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Determinants of Small Mammals' Body Condition in *Eucalyptus* Dominated Landscapes

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Abstract: The timber industry has increased considerably in recent decades to meet human needs for wood. In Portugal, *Eucalyptus* plantations are the most common use of forested land, presenting the largest coverage of *Eucalyptus globulus* in Europe. Although it is established that this landscape can affect biodiversity patterns, it is not clear what its role in shaping small mammals' body condition is. Here, we tested the effect of *Eucalyptus* plantations on small mammals' body condition, together with vegetation structure, weather, predators/competitors' abundance, and parasites' prevalence, using the Scaled Mass Index (SMI) as a surrogate. Capture of small mammals took place in 11 study areas in central Portugal from 2019 to 2022. The drivers' influence was tested using structural equation models (SEM). The response of body condition to *Eucalyptus* is species-specific, with *Crocidura russula* displaying better individual condition in native habitats (i.e., there was an indirect negative effect of *Eucalyptus* plantations). The overall model suggested that deer abundance, precipitation, and forest integrity promoted higher body condition levels, while wild boar abundance had an adverse effect. The management of these plantations must ensure the integrity of the remnants of native patches and control of highly abundant competitors (e.g., wild boar) to maintain a healthy and functional small mammal community.

Keywords: scale mass index; health conditions; rodents; forestry; exotic plantations; biodiversity conservation

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1. Introduction

Conversion of native ecosystems to agriculture or forestry systems is considered a major threat to biodiversity, since it induces changes in the composition and structure of communities, and the modification of ecological processes [1,2]. In several regions, forestry systems are composed of exotic species, such as *Eucalyptus* spp., a genus native to Australia, Tasmania, New Guinea, Philippines, and Indonesia that is being used worldwide for wood, biofuel, and paper pulp production [3,4]. *Eucalyptus* spp. covers > 20 million hectares in tropical and temperate regions [5,6], where these monospecific species' stands are considered some of the most productive and profitable forestry systems, mainly due to their tree fiber quality, high growth rate, and short production cycle [7,8].

Several studies have reported that *Eucalyptus* exotic plantations impose varying taxa and landscape-specific impacts on native wildlife (e.g., changes in activity and occupancy patterns, modification of interspecific relationships, and increase in parasites' prevalence; [9–12]), leading to changes in communities' composition (e.g., simplification of predator communities; [13]), thus inducing conservation concerns (e.g., [14,15]). This forestry system management affects the diversity and abundance of native understory [7], which is one of the most influential factors supporting biodiversity in forestry plantations.

Moreover, *Eucalyptus* stands lead to varied disturbance of native vegetation throughout the production cycle [16], taking into account management intensity [7]. These vegetation changes and disturbances can affect species at the lower trophic level (e.g., small mammals), which may jeopardize the entire wildlife community through cascading effects. For example, in southeastern Brazil, non-volant small mammal communities inhabiting tropical *Eucalyptus* plantations revealed lower abundance and species richness than those living in native areas. This indicates that the amount of food resources available in these anthropic systems for small mammals' predators (e.g., mesocarnivores, snakes, and raptors) is more limited [17] than in native habitats. In Portugal, Teixeira and colleagues [18] also showed that small mammal abundances within *Eucalyptus*-dominated landscapes were positively related to a well-developed understory, since the understory may provide food and refugee resources. Thus, the management of these plantations, which includes understory removal, will have cascading effects on the ability of this system to provide resources to wildlife.

All the examples mentioned above show that some species, often those more resilient [13], can survive in *Eucalyptus* plantations. However, although species may be present in exotic plantations, their individual body condition might be affected, decreasing their fitness [19]. Individuals' health and fitness are commonly assessed by using body condition indexes as a surrogate [20], since they evaluate the body reserves or fat accumulation of an animal, which influences reproduction success and survival [21,22]. Low body condition indexes are usually associated with environmental degradation, such as habitat fragmentation and food competition/shortage [20], leading to a generalized negative effect on populations. Thus, they can be used to assess the impact of landscape changes, including those linked to forestry management. For example, Prosser and colleagues [23] showed that Bornean banteng (*Bos javanicus lowi*) populations inhabiting logged forests showed a lower body condition than those living in reduced-impact logging areas., and in California, timber management caused amphibians' body condition to improve in patches of untinned forest [24].

Despite the large cover of *Eucalyptus* plantations in Europe (covering almost 1.5 million ha; [25]), few studies have assessed how these landscapes affect wildlife health/fitness (i.e., body condition), particularly in small mammals, whose condition will affect upper trophic levels within the community, e.g., [26]. Additionally, the available data are from local-scale studies (e.g., only one study area), and often did not present conclusive results regarding the effect of plantations on small mammals' body condition [12,17]. Small mammals are responsible for some fundamental ecosystem functions such as soil aeration and seed dispersal [27]. They support a large community of predators because they are on the bottom of the trophic chain and are primary consumers [28], and due to their small life cycles, they respond rapidly to habitat condition changes. All these characteristics make these taxa useful indicators of ecosystem functioning and valuable tools for describing habitat integrity [27] and sustainable forest management [29].

Therefore, to fulfill the mentioned knowledge gap, we implemented a study at a regional level in one of Europe's widest *Eucalyptus* plantation regions (central Portugal), which used small mammals as models, aiming to evaluate the following questions: (i) what is the effect of *Eucalyptus*-dominated landscapes on the small mammals' body condition (when compared to native areas)?; and (ii) what biotic and abiotic factors may be determining variation in small mammals' body condition (and consequently, their health)? Specifically, using small mammal body condition data from several *Eucalyptus* plantation concessions and control sites (i.e., native areas), we specifically tested the influence of (i) habitat structure (e.g., shrubs, herbs cover, and the Forest Landscape Integrity Index that combines observed and inferred forest pressures and the loss of connectivity of forest patches; see [30] for index details); (ii) weather conditions (e.g., monthly average precipitation); and (iii) relative abundance of predators (i.e., mesocarnivores), ectoparasites, and competitors (i.e., wild ungulates) on small mammals' body condition (see Table 1 for variables and hypothesis reasoning).

Table 1. Considered hypotheses on the drivers of SMI and the underlying reasoning and effect predictions; tested variables in each hypothesis; ranges; and data sources.

Hypothesis, Reasoning and Predictions	Variable	Description	Units [Range]	Source
H1—Understory composition: Areas dominated by native cover with a greater cover of understory may provide suitable resources for small mammals to thrive [18,31], thus achieving healthy conditions (i.e., higher body condition values).	Shrubs	Percentage of cover of all types of shrubs within the 1 m radius	Categories: 1 [0–35] % 2 [36–70] % 3 [71–100] %	Field observation
	Herbs	Percentage of cover of herbaceous within the 1 m radius		
H2—Weather conditions: The increase in the water availability for plants increases the success of understory development and productivity [32]., hence increasing the resources and shelter availability, which may allow small mammals to maintain better body condition.	Precipitation	Average month precipitation at trap centroids	[0.12–3.35] mm	[33]
H3—Forest integrity: Forests with higher landscape integrity are expected to have lower intensity of human activity, and human disturbance has been identified as a potential stressor of wildlife health [34]. Therefore, areas with higher forest integrity should support higher SMI values.	FLII	Average forest landscape integrity index within the 50 m radius	[0–10]	https://www.forestintegrity.com (accessed on 19 April 2023)
H4—Abundance of predators and competitor: Areas with higher carnivore abundances will induce a higher predation risk for small mammals, since they are the main prey of carnivores in the study areas [35]. Therefore, individuals subject to higher predation risks may present lower body condition values [36]. Moreover, ungulates can alter habitat quality by decreasing vegetation cover and in turn, resources availability for small mammals [37]. In addition, they can also alter the landscape (e.g., wild boar trampling leads to disturbed soil and vegetation removal; [38]). These disturbances may affect the small mammals' availability of food and shelter resources, leading to lower health conditions.	Carnivore abundance	Relative abundance of mammalian carnivores (e.g., red fox, *Vulpes vulpes*) per camera-trap grid	No. records/No. days cameras were active [0–24]	[39]; Unpublished data (Force Project ; Ref: 2022.03253.PTDC)
	Deer abundance	Relative abundance of red deer (*Cervus elaphus*), roe deer (*C. capreolus*) and fallow deer (*D. dama*) per camera-trap grid		
	Wild boar abundance	Relative abundance of wild boar (*Sus scrofa*) per camera-trap grid		
H5—Ectoparasites abundance: Individuals with a higher parasite load will have lower SMI values, since parasites strongly affect their hosts through mechanisms such as increased energetic costs [40], directly due to the consumption of host resources and tissues, and indirectly by stimulating the host immune response and by changing host movement, foraging, and social behaviors [41].	Parasites	Ectoparasites abundance (fleas and ticks)	No. parasites per individual [0–19]	[12]; Unpublished data (Force Project; Ref: 2022.03253.PTDC)

2. Materials and Methods

2.1. Study Area

The study was carried out in 11 areas, located in central Portugal (Figure 1). Eight areas consisted of *Eucalyptus* plantations (ca. 16 km^2). The remaining three sites corresponded to native areas (Lousã Mountain, "Serra da Malcata" Nature Reserve, and "Serra da Estrela" Natural Park), used as control sites. Plantations vary greatly in structure in phases of the production cycle (these include early planted stands, middle-aged stands, and pre-harvesting stands), due to management options that assume control of the understory, and also due to the growth of the trees itself over the 9-year harvesting cycle. Therefore, to incorporate such variation in plantations, the number of plantation sites is higher than in native vegetation areas. To ensure that all areas were spatially independent, all sampled areas were at least at 10 km apart. Native areas consisted of Mediterranean deciduous vegetation, such as oaks (*Quercus* spp.), poplars (*Populus* spp.), ash (*Fraxinus angustifolia*), and chestnut (*Castanea sativa*). Shrubs were predominant in the sampled sites, including *Cistus* spp., *Lavandula* sp., *Ulex* spp., *Rubus* spp., *Erica* spp., and *Cytisus* spp. Small mammal sampling was carried out in two seasons (wet and dry) in 2019, 2020, and 2022 (Table S1).

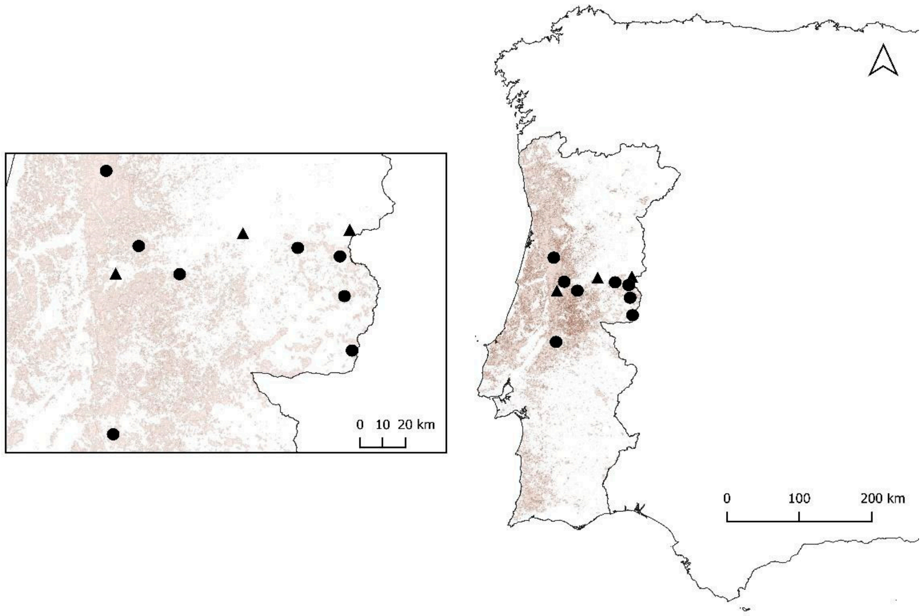

Figure 1. Study area location in central Portugal. *Eucalyptus* plantations are represented in brown [42]. *Eucalyptus* plantations study sites are indicated by black circles, and native areas (control sites) by black triangles.

2.2. Sampling Design and Animal Capture

The sampling design varied between study sites (Table S1). In eight study sites, we set 25 Sherman traps, located 10 m apart, in 40 × 40 m^2 sampling grids. On the remaining three sites, we used a linear design, comprising three and six trap lines with 15 and 20 traps, respectively, separated by 10 m. For all sampling sites, we used two Sherman trap types (XLF15 Folding Live Capture, 10.2 × 11.4 × 38.1 cm, and LFA Folding Live Capture Traps, 7.6 × 8.9 × 22.9 cm), to guarantee the capture of all rodent species present in the study sites, including large (e.g., *Rattus rattus*) and small species (e.g., *Mus spretus*) [43]. All traps were baited with a mixture of canned oiled sardines and oat flakes, and cotton was supplied to prevent animal hypothermia [44]. Traps were active for four consecutive nights each season, and checked daily and rebaited if required [44].

For each captured individual, we determined the species, gender, and age using morphometric characteristics (weight, body size, tail size, and hind foot size) [44]. Animal weight and size measures were recorded using a scale with 0.1 g accuracy and a ruler with 0.1 cm accuracy, respectively. All captured animals were individually marked, with different marking approaches between study sites. Two marking designs were used: (1) haircut marking, and (2) color marking. For individuals marked with a haircut, some fur was removed from a specific area(s) of the body (e.g., right/left hind/front paw) to create a unique haircut code. Color marking was achieved with color-coded dot tattoos on the tail (red, blue, green, purple, or black), with a 0.45 × 12 mm syringe, as suggested by Chen and colleagues [45]. Capture and handling procedures followed national and international standards [46], and were authorized by the Portuguese Institute for Nature Conservation and Forests (ICNF) through capture licenses 138/2019/CAPT, 139/2019/CAPT, 09/2020/CAPT, 10/2020/CAPT, 752/2020/CAPT, 753/2020/CAPT, 923/2022/CAPT, 924/2022/CAPT, and 925/2022/CAPT.

2.3. Data Analysis and Statistical Procedure

For each captured individual, we estimated the body condition index, excluding juveniles (using body mass and size metrics; [44]) and pregnant females, to reduce variation from age and breeding effects. Small mammal body condition was assessed through the Scaled Mass Index (SMI), which accounts for the effect of growth and the scaling relationship between body length and body mass (e.g., sexual dimorphism); [47], thus, it isconsidered an effective indicator. SMI was calculated as follows:

$$SMI = M_i \left[\frac{L_0}{L_i} \right]^{b_{SMA}} \quad (1)$$

where M_i represents the small mammal body mass, and L_i the body length of a specific individual. L_0 corresponds to the arithmetic average of body length of all the individuals of the same species of the individual *i*, and b_{SMA} is a scaling exponent regression derived from the major axis (SMA) of the body mass and body length, estimated using the "smatr" R package [48].

Carnivores' and ungulates' abundance was estimated based on camera-trap data. Camera-traps were set in each study area in a 25 camera-grid of 1 × 1 km overlapping the areas wherein small mammal traps were implemented. Cameras were active for 30 days in each area per season, attached to trees or poles at ca. 50 cm high, and no bait was used. Abundance was estimated as the ratio between the number of independent records of each species (i.e., with a minimum of 30 min between consecutive detection) and the total number of days cameras were active. Ectoparasites abundance was estimated as the number of ectoparasites (i.e., number of ticks and fleas) detected in each of the captured individuals.

We used a *t*-test to identify differences in SMI (with a normal distribution) between habitat types (i.e., plantations and control sites) and genders, per species. Since our study areas exhibited different habitat characteristics, we tested the direct impact of habitat type and proportion of vegetation on small mammal SMI (Table 1). For three study areas, we were not able to collect this information, although two-thirds of the data were suitable for studying the effect of these covariates on the small mammal SMI. To account for variable interdependencies and test the effect of the biotic and abiotic candidate factors on small mammal SMI (Table 1) in a more ecologically realistic way, we used a structural equation modelling (SEM) approach [49]. The SEM method is based on a series of general linear models that associate several predictors and response variables in a single causal network [49]. This enables us to identify direct and indirect associations among the multiple predictors to assess their relative significance and identify relationships between those not hypothesized primarily. The tested interrelationships between the candidate factors and small mammals' SMI and within the candidate factors are detailed in results. SEM (using linear regressions, with Gaussian distribution) were produced for small mammals (data from the three species), rodents (wood mouse *A. sylvaticus* and Algerian mouse *M. spretus*) and the greater-white-toothed shrew *C. russula* (Eulipotyphla). We analysed the rodents' data together because *M.spretus* models did not converge, and both species present several similarities in their ecological patterns in some Mediterranean regions, which can shape body condition values (e.g., similar diet composition; [50]). All variables were z-scored [51] prior to analysis using the "standardize" R package [52]. The modelling was performed using the "picewiseSEM" R package [49], and model fit was measured by estimating R^2, i.e., the proportion of variance in the SMI explained by the model. All analyses were implemented using R software, version 4.2.3 [53].

3. Results

We captured 157 individuals from 8080 trap nights across all study areas. We trapped three species of Rodentia: wood mouse (*Apodemus sylvaticus*: N_{total} = 80, 0.99 ind/100 trap nights; $N_{Eucalyptus}$ = 56, 0.69 ind/100 trap nights; N_{native} = 24, 0.30 ind/100 trap nights), Algerian mouse (*Mus spretus*: N_{total} = 47, 0.58 ind/100 trap nights; $N_{Eucalyptus}$ = 34, 0.42 ind/100 trap nights; N_{native} = 13, 0.16 ind/100 trap nights), Cabrera vole (*Microtus cabrerae*: $N_{total/native}$ = 1, 0.01 ind/100 trap nights), and one species of Eulipotyphla (greater-white-toothed shrew *Crocidura russula*: N_{total} = 29, 0.36 ind/100 trap nights; $N_{Eucalyptus}$ = 19, 0.23 ind/100 trap nights; N_{native} = 10, 0.12 ind/100 trap nights). Two-thirds of small mammals were captured in *Eucalyptus* plantations (N = 109), whereas 30% (N = 47) were from control areas. Moreover, males had a higher capture rate (62% of all captures) compared to females (N = 60).

Overall, small mammal SMI did not vary between *Eucalyptus* plantations and control sites ($t_{(86)} = -0.19$, $p = 0.85$), and the same pattern was detected by gender ($t_{(143)} = -1.37$, $p = 0.20$). However, our results exhibited a species-specific variation in SMI between both landcovers. *C. russula* revealed higher SMI values in native areas when compared to *Eucalyptus* stands ($t_{(17)} = -2.41$, $p = 0.03$; Figure 2).

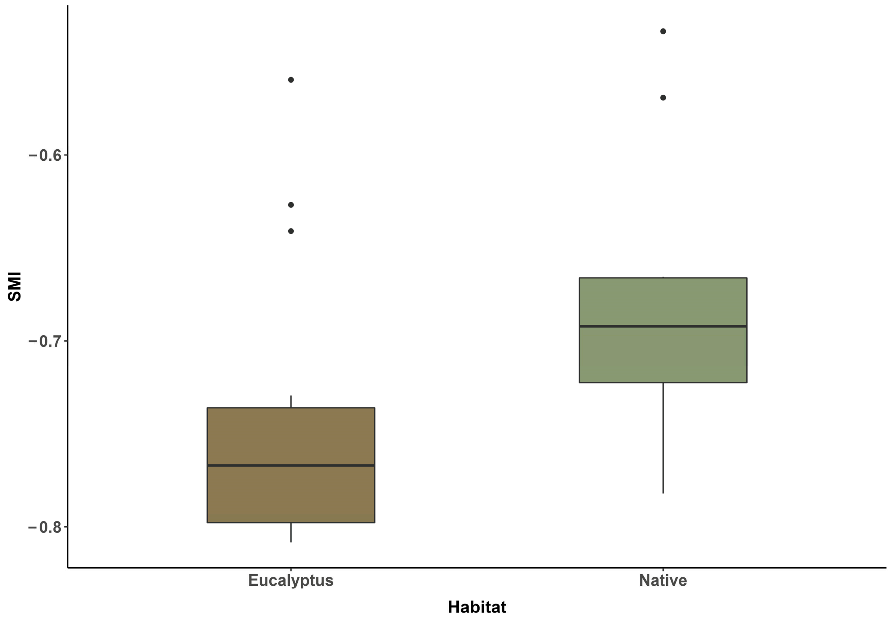

Figure 2. Body condition of *C. russula* per habitat type, estimated using the Scale Mass Index (SMI). SMI values are standardized using z-scores.

C. russula was the only species that exhibited a significant difference in SMI between genders within habitats, with females exhibiting higher values in native areas ($t_{(11)} = -2.40$, $p = 0.03$; Figure 3).

Our SEM analysis revealed a combined direct relationship of several distinct drivers with the overall small mammals' SMI (Figure 4a). The overall model (i.e., the model including the three species) suggested that deer abundance ($\beta = 0.17$, SD = 0.08, $p = 0.03$), precipitation ($\beta = 0.44$, SD = 0.10, $p < 0.001$) and FLII ($\beta = 0.12$, SD = 0.05, $p = 0.02$) promoted higher body condition levels, while wild boar abundance ($\beta = -0.42$, SD = 0.15, $p = 0.01$) had the inverse relationship. None of the remaining variables significantly influenced small mammals' SMI (Figure 4a). We also detected an indirect link between some drivers with small mammals' SMI. High shrub cover and *Eucalyptus* plantations indirectly decrease small mammals' SMI, as they negatively affect the forest landscape integrity index ($\beta = -5.90$, SD = 1.30, $p < 0.001$; Figure S1a) and deer abundance ($\beta = -0.36$, SD = 0.10, $p < 0.001$). Inversely, native habitats indirectly promote animals' SMI by increasing deer abundance ($\beta = 0.32$, SD = 0.10, $p = 0.00$) (Figure S1a). The SEM explained a moderate amount of the variance in small mammals' body condition across our study sites ($R^2 = 0.27$). Additionally, the goodness-of-fit measures (the comparative fit index (CFI) = 0.89, and the standardized root mean square residual (SRMR) = 0.06) indicated a suitable fit.

The rodent model showed that wood mouse and Algerian mouse SMI is higher in areas with higher precipitation ($\beta = 0.39$, SD = 0.10, $p = 0.00$), while wild boar abundance exhibited a negative relationship with rodents' SMI ($\beta = -0.41$, SD = 0.15, $p = 0.01$; Figure 4b). This model explained a moderate amount of variance ($R^2 = 0.26$; Figure 4b). We could not detect a positive or negative indirect relationship for most of the tested variables on rodents' SMI. However, our data showed that in areas with higher wild boar abundance, carnivores were less common ($\beta = -0.93$, SD = 0.35, $p = 0.01$; Figure S1b). This might indicate that carnivore abundance could indirectly promote rodents' SMI. No other significant relationships were detected between independent variables (see Supplementary Material).

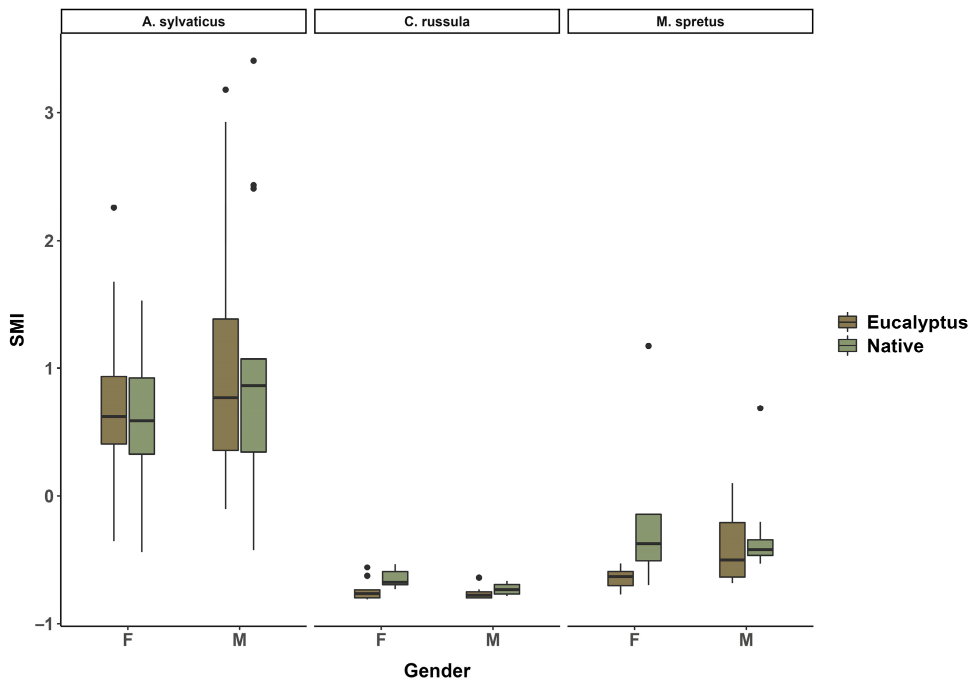

Figure 3. Species-specific body condition per gender and habitat type, estimated using the Scale Mass Index (SMI). SMI values are standardized using z-scores.

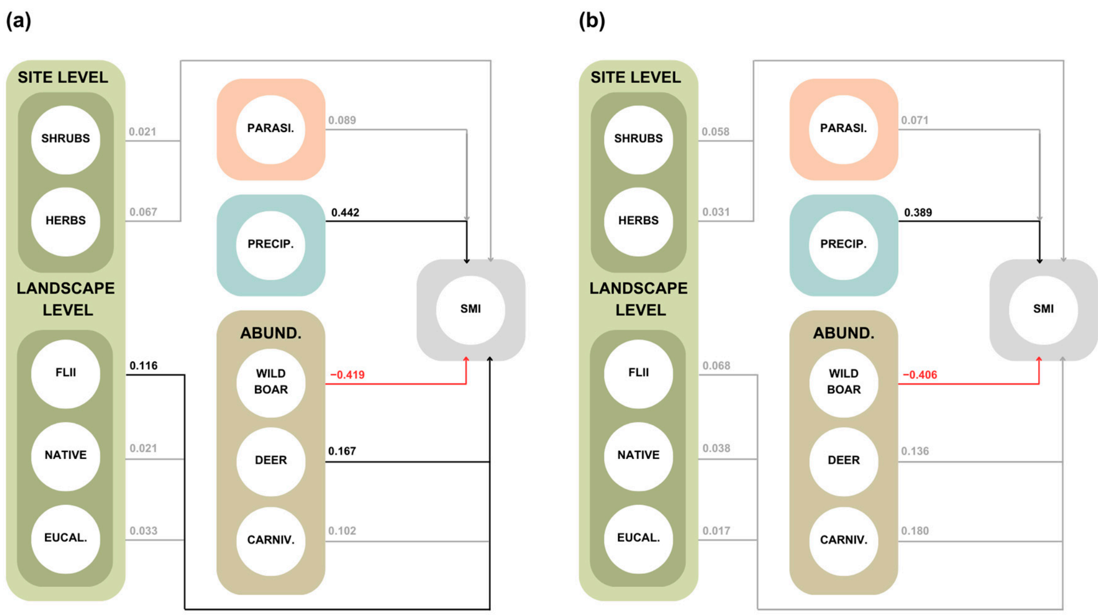

Figure 4. Results of SEM highlