brown bear (*Ursus arctos arctos*), is a critically endangered species with a potential high risk of extinction (Gervasi et al., 2008; Tosoni and Latini, 2015). It is endemic to the Abruzzo region in the central Apennines, Italy, and protected internationally and nationally. The species is listed on the Red list of Italian vertebrates of the IUCN (IUCN Comitato Italiano, 2021), included in Annex II and IV of the Habitat Directive 92/43/CEE, protected by national law (L. 157/92 and L. 150/92) and included in Appendix II of the Bern Convention and Appendix II of CITES (Convention on International Trade in Endangered Species) (Ciucci and Boitani, 2008). Its core area is the Abruzzo, Lazio and Molise National Park (PNALM) (figure 2), which was established in 1922 (and is thereby the oldest national park together with Gran Paradiso National Park in Italy) and stretches up to 50.000ha (Ciucci and Boitani, 2008; Parco Nazionale d'Abruzzo, Lazio e Molise, 2021). This subspecies has been isolated for thousands of years (peak probably 4000 years) from the Eurasian brown bears, which resulted in low genetic variability, extremely limited effective population size and a high level of inbreeding (Benazzo et al., 2017). Current estimates of the population size are 51 (47-66) individuals in the PNALM (Ciucci et al., 2015; Parco Nazionale d'Abruzzo, Lazio e Molise, 2021).

Nevertheless, almost 100 years of protection within the PNALM (Boscagli, 1999), and the availability of sufficient and suitable habitat and landscape connectivity (Posillico et al., 2004; Falcucci et al. 2009; Maiorano et al. 2017), failed to increase both, the population size and range of the Marsican brown bear (Ciucci and Boitani 2008). Gervasi et al. (2017) found an increase of only 3% of the population size between 2003 and 2014. The reason therefore could be, on the one hand, the possible reached carrying capacity of bears inside PNALM, which can be assumed by a high density of 39.7 bears/1000 km2 (Ciucci et al., 2015). On the other hand, high mortality levels caused by humans (50%, between 1980 and 2007 through poisoning, poaching and road kills; total number of deaths = 74; Falcucci et al. 2009), or intrinsic factors, like low reproductive rate, or a small number of reproducing females (Gervasi et al., 2017; Tosoni et al., 2017), could be the cause of the stagnating population size and range. Rewilding Europe, as a big non-profit organisation of nature conservation, considered therefore, the Marsican brown bear still as a conservation priority (Rewilding Europe, 2013). Rewilding Apennines is the Italian branch of Rewilding Europe and partners with the local non-profit association Salviamo l'Orso, which is working to save the Marsican brown bears from extinction by pairing institutional dialogue and efforts with practical actions in the field, like monitoring their territory and studying and financing projects aimed at their conservation (Salviamo l'Orso, 2020). Salviamo l'Orso was established in 2012 and has one of its operational bases in the Riserva Naturale Regionale Monte Genzana Alto Gizio (RNRMGAG), which lies in the core area of the bears.

The diet of the Marsican brown bear includes high-quality foods like grasses, forbs, fruits, roots, invertebrates and mammals. Ciucci et al. (2014) did a three-year-long research on the seasonal and annual variation in the food habits of the bears in the PNALM. It was stated that the most important foods are hard mast, especially beechnuts (*Fagus sylvatica*), and fleshy fruits, most notably Buckthorn berries (*Rhamnus* sp.), but also pear (*Pyrus* sp.) and apple (*Malus* sp.). Furthermore insects, especially ants (*Formicidae* sp.), wild ungulates, most notably Red deer fawns (*Cervus elaphus*), and livestock, especially carcasses like sheep (*Ovis aries*) and calves (*Bos taurus*), are scavenged and sometimes predated. (Ciucci et al., 2014) However, it has not been studied which seasonal foods are available in regional parks and reserves within the species' core area, like the RNRMGAG.

Knowledge of food habits is an essential step in understanding the general habitat productivity, but also food accessibility to bears and the performance of their local populations (Craighead et al., 1995; Persson et al., 2001; Naves et al., 2006; Baldwin and Bender, 2009; Ciucci et al. 2014). Hence, management purposes regarding maintenance and enhancement of long-term habitat productivity based hereon are crucial for successful conservation (Reynolds-Hogland et al., 2007). This proves especially important for endemic, small and isolated species such as the Marsican brown bear (Loy et al., 2008; Colangelo et al., 2012; Ciucci et al., 2014). According to Gervasi and Ciucci (2018), '*a primary management goal for the conservation of this endangered bear population should be to maintain the current diversity and accessibility of foods to bears in the long term. Habitat management should aim to maintain abundant mature stands of beech and oak, while ensuring the sustained availability of other key foods*'. In addition, Naves et al. (2006) recommended the mapping of critical foraging areas, which should be put under high conservation priority. A detailed database showing actual and potential foods and habitats for the Marsican brown bear could help to improve habitat availability.

Under these premises, a pilot study was carried out to identify and map the seasonal potential plant-based foods for the Marsican brown bear in the different vegetation types within the RNRMGAG protected area in Abruzzo Region, Italy. Additionally, classification of the dietary seasons was in line with Ciucci et al. (spring=March-May, early summer=June-July, late summer= August-September and autumn=October-mid-December), which are relevant in the availability of the bears' primary foods.

This gave rise to the main objective of this pilot study, which aimed to investigate to what extend plant-based foods and present vegetation types correlate with bear signs within the RNRMGAG. Concerning this objective, sub-questions were set up for guidance through the process and to gather the information needed:

1. Which plant-based foods are available in which dietary season in the vegetation types for the Marsican brown bears?
2. Where and how many bear signs are found and how do they correlate with food availability and the different vegetation types?

Likewise, the methodology applied was scaled to map the areas that have the intrinsic potential to host Marsican brown bear populations. To determine if the present vegetation types and bear signs correlate with each other, data of potential plant-based foods were linked to signs of bear activity in those vegetation types across the study area. The collection of data on the species presence was done by monitoring with camera traps and by tracking other signs of presence, like scats, hair, tracks and markings on trees. Plant-based foods included all parts of plants, like buds, leaves and fruits, that Marsican brown bears consume.

Materials and methods

Study location

The RNRMGAG (41.972712, 13.954037 DD) is included in the Rewilding Apennines operating area, in the so called 'Bear-coexistence corridor 2', which is one of their priority areas, and falls in the territory of the municipality of Pettorano sul Gizio, Abruzzo. The RNRMGAG was established in 1996, with the vision to manage and preserve the natural heritage and provide ecosystem services. In the past, the land was mainly used to cultivate corn and wheat, but also fruit trees, like apple, cherry and plum. After World War II many people left the rural area to work in the surrounding cities and abroad. So, the land was abandoned, turned wild and lost its economic value for citizens. The reserve is considered an important ecological corridor (figure 1) between the PNALM and the Majella National Park (Giangregorio et al., 2014; Salviamo l'Orso, 2020). It is the largest nature reserve in Abruzzo (RNRMGAG, 2021) covering an area of 3164ha, consisting mostly of deciduous forest with high occurrence of beech (*Fagus*), with an altitudinal range from 530-2170m above sea level. The highest point of the reserve is Mount Genzana. In 2019 the presence of 12 bears was assessed after a monitoring program (Latini et al., 2020).

Comagnoni et al. established a forest plan of the reserve in 2010 by taking the land cover class from the Corine level 3 classification and thereupon conducted field surveys to produce a vegetation shapefile (figure 3). The forest plan classified six vegetation types within the reserve: High forest with prevalence of beech, Mixed coppice with prevalence of Mediterranean oaks, Beech coppice, Pine forest and Pasture lands (which sometimes turned into shrubland, since they have not been grazed for decades) and Protection forest. No other information about the methodology or vegetation type classification was reported in the forest plan.

The mammal fauna of the RNRMGAG includes amongst others ungulates, like Red deer (*Cervus elaphus*), Roe deer (*Capreolus capreolus*) and Wild boar (*Sus scrofa*), but also free roaming goats (*Capra hircus*) and cattle (*Bos taurus*), which are under surveillance of sheep dogs and shepherds, and carnivores, like the Italian wolf (*Canis lupus italicus*), Red fox (*Vulpes vulpes*) and European wildcat (*Felis silvestris silvestris*) (RNRMGAG, 2021).

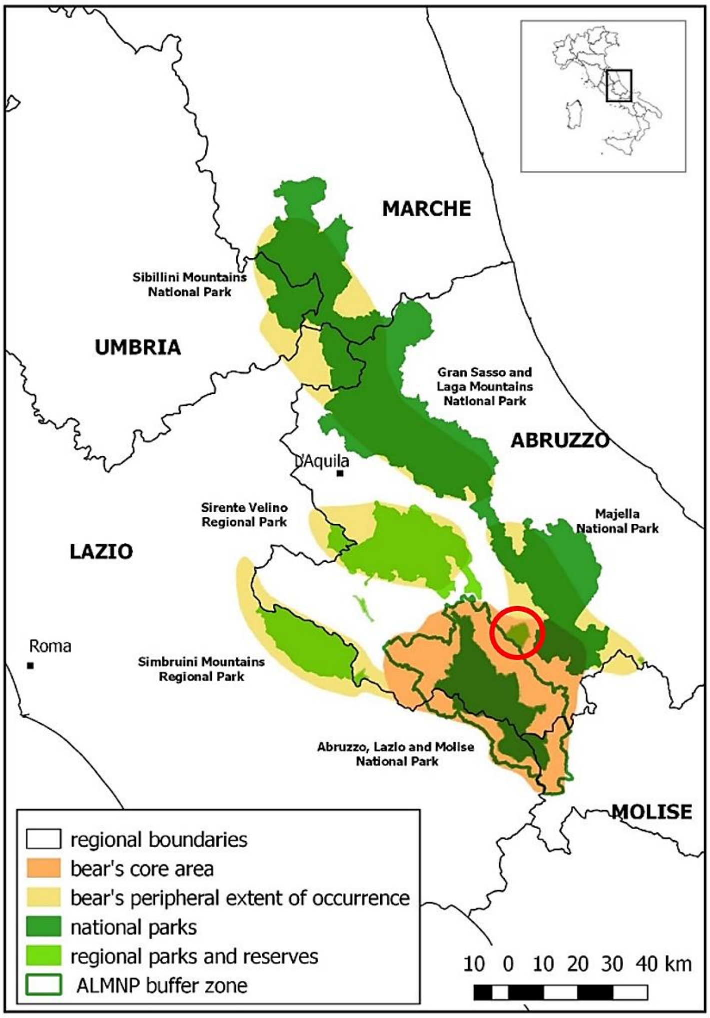


Figure 1 Approximate range of the Apennine brown bear and distribution of the main protected areas in the central Apennines. The red circle shows the Riserva Naturale Regionale Monte Genzana Alto Gizio. ALMNP is the English abbreviation for Parco Nazionale d'Abruzzo, Lazio e Molise (modified from Ciucci and Boitani, 2008).

Vegetation investigation of plant-based foods

In the Appendix 2 background information about the results of Ciucci et al.´s paper (2014) 'Seasonal and annual variation in the food habits of Apennine brown bears, central Italy' can be found. This paper was used as a reference for all foods that the Marsican brown bears eat and that could be possibly present in the RNRMGAG.

Data collection

In order to identify which plant-based foods (hereafter referred as to 'foods') are available in the six vegetation types (High forest with prevalence of beech, Mixed coppice with prevalence of Mediterranean oaks, Beech coppice, Pine forest and Pasture lands and Protection forest) within the RNRMGAG, parts of trails were pre-selected from the reserve's field officer, Antonio Monaco, and a buffer radius of 50m on both sides of the trails was created in QGIS (version 3.14.16), in which samples were taken (figure 3). Only in the pre-selected parts of trails the execution of the vegetation investigation was allowed, because of the start of the hibernation time of the Marsican brown bears and their search for dens. Executing the study too far off trail and further into the reserve could disturb the bears from finding a good hibernation spot (Monaco, personal communication, 09.11.2020; Westekemper et al., 2018). The chosen trails were the ones mostly used by people and closest to Pettorano sul Gizio. Monaco also provided shapefiles of the vegetation types from 2013 within the RNRMGAG. The striped area in figure 3 was added to show where no vegetation type was assigned. Part of that 'not specified' area were private lands, located primarily in the center of the reserve. The 'not specified' area was not included in the vegetation investigation.

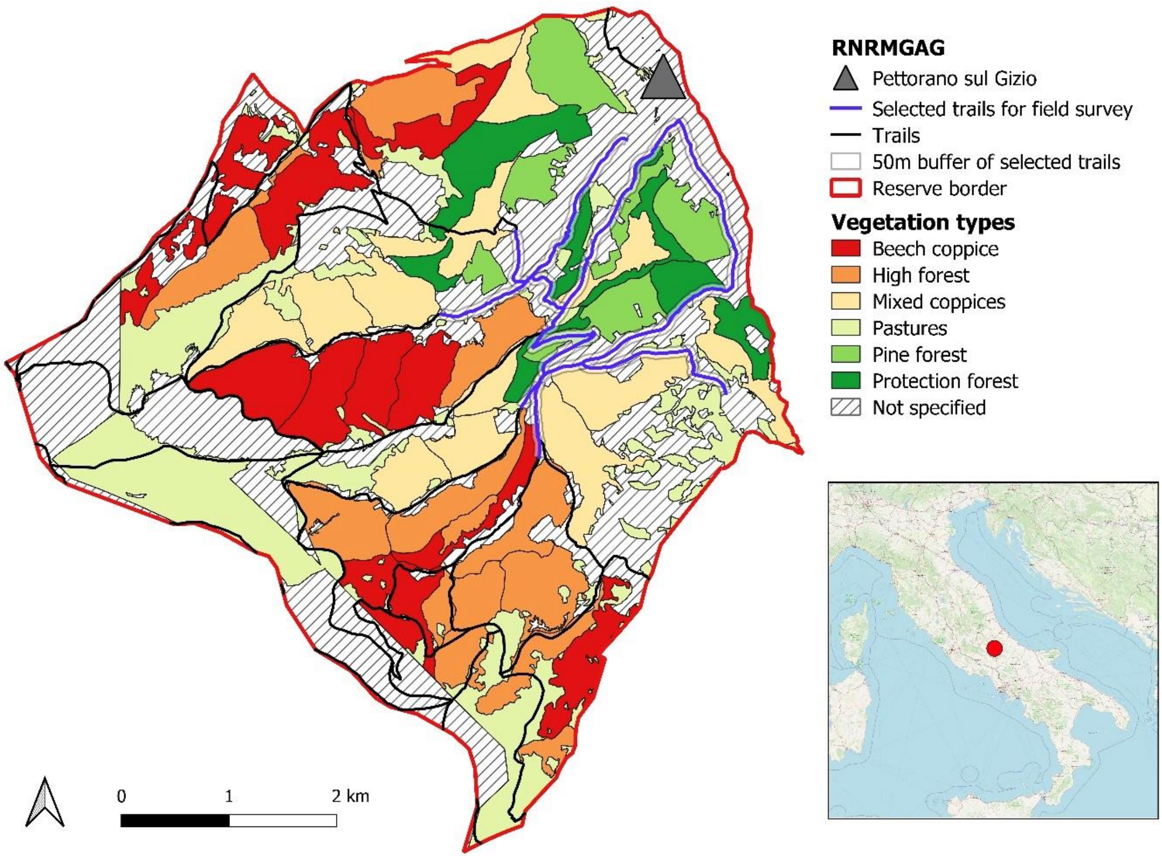


Figure 2 Vegetation types and trails within the Riserva Naturale Regionale Monte Genzana Alto Gizio, central Italy (Martin, 2021). The blue trails were the selected trails for the vegetation investigation. The small map in the bottom right corner shows the location of the reserve in Italy.

Within QGIS and the 'random selection' research tool 15 random plots of one hectare (50m x 200m) were selected in the six vegetation types and had a minimum distance of 400m to another (figure 4). As can be seen in figure 4, big parts of the selected trails were not assigned with a specified vegetation type. Consequently, the available area to investigate within the 50m-buffer was small. The area size of each vegetation type in the 50m-buffer was calculated within QGIS. The number of plots per vegetation type was determined by 25% of the total area size of each vegetation type within the 50m-buffer. Hence, 4 plots were selected within Pasture lands (hereafter referred as to 'Pastures'), 3 plots within Mixed coppice with prevalence of Mediterranean oaks (hereafter referred as to 'Mixed coppices'), Pine forest and Protection forest and 1 plot within Beech coppice and High forest with beech prevalence (hereafter referred as to 'High forest'). Presence/ absence data of all foods within the plots were recorded between 23 and 29 November 2020.

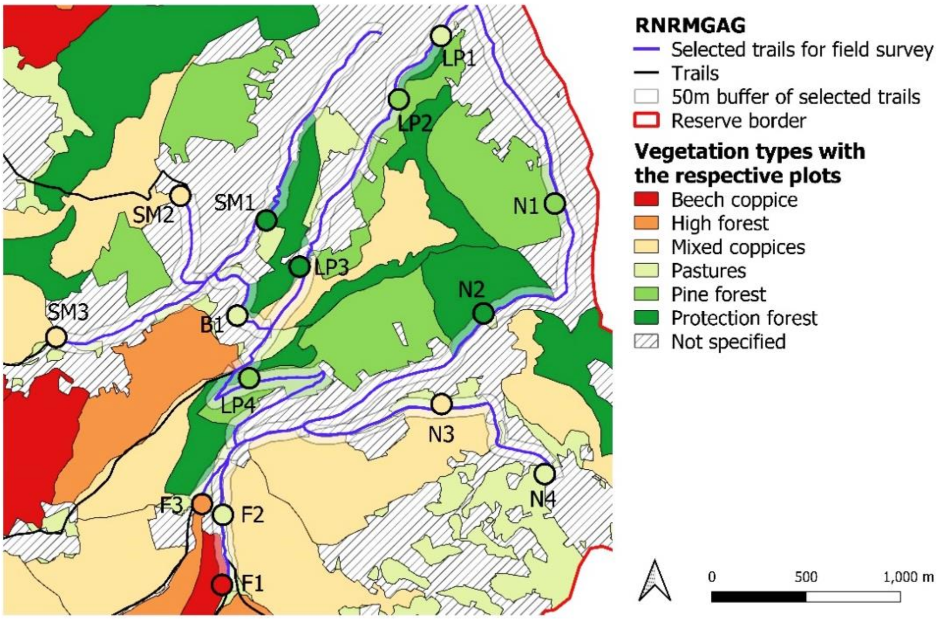


Figure 3 Selected plots for the vegetation investigation in the Riserva Naturale Regionale Monte Genzana Alto Gizio, central Italy (Martin, 2021). The abbreviations of the plots stand for the trail names (SM=Santa Margarita, LP=Le pendici, B=Botanical, N=Napoleonica, F=Farmer). F1 lies in Beech coppice; F3 lies within High forest; SM2, SM3 and N3 lie within Mixed coppices; B1, LP1, N4 and F2 lie within Pastures; LP2, LP4 and N1 lie within Pine forest; SM1, LP3 and N2 lie within Protection forest.

Another data set from 2020 containing coordinates of 402 apple trees inside the reserve recorded was provided and a map showing the distribution was created. Because the data has already been collected it has not been limited to the 50m-buffer from the vegetation type analysis, but it will be analysed following the data collection methods of the correlation analysis. Thereby true data was not lost and possible correlations with bear signs could be analysed. Apple trees outside the buffer were not used for the analysis. The apple tree data was added separately to the correlation analysis next to vegetation types, because there was a sufficient amount of data on apple trees. Apple trees were only be added as a food source to a vegetation type if found within the plots.

Within each investigated plot of the vegetation investigation, a camera trap was deployed to gain further data on bear presence in the six vegetation types. Two different camera types were used: BolyGuard (model SG520) and Browning (model BTC-5HDP). The cameras were deployed on the same days as the vegetation investigation took place and were checked after two weeks and five weeks. All cameras were mounted on a tree at a height of 40cm, facing the contour of the slope and angled parallel to the ground. The settings were adjusted to: camera mode: video, video length: 10 sec, PIR Interval: 1 sec. All other settings stayed in default. All cameras were demounted on the 29 and 30 December 2020. Three camera traps were slightly moved after the first check, because almost no data was recorded. One camera got stolen after the first check.

Data preparation

Using the software Excel, the obtained data from the vegetation investigation was listed under the respective plot. The data from the same vegetation type was merged and assigned to the respective seasons, following Ciucci et al.'s paper (2014), that shows which foods were eaten by the bears in which season between 2006 and 2009.

The data obtained from the camera traps was listed in a comma separated value file (csv) file including information about the location ID (figure 4), pick up date, image number, date and time, common species name and scientific name, number of individuals (split in adults, juveniles and age unknown) and sex (split in male, female and sex unknown). Only relevant bear data was extracted and added to the already existing data set for the correlation analysis.

Data analysis

Within QGIS the data was used to create a map showing the number of seasonal foods per vegetation type.

Correlation between plant-based foods, vegetation types and bear signs

Data collection

For the correlation analysis additional data sets with GPS locations of overall 60 bear signs (from 2019-2020) were provided by Salviamo l'Orso to analyse and map their distribution in the reserve.

Data preparation

Using the software QGIS, a 50m-buffer around all trails was created. The reason being that bear signs are usually found along trails that researchers and volunteers use and thus are highly surveilled. Only signs within the buffer were considered for further analysis. A big part of the trails, and thus also bear signs, were not assigned with a vegetation type, therefore the polygons of the vegetation types were reshaped (figure 5), so all bear signs were able to be assigned to the respective vegetation types and could be included in the analysis. Polygons that were close to the trail were reshaped towards the trails; polygons that were further away from trails were reshaped following a satellite image. It was assumed that the vegetation types close to the trails are the same as the surrounding vegetation types.

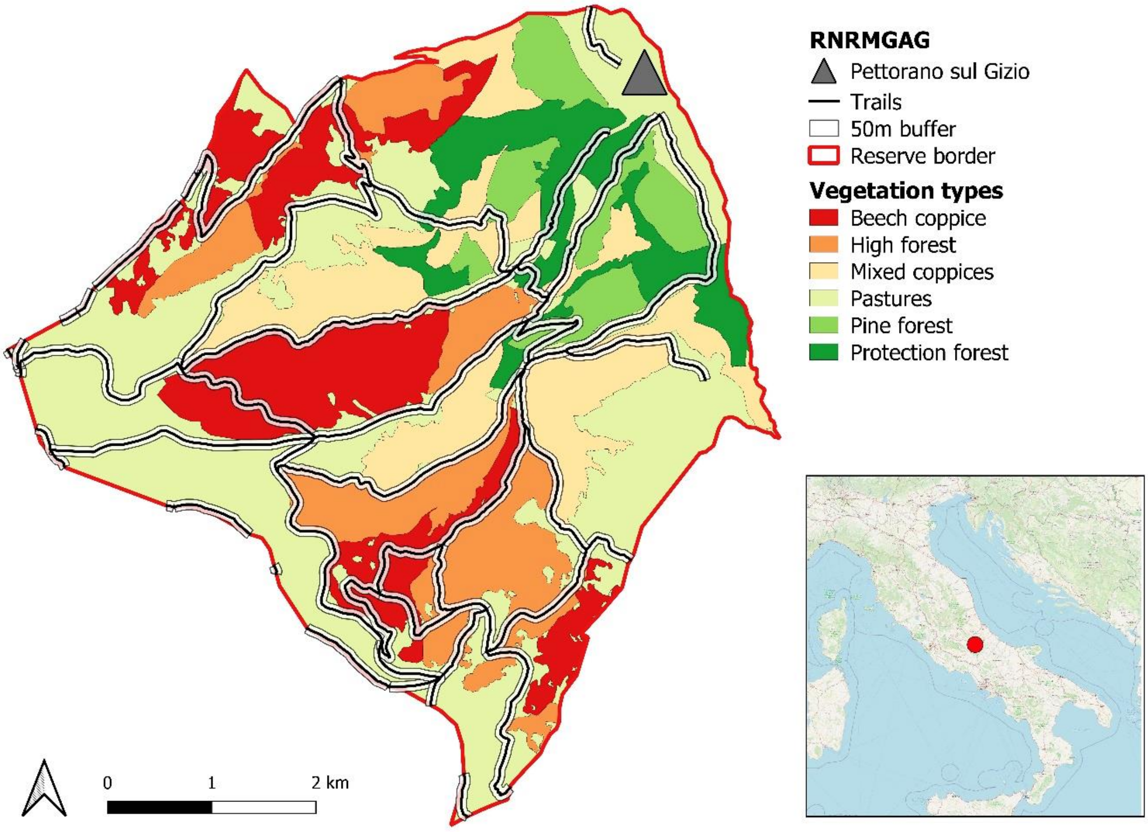


Figure 4 Reshaped vegetation types and trails within the Riserva Naturale Regionale Monte Genzana Alto Gizio, central Italy (Martin, 2021). The small map in the bottom right corner shows the location of the reserve in Italy.

To identify possible correlations between foods and bear signs and vegetation types and bear signs the trails were divided into 200m-sections (sections of trail ends were shorter) within QGIS, each having their own buffer radius of 50m on both sides. Trail sections of which the 50m-buffers were overlapping were deleted to prevent double counting of bear signs or apple trees. Each vegetation type within a trail section is called a fraction (figure 6). Those fractions were given an individual case number. For each fraction, the area size, as well as the number of bear signs and apple trees were calculated.

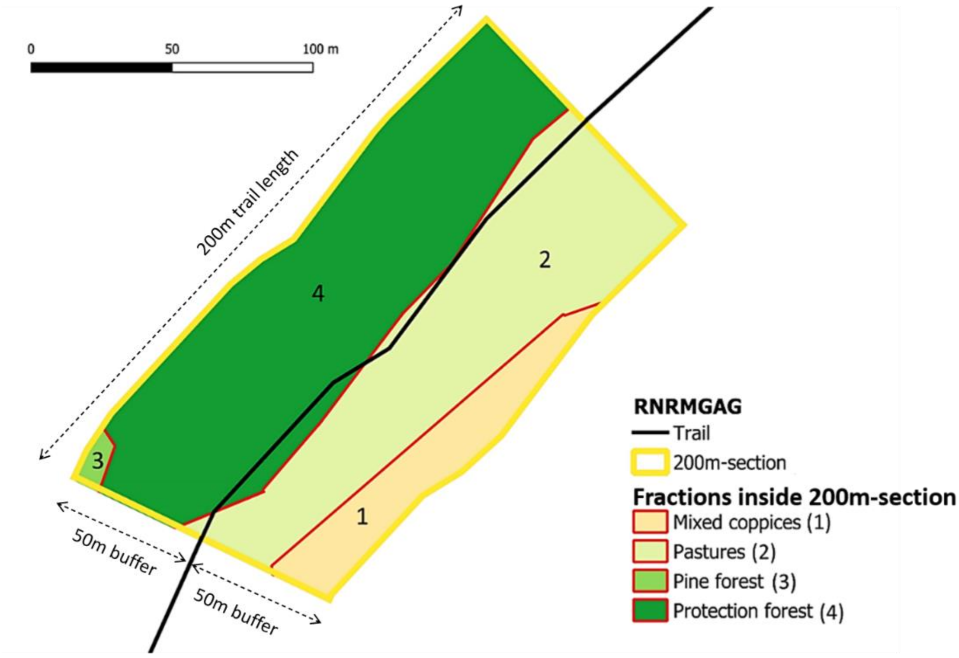


Figure 5 Example of a 200m-trail section with its inside fractions of different vegetation types in the Riserva Naturale Regionale Monte Genzana Alto Gizio, central Italy (Martin, 2021).

The provided data sets on bear signs were adjusted to contain the same information in the same order and were merged afterwards. GPS locations were transformed from Standard UTM into Decimal degrees. The time was transformed from a 12h-clock format into a 24h-clock format. The count data of apple trees was converted into presence/ absence data per fraction, because of the high number of zeros. The area sizes of the fractions were transformed to the natural logarithm (ln).

Data analysis

In SPSS (Version 27), the data was validated following the eight steps of data exploration by Zuur et al. (2010). In RStudio (Version 1.4.1103) a negative binomial generalized linear model (GLM) has been chosen to account for the high number of zeros. The packages used for the validation and modelling in RStudio were 'ggeffects', 'DHARMa', 'ggplot2', 'glmTMB', 'emmeans', 'gamm4' and 'stats'.

A pioneer negative binominal GLM (model 1, Appendix 3) tested in RStudio featured the number of bear signs as the dependent variable, vegetation types and presence/ absence data of apple trees (0/1) as independent variable and natural logarithm (ln) of the area size (ha) of the fractions as an offset variable. The offset variable accounts for different exposure levels of the fractions (Coxe et al., 2009), because bigger fractions have a higher opportunity to host more apple trees and bear signs (Crowson, 2019). The number of apple trees per vegetation type was not large enough to add as an interaction in the model. For that reason, it was added as a main effect. Vegetation types were also added as a main effect.

Results

Vegetation investigation

In total 15ha were investigated; 1ha in Beech coppice (plot F1), 1ha in High forest (plot F3), 3ha in Mixed coppices (plots SM2, SM3 and N3), 4ha in Pastures (plots B1, LP1, N4 and F2), 3ha in Pine forest (plots LP2, N1, LP4) and 3ha Protection forest (plots N2, SM1, LP3). In plot F2 the highest number of foods was found (n=10; figure 6; Appendix 1), followed by F1 (n=9) and LP4 (n=9). In B1 the lowest number of foods was found (n=4).

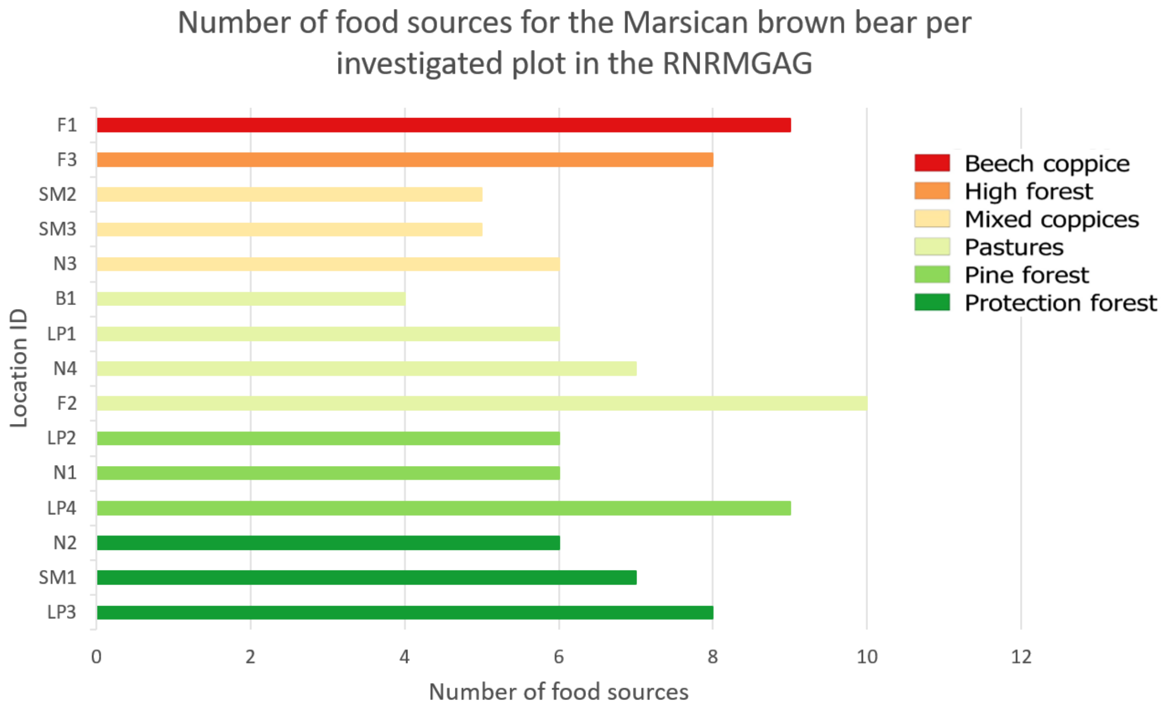


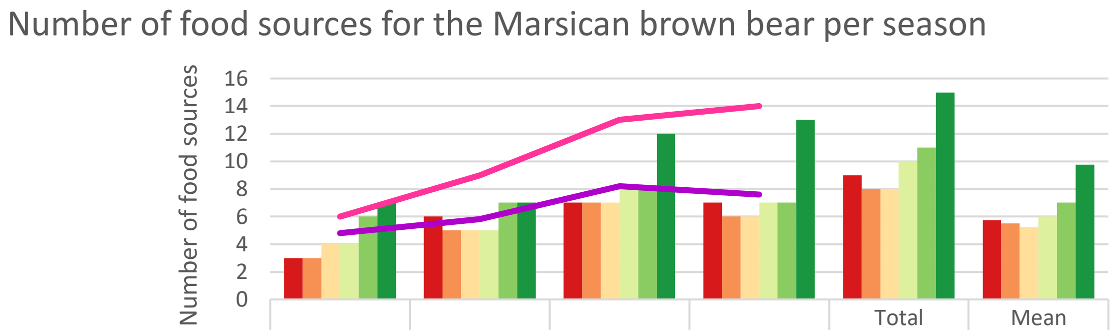
Figure 6 Number of foods for the Marsican brown bear per investigated plot resulting from the vegetation investigation in the Riserva Naturale Regionale Monte Genzana Alto Gizio, central Italy. The abbreviations of the plots stand for the trail names (SM= Santa Margarita, LP=Le pendici, B=Botanical, N=Napoleonica, F=Farmer).

A total of n=18 species of foods for the Marsican brown bear were identified within the 15 plots. The most frequent species were Oak (n=15; table 1), Beech (n=13) and Blackberry (n=12, *Rubus* sp.). Grass (*Gramineae*) and Hazelnut (*Corylus* sp.) were found n=10 times and Strawberry (*Fragaria* sp.) and Wild rose (*Rosa canina*) n=9 times.

Table 1 List of seasonal available foods in the 6 present vegetation types for the Marsican brown bear within in the Riserva Naturale Regionale Monte Genzana Alto Gizio, central Italy, resulting from a vegetation investigation from 15 plots.

	Beech coppice	**High forest**	**Mixed coppices**	**Pastures**	**Pine forest**	**Protection forest**
Spring	Beech Oak Wild rose	Beech Oak Wild rose	Beech Grass Oak Wild rose	Beech Grass Oak Wild rose	Beech Cherry Grass Evergreen oak Oak Wild rose	Beech Cherry Evergreen oak Grass Oak Olive Wild rose
Early summer	Apple Beech Oak Strawberry Wayfaring tree Wild rose	Apple Beech Oak Strawberry Wild rose	Beech Grass Oak Strawberry Wild rose	Beech Grass Oak Strawberry Wild rose	Beech Cherry plum Evergreen oak Grass Oak Strawberry Wild rose	Beech Cherry Evergreen oak Grass Oak Strawberry Wild rose
Late summer	Apple Beech Blackberry Hazelnut Oak Wayfaring tree Wild rose	Apple Beech Blackberry Blackthorn Hazelnut Oak Wild rose	Beech Blackberry Cornelian cherry Grass Hazelnut Oak Wild rose	Beech Blackberry Blackthorn Hazelnut Grass Oak Whitebeam Wild rose	Beech Blackberry Blackthorn Evergreen oak Hazelnut Grass Oak Wild rose	Beech Blackberry Blackthorn Cherry Cornelian cherry Evergreen oak Hazelnut Grass Oak Pear Whitebeam Wild rose
Autumn	Apple Beech Blackberry Oak Wayfaring tree Whitethorn Wild rose	Apple Beech Blackberry Blackthorn Oak Wild rose	Beech Blackberry Cornelian cherry Grass Oak Wild rose	Beech Blackberry Blackthorn Grass Oak Whitethorn Wild rose	Beech Blackberry Blackthorn Evergreen oak Grass Oak Wild rose	Beech Blackberry Blackthorn Cherry Cornelian cherry Evergreen oak Grass Oak Olive Pear Whitebeam Whitethorn Wild rose

Overall, n=6 foods were identified to be available in spring, n=9 in early summer, n=13 in late summer and n=14 in autumn (figure 8). On average n=4.8 foods are available per vegetation type in spring, n=5.8 in early summer, n=8.2 in late summer and n=7.6 in autumn. In Protection forest, the highest number of foods was found (n=15), followed by Pine forest (n=11) and Pastures (n=10). In Beech coppice n=9 foods were found and in High forest and Mixed coppices n=8. Protection forest has the highest mean number of foods per season (n=9.75), followed by Pine forest (n=7) and Pastures (n=6). The mean number of foods per season of Beech coppice, Mixed coppices and High forest are respectively n=5.75, n=5.5 and n=5.25.



	Spring	Early summer	Late summer	Autumn	Total number of food sources	Mean number of food sources
Beech coppice	3	6	7	7	9	5,75
High forest	3	5	7	6	8	5,5
Mixed coppices	4	5	7	6	8	5,25
Pastures	4	5	8	7	10	6
Pine forest	6	7	8	7	11	7
Protection forest	7	7	12	13	15	9,75
Total number of food sources	6	9	13	14		
Mean number of food sources	4,8	5,8	8,2	7,6		

Figure 7 Number of foods for the Marsican brown bear per season in the six vegetation types in the Riserva Naturale Regionale Monte Genzana Alto Gizio, central Italy.

In spring, Protection forest offered the highest number of foods (n=7), followed by Pine forest (n=6; figure 9). In Beech coppice and High forest Beech, Oak and Wild rose were available in spring (n=3; table 1). All vegetation types offered Beech, Oak and Wild rose in spring.

In early summer both Protection Forest and Pine forest offered n=7 foods, the only difference being that in Protection forest Cherry was found and in Pine forest Cherry plum. In Beech coppice n=6 foods were found. In High forest, Mixed coppices and Pastures each n=5 foods were present. All vegetation types offered Beech, Oak, Strawberry and Wild rose in early summer.

In late summer Protection forest offered the highest number of foods (n=12). In Pastures and Pine forest n=8 foods were found and n=7 in Beech coppice, High forest and Mixed coppices. All vegetation types offered Beech, Blackberry and Hazelnut, Oak and Wild rose in late summer.

Lastly, in autumn Protection forest again offered the highest number of foods (n=13). In Beech coppice, Pastures and Pine forest n=7 foods were found. In High forest and Mixed coppices n=6 foods were present. All vegetation types offered Beech, Blackberry, Oak and Wild rose in autumn.

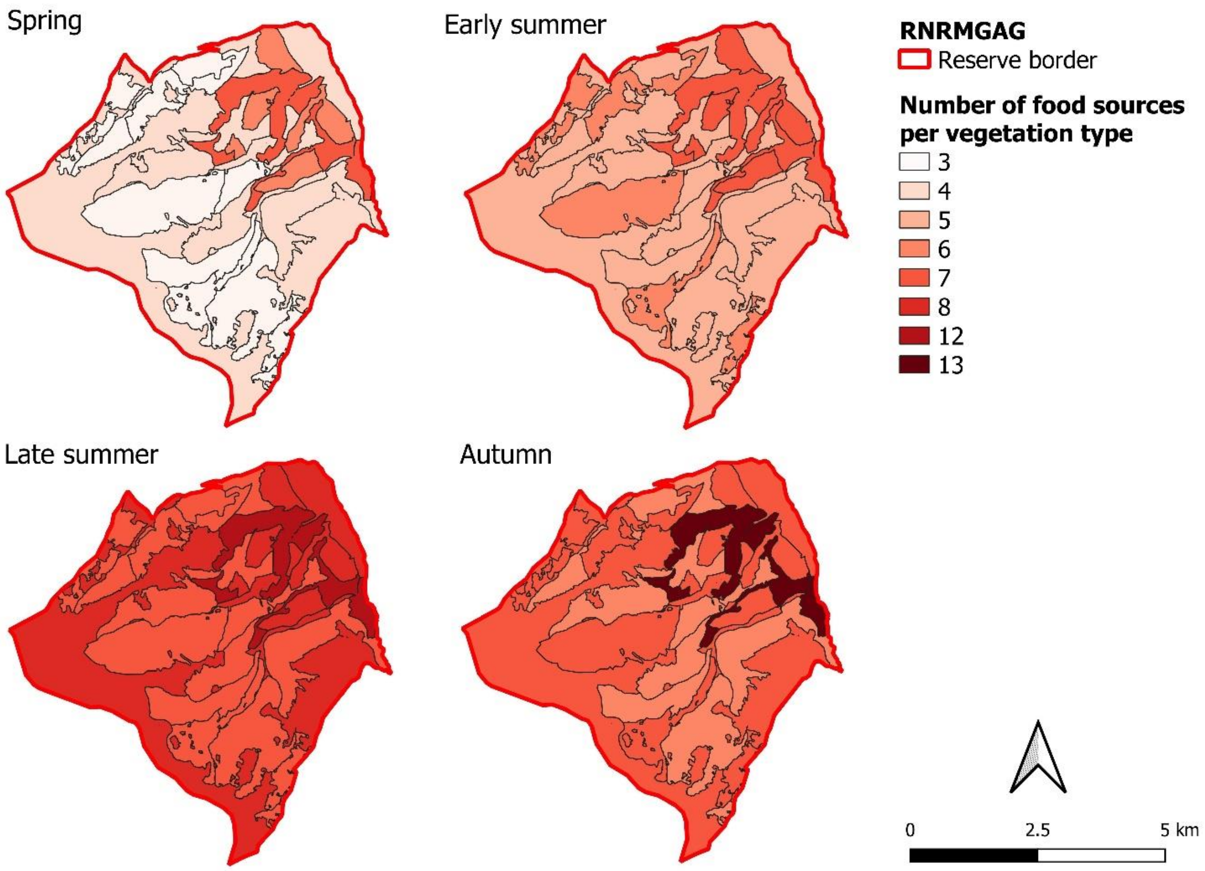


Figure 8 Number of foods per vegetation type in spring (March-May), early summer (June-July), late summer (August-September) and autumn (October-mid December) in the Riserva Naturale Regionale Monte Genzana Alto Gizio, central Italy (Martin, 2021). In all four seasons Protection forest offers the highest number of foods (in spring n=7, in early summer n=7, in late summer n=12 and in autumn n=13). Pine forest offer 7 foods in early spring as well.

The obtained data from the vegetation investigation, however, was not sufficient enough to further analyse statistically. Thus, no correlation between food availability and bear signs could be analysed. Only apple tree data was sufficient to be added to the correlation analysis.

Within the 15 camera trapping locations the Marsican brown bear was only captured at two locations (LP2 and LP4). Two individuals were identified.

Correlation between vegetation types and bear signs

In total, 64.428km of trails were investigated for the correlation between vegetation types, apple trees and bear signs. The total number of remaining 200m-trail sections was n=277, in which one or more vegetation types were present. There were n=501 fractions in the n=277 200m-trail sections. The highest number of vegetation types being present in one 200m-section was n=4. On average n=1.8 vegetation types (pieces) were present in one 200m-trail section. In total there were 329 apple trees (figure 10) and 58 bear signs (figure 10) within the 50m-buffer.

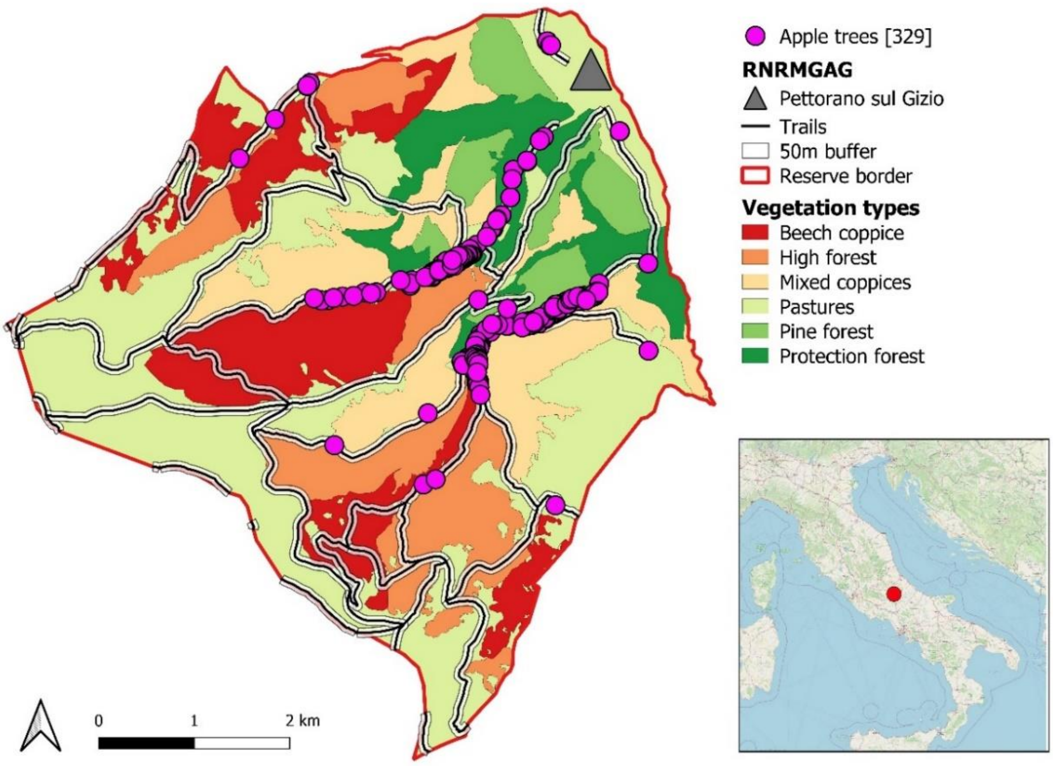


Figure 9 Distribution of apple trees within the Riserva Naturale Regionale Monte Genzana Alto Gizio, central Italy (Martin, 2021).

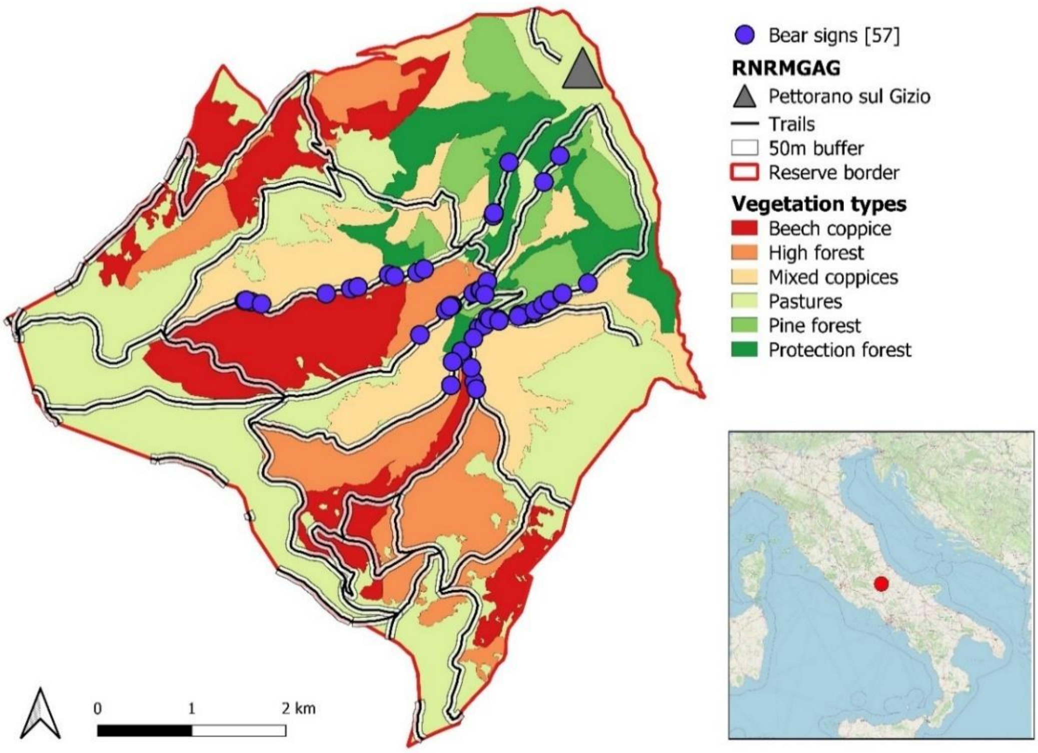
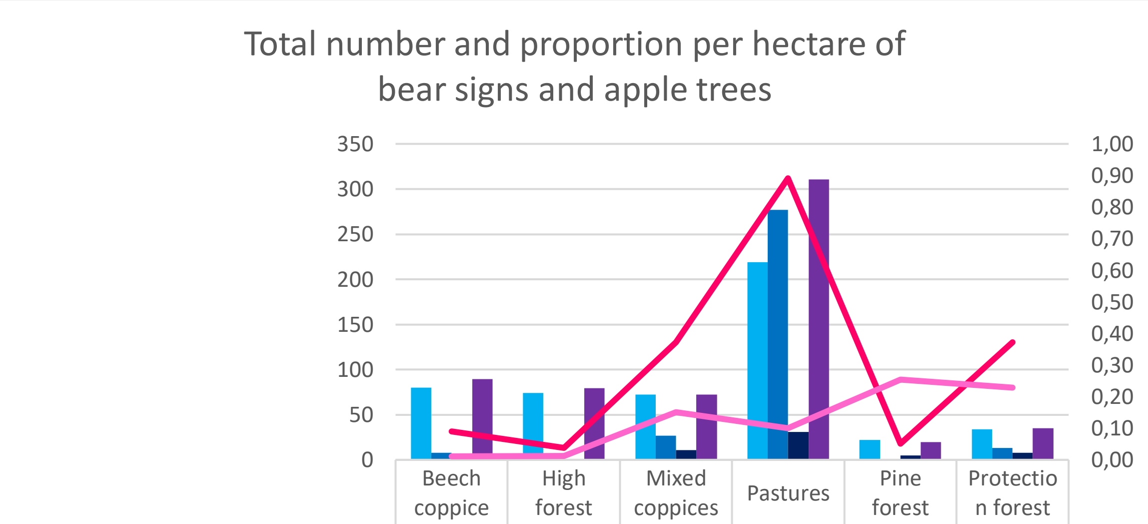


Figure 10 Distribution of bear signs within the Riserva Naturale Regionale Monte Genzana Alto Gizio, central Italy (Martin, 2021).

On average n=0.2 bear signs and n=1.19 apple trees were present in a fraction. The highest number of bear signs within a fraction was n=4 and of apple trees n=43. As can be seen in figure 10 and 11 most bear signs and apple trees were located along two trails. Therefore, numerous fractions had zero bear signs (n=468, 93.4%), nor apple trees (n=444, 88.6%). A total of 84.8% (n=425) of the fractions had no bear signs nor apple trees.

Pastures had the highest number of n=219 fractions, in which n=277 apple trees were present and n=31 bear signs were found (figure 12). In Mixed coppices n=27 apple trees and n=11 bear signs were found. In Protection forest n=13 apple trees and n=8 bear signs were found. Only one apple tree was found in Pine forest and only one bear sign was found in Beech coppice and High forest. In total an area of 310.83ha was surveyed in Pastures, resulting in the highest proportion of apple trees per hectare (0.89), but the highest proportion of bear signs per hectare is in Pine forest (0.25). In Protection forest and Mixed coppices 0.37 apple trees per hectare were found.



	Beech coppice	High forest	Mixed coppices	Pastures	Pine forest	Protectio n forest
Total number of vegetation type pieces	80	74	72	219	22	34
Total number of apple trees	8	3	27	277	1	13
Total number of bear signs	1	1	11	31	5	8
Total area size of vegetation type pieces (ha)	89,63	79,33	72,58	310,83	19,69	35,01
Proportion of apple trees/ha	0,09	0,04	0,37	0,89	0,05	0,37
Proportion of bear signs/ha	0,01	0,01	0,15	0,10	0,25	0,23

Figure 11 Total number and proportion per hectare of bear signs and apple trees within the Riserva Naturale Regionale Monte Genzana Alto Gizio, central Italy (Martin, 2021).

The Akaike Information Criterion (AIC) for the first negative binominal GLM was 293.8. Mixed coppices, Pine forest, Protection forest and presence of apple trees were significant on the number of bear signs. The function of the model in R can be found in the Appendix 2.

A spatial dependency of the residuals of the fractions was found. Therefore, trails were added as a random factor to generalize the results to all trails (Dallal, 2020), which resulted in a better explanation of variation of the data.

The best model to answer which correlation can be seen between vegetation types, apple trees and bear signs featured the number of bear signs as the dependent variable, presence of apple trees and vegetation type as independent variable, ln of the area size (ha) of the fractions as an offset variable and the trails as a random factor (model 2). No correlation between the vegetation types and bear signs was found. The AIC for model 2 was 291.4 and the overdispersion parameter 1.58. The overdispersion parameter shows how good the model fits the data (the closer to 1 the better). No vegetation type was significant on the number of bear signs, but presence of apple trees (p=1.92e-05 ***) was.

Overall, the predicted value of bear signs found in a hectare without apple trees was are considerably lower than in a hectare with apple trees (table 2). Pine forest had the highest mean number of bear signs per hectare without apple trees (0.03) and with apples trees (0.44). However, there were only n=22 fractions (lowest number of all vegetation types; figure 11) of Pine forest, in which there were only one apple tree and n=5 bear signs resulting in a high upper quartile of the 95% confidence interval (10.90). In Protection forest the predicted value of bear signs per hectare with apple trees was 0.27 and for bear signs per hectare without apple trees 0.02. In Beech coppice and High forest only one sign of bear presence was found and therefore the predicted value for bear signs per hectare without apple trees was for both 0.00. Furthermore, in Beech coppice the lowest predicted value of bear signs per hectare with apple trees was found (0.03).

Table 2 Predicted values and confidence intervals of the mean number of bear signs per hectare in each vegetation type

	Mean number of bear signs per hectare without apple trees		Mean number of bear signs per hectare with apple trees	
Vegetation type	Predicted value	95% Confidence interval	Predicted value	95% Confidence interval
Beech coppice	**0.00**	0.00, 0.04	**0.03**	0.00, 0.69
High forest	**0.00**	0.00, 0.05	0.04	0.00, 0.84
Mixed coppices	0.02	0.00, 0.15	0.22	0.02, 2.72
Pastures	0.01	0.00, 0.06	0.11	0.01, 0.89
Pine forest	**0.03**	0.00, 0.58	**0.44**	0.02, 10.90
Protection forest	0.02	0.00, 0.27	**0.27**	0.02, 4.58

However, it was found that when deleting vegetation types from the second model the AIC improved to 288.8 (former 291.4), which shows again that vegetation types are not significant on the bear signs. On the contrary when deleting apple trees, the AIC declined to 307.4, which shows that there is a correlation between apple trees and bear signs. The model without the vegetation types (model 3) also has a lower overdispersion parameter (1.34). The presence of apple trees was still significant (4.67e-06 ***). With Estimates Marginal Means it was calculated that in a vegetation type without apple trees 0.00456 bear signs per hectare are expected and in a vegetation type with apple trees 0.05545 bear signs per hectare, which is more than 10 times higher (Table 3). The standard error shows that the observations lie very close to the regression line.

Table 3 Number of bear signs per hectare within a fraction with (1) or without (0) apple trees. The standard error (SE) indicates how close the observations are to the regression line and the degree of freedom (df) indicates the number of independent values that are free to vary and it equals the sample size minus the number of parameters (Frost, 2021). Lower and upper CL stand for the lower and upper bound of the 95% confidence interval, which corrects for the SE of the mean.

Apple	response	SE	df	lower CL	upper CL
0	0.00456	0.00653	497	0.000273	0.076
1	0.05545	0.08446	497	0.002781	1.106

Discussion

The key issue in this pilot study is the low number of investigated plots and the restriction to pre-selected trails. The pre-selected trails only provide information about that part of the reserve. It is known that amongst other factors elevation is the most important one that affects the distribution of vegetation in mountain areas (Busing et al., 1992; Titshall et al., 2000). Thus, other food species could have been found in the south-western part of the reserve. In this pilot study 0.47% of the whole reserve has been surveyed. Şahin et al. (2008) surveyed 5% of the study area to assess the vegetation structure. Noyce et al. (1990) surveyed 12 circular plots of $28m^2$ in 10 vegetation types which equals to almost 10% of the study area to assess the 'abundance and productivity of bear food species in different forest types of northcentral Minnesota'. Further, McCune and Grace (2002) stated that many and small plots will provide accuracy of the abundance of mostly common species, while few and large plots will give a more complete species list of all species, but also overestimates rarer species. Thus, it can be expected that most common species, at least in the lower eastern part of the reserve, were identified.

Furthermore, more plots should have been investigated and the number of plots should have been evenly distributed within the vegetation types, which would have resulted in the am effort for all vegetation types, to give more precise results (Nowak et al., 2008). High forest with beech prevalence and Beech coppice were only investigated once because their area size within the buffer of the selected trails was smaller than 1.5ha. Thereby the obtained data cannot be accounted for and projected on the whole reserve as significant data on the number of foods. The other vegetation types were investigated three or four times, which gives more data, but still not significant enough to make an accurate statement about the number of foods in each vegetation type within the reserve. Initially, 5% of all vegetation types was planned to be investigated (100m x 100m plots), which would have resulted in a studied area of 21.4ha for Beech coppice, 20.7ha for High forest, 23.0ha for Mixed coppices, 28,2ha for Pastures, 8,4ha for Pine forest and 13,4ha for Protection forest.

In addition, investigating the vegetation only 50m next to trails within the reserve is not scientifically representative. The significance of the results is further decreased when investigating only specific trails. The vegetation next to trails can be impacted by their usage (Müllerova et al., 2011; Ballantyne and Pickering, 2015) and even invasive species can spread easier and farther (Liedtke et al., 2019), resulting in the possibility that some species were predominately found next to trails and might not be found farther off trail. Initially, 5% of all vegetation types was planned to be investigated excluding the area of 50m next to the trails, which would have given considerably higher amount of data, that is further not biased by the trails. To decrease disturbance too far off trail during the hibernation period of the bears the plots had to be rearranged to the area of 50m next to chosen trails. However, it has to be considered that there was also a disturbance of human presence and the leaving of human scent during investigation and especially camera deployment and the related camera checks next to the trails (Caravaggi et al., 2020).

Reshaping the polygons of the vegetation types without knowing the actual underlying vegetation types can increase the data of being corrupted. Reshaping the polygons following a satellite image can cause lower errors, but errors still need to be considered. It would have been better to examine the present vegetation types in the field, especially the area 50m next to the trails. For a following research it is recommended to either only focus on the areas with known vegetation type or to examine the area with missing vegetation type data and to assign a vegetation type. It was assumed that the vegetation types close to the trails are the same as the surrounding vegetation types, but many research papers assessed that trails have an impact on vegetation composition and structure (Runkovski and Pickering, 2015). That is why it would be important to update the vegetation shapefile of the reserve and evaluate the area with unknown vegetation type, or solely execute a vegetation investigation on known ground. Follow-up researches should not refer to the maps with altered vegetation types shown in this pilot study.

Data about the foods available were only recorded in presence/ absence. Due to only 15 chosen plots, little presence absence data of foods was available and thus could not be included in the statistical analysis. The methods for data collection for foods should be changed from presence/ absence to count data. With the presence/ absence data, a first picture of number of foods within the reserve was established. Changing the data collection of the foods into count would give more detailed data and better comparisons between the vegetation types and abundance of foods could be made.

Within the vegetation investigation it was found that the RNRMGAG offers 6-14 foods of hard mast, fleshy fruit and green vegetation in the four seasons, which equates 60-70% of the foods that Ciucci et al. (2014) identified in scats. Thereby the reserve is not only an important ecological corridor (Giangregorio et al., 2014), but could give an indication on the value of the habitat relating to number of foods for the Marsican brown bears. Surprising was that Buckthorn (*Rhamnus* ssp.) was not found, but makes up 42.2% of the scat components found by Ciucci et al. (2014) and is thus considered an important food source in late summer. This might be explained by the low number of investigated plots (n=15), sample point locations, the season and also identification errors. However, Buckthorn is known to be present in a small area in the west of the reserve. Ciucci et al. (2014) found a negative trend of the consumption of the berries from 2006 to 2009, hence it is important to implement management measures to secure availability of the berries and to investigate this specific area to identify the bears' presence.

Hard mast is described as the most important food source for Marsican brown bears (Ciucci et al., 2014), because of its high caloric content hard mast is critical to fatten up for winter (Watts and Jonkel, 1988) and especially for reproducing females (Persson et al. 2001). In all six vegetation types Beechnut, Oak and Hazelnut were found. It is even predicted that hard mast is one of the major predictors of the bears' reproductive rate (Rogers 1987; Clevenger et al. 1992; Costello et al. 2003; Hashimoto et al. 2003; Reynolds-Hogland et al. 2007). In years with poor hard mast production the bears tend to eat more fleshy fruits, which are an important source for fat accumulation for the hibernation period, providing energy from digestible carbohydrates (Dahle et al, 1998). At least 403 apple trees, but also other fruiting trees known to be present in lo numbers in the reserve, like cherry (*Prunus avium*), plum (*Prunus domestica*) and sorb (*Sorbus domestica*), are providing fruits in summer and autumn for the bears. From the apple tree shapefile, it is seen that apple trees are present in all six vegetation types, but mostly in Pastures and along two trails (Santa Margarita and Napoleonica). However, vegetation type errors have to be expected, because of the altered vegetation type shapefile, meaning that apple trees might lie in a different vegetation type than assumed. The apple trees were mostly planted from farmers close to the trails or along property boarders before World War II. Within the vegetation investigation only two apple trees and three cherry trees were found, which can be again explained by the low number of investigated plots, sample point locations, the season and also identification errors. In total 62% of the 21 fleshy fruit species identified within the scat analysis of Ciucci et al. were found in the RNRMGAG. Assuming, that the results showing that most apple trees were found in pastures is accurately, it would support the fact of bears eating agricultural farm foods and thus creating human-bear conflict (Romagnuolo, 2016; Ciucci and Boitani, 2008). Ciucci and Boitani (2008) stated that 15% of bear damages are on cops and fruit trees. For that reason, Salviamo l'Orso tries to reduce the conflict by offering local farmers to build electric fences around agricultural fields and also livestock as a preventive measure (Salviamo l'Orso, 2020).

Looking at the figure 9, which shows the number of foods per vegetation type and season it could appear that there is a coincidence between sample area and number of foods, but it has to be considered that Pine forest and Protection forest is only present in that area. However, it was conspicuous that both vegetation types showed higher numbers of foods compared to the other four, even though in both only one plot was investigated. For that reason, it could be expected that even more bear signs can be found in Pine forest and Protection forest. Studies, like Wu et al. (2017), found contradictorily that Pine forest host lower species richness compared to other forest types. Another factor to consider concerning the high number of foods found in Pine forest and Protection forest is a possible error of the assigned vegetation type through the altered shapefile.

The statistical analysis of the correlation between vegetation types and number of bear signs showed no significance. This can be explained by the fact that most bear signs were found along two trails (Santa Margarita and Napoleonica), which are the most frequently used trails by humans. Thereby there is a trail effect and not a vegetation type effect. If the bear signs were found more evenly distributed along all trails within the reserve, a possible correlation between vegetation types and bear signs could have been evaluated. Even though this pilot study found indications that vegetation types are not correlated on bear signs, land cover is a potential determent on bear sign abundance (Clevenger et al. 1997). Especially beech an oak, which are found in all vegetation types and in all season in the RNRMGAG, supply a staple food source and also cover to the bears. The fact that most bear signs were found along two trails could also be influences by other environmental factors, like water availability or elevation, that were not included in the analysis. In the Majella national Park (MNP), which lies closely to the RNRMGAG, it was found that distance to water has a negative effect on the occurrence of bears, meaning that the further away from water the less sightings were recorded. Given that the RNRMGAG and MNP share the same terrain a possible correlation between water availability and bear occurrence could also be found in the RNRMGAG (Adjaye, 2011). Posilico et al. (2004) stated that in the Apennines the probability of finding brown bears increase with elevation, which might be connected with lower human presence and also the availability of Buckthorn. This supports the recommendation of investigating the small area hosting Buckthorn in the RNRMGAG, because finding bear signs there can be considered high.

The presence of apple trees was significant in all three models. When deleting the vegetation types from the model, the model fitted the data better and presence of apple trees was still significant, which means that there is a correlation between presence of apple trees and bear signs. The results also showed that 10 times more bear signs were found per hectare, when apple trees were present. In Pastures 84% off all apple trees and 54% of all bear signs were found. This could indicate that Pastures is the most visited vegetation type within the RNRMGAG, even though Protection forest offers the highest number of foods. When considering that most bear signs were found close to apple trees, it is promising that those apple trees are an important food source of the bears within the RNRMGAG and should thereby be protected and maintained.

Recommendations

A follow-up research should most importantly modify the data collection. Trails that are less used within the reserve should be considerably more investigated to receive data on bear signs on those trails. The vegetation investigation should be executed in a lesser sensitive period of the Marsican brown bears to ensure no disturbance, but to guarantee the gathering of more valuable data of plots further off the trails and distributed over the whole reserve. Data of foods should be collected in count data. In all vegetation types a considerably higher number of plots should be investigated to be able to receive more data to make clearer comparisons. Especially the Buckthorn area should be investigated to evaluate the bear presence. Furthermore, management measures to increase the abundance of Buckthorn throughout the reserve could increase the valuableness of the reserve to the bears. Data about wild and domestic ungulate presence should also be included in the study as well as the recording of all other foods studied by Ciucci et al. (2014). An updated shapefile of the vegetation types covering the whole reserve would increase the accuracy of the results. Otherwise, the vegetation investigation should only be executed in the already known vegetation types to decrease vegetation type errors. Lastly, other factors like elevation, distance to water availability or distance to human settlements could be included to give a broader insight about possible correlations with bear signs. The management of the RNRMGAG should focus on conserving and protecting the stands of beech, oak, apple trees and Buckthorn to offer the Marsican brown bears a sufficient amount of foods and thus decrease damage on crops and fruit trees of local farmers.

Conclusion

In Conclusion, this pilot study was an interesting attend and a step forward in getting a picture of available foods within the Riserva Naturale Regionale Monte Genzana Alto Gizio and gave an indication on a possible correlation between the presence of apple trees and bear signs. Nevertheless, the acquired data is not sufficient to make significant statements.

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Appendices

Appendix 1

Table 4 Foods found per investigated plot in the Riserva Naturale Regionale Monte Genzana Alto Gizio, central Italy.

Trail	Location	Vegetation type	English name	Scientific name
Santa Margarita	SM1	Protection forest	**Beech**	*Fagus sylvatica*
			Blackberry	*Rubus* sp.
			Blackthorn	*Prunus spinosa*
			Cherry	*Prunus avium*
			Oak	*Quercus* sp.
			Pear	*Pyrus* sp.
			Strawberry	*Fragaria*
	SM2	Mixed coppices	Beech	*Fagus sylvatica*
			Grass	*Gramineae* sp.
			Hazelnut	*Corylus* sp.
			Oak	*Quercus* sp.
			Strawberry	*Fragaria* sp.
	SM3	Mixed coppices	**Beech**	*Fagus sylvatica*
			Blackberry	*Rubus* sp.
			Cornelian cherry	*Cornus mas*
			Grass	*Gramineae* sp.
			Oak	*Quercus* sp.
Botanical	B1	Pastures	Hazelnut	*Corylus* sp.
			Oak	*Quercus* sp.
			Strawberry	*Fragaria* sp.
			Whitethorn	*Crataegus* sp.
Le pendici	LP1	Pastures	**Beech**	*Fagus sylvatica*
			Blackberry	*Rubus* sp.
			Grass	*Gramineae* sp.
			Oak	*Quercus* sp.
			Wild rose	*Rosa canina*
			Whitethorn	*Crataegus* sp.
	LP2	Pine forest	Blackberry	*Rubus* sp.
			Blackthorn	*Prunus spinosa*
			Hazelnut	*Corylus* sp.
			Oak	*Quercus* sp.
			Strawberry	*Fragaria* sp.
	LP3	Protection forest	**Beech**	*Fagus sylvatica*
			Cornelian cherry	*Cornus mas*
			Grass	*Gramineae* sp.
			Hazelnut	*Corylus* sp.
			Oak	*Quercus* sp.
			Olive	*Olea europaea*
			Whitebeam	*Sorbus aria*
			Whitethorn	*Crataegus* sp.
	LP4	Pine forest	Beech	*Fagus sylvatica*
			Blackberry	*Rubus* sp.
			Blackthorn	*Prunus spinosa*
			Cherry plum	*Prunus cerasifera*
			Grass	*Gramineae* sp.
			Hazelnut	*Corylus* sp.
			Oak	*Quercus* sp.
			Strawberry	*Fragaria* sp.
			Wild rose	*Rosa canina*

Napoleonica	N1	Pine forest	Beech	*Fagus sylvatica*
			Blackberry	*Rubus* sp.
			Evergreen oak	*Quercus ilex*
			Grass	*Gramineae* sp.
			Oak	*Quercus* sp.
			Wild rose	*Rosa canina*
	N2	Protection forest	Beech	*Fagus sylvatica*
			Blackberry	*Rubus* sp.
			Evergreen oak	*Quercus ilex*
			Grass	*Gramineae* sp.
			Oak	*Quercus* sp.
			Wild rose	*Rosa canina*
	N3	Mixed coppices	**Beech**	*Fagus sylvatica*
			Blackberry	*Rubus* sp.
			Grass	*Gramineae*
			Hazelnut	*Corylus* sp.
			Oak	*Quercus* sp.
			Wild rose	*Rosa canina*
	N4	Pastures	Beech	*Fagus sylvatica*
			Blackberry	*Rubus* sp.
			Strawberry	*Fragaria* sp.
			Oak	*Quercus* sp.
			Hazelnut	*Corylus* sp.
			Grass	*Gramineae* sp.
			Wild rose	*Rosa canina*
Farmer	F1	Beech coppices	Apple	*Malus* sp.
			Beech	*Fagus sylvatica*
			Blackberry	*Rubus* sp.
			Hazelnut	*Corylus* sp.
			Oak	*Quercus* sp.
			Strawberry	*Fragaria* sp.
			Wayfaring tree	*Viburnum lantana*
			Wild rose	*Rosa canina*
			Whitethorn	*Crataegus* sp.
	F2	Pastures	Beech	*Fagus sylvatica*
			Blackberry	*Rubus* sp.
			Blackthorn	*Prunus spinosa*
			Grass	*Gramineae* sp.
			Hazelnut	*Corylus* sp.
			Oak	*Quercus* sp.
			Strawberry	*Fragaria* sp.
			Whitebeam	Sorbus aria
			Wild rose	Rosa canina
			Whitethorn	Crataegus sp.
	F3	High forest with prevalence of Beech	Beech	Fagus sylvatica
			Blackberry	Rubus sp.
			Hazelnut	Corylus sp.
			Strawberry	Fragaria sp.
			Apple	Malus sp.
			Wild rose	Rosa canina
			Oak	Quercus sp.
			Blackthorn	Prunus spinosa

Appendix 2

The results of Ciucci et al.'s paper (2014) on the seasonal and annual variation in the food habits of the Marsican brown bear in the PNALM show that in spring almost half of the bear's diet is made up of green vegetation (46.5%), of which 24.6% were graminoids and 18.5% were forbs (figure 1). Hard mast adds up to 24%, of which 21% was European beech. Mammals made up 17.8% in spring, of which wild ungulates, especially fawns and piglets, made up 13.6% of their diet. In early summer green vegetation still adds up to 31.6%, 22,9% by forbs. During this season insects (30.8%), especially ants (27.6%) are a big part of the bears diet as well. Furthermore, fleshy fruit, like cherry (*Prunus avium*, 11.7%), makes up 19.3% of the bear's diet. In late summer fleshy fruit becomes the main food source (66.8%). Buckthorn adds up to 42.2%. Domestic ungulates, especially cattle (4.1%), made up 7.7% and European beech made up 7.2% of the bear's diet. Lastly, in autumn more than half of the bear's diet is made out of hard mast (55.8%), European beech by 38.2% and Oak (*Quercus* sp.) by 17.5%. Fleshy fruit still makes up 29.8%. Apple adds up to 8.7% and pear 8.7%.

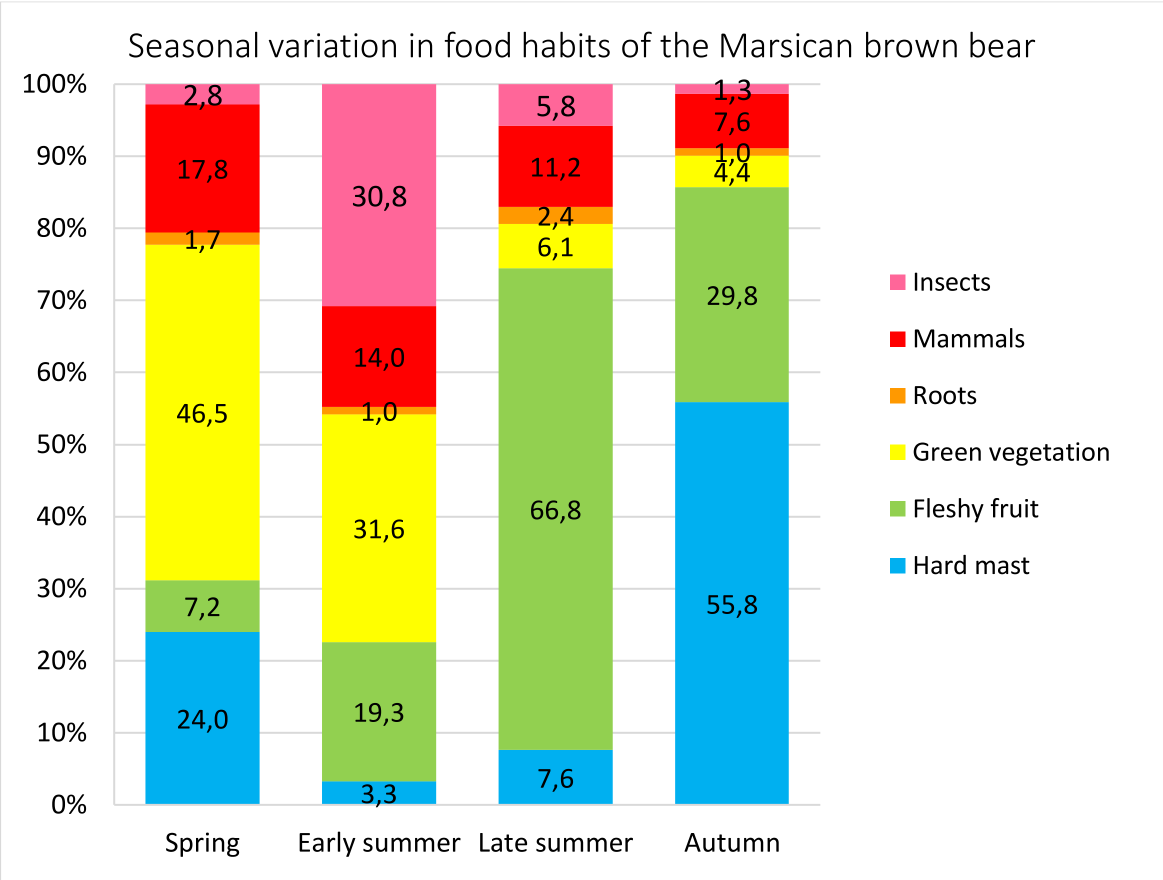

Figure 12 Seasonal variation in food habits of the Marsican brown bear (Martin, 2021). The raw data was retrieved from Ciucci et al. (2014).

Appendix 3

Pioneer model 1 (in R): glmmTMB(NrBears ~ Vegetation types + Apple trees + offset(ln area pieces),

family = "nbinom2"

Model 2 (in R): glmmTMB(NrBears ~ Vegetation types + Apple trees + offset(ln area pieces)

+ (1|Trail),

family = "nbinom2"

Model 3 (in R): glmmTMB(NrBears ~ Apple trees + offset(ln area pieces)

+ (1|Trail),

family = "nbinom2"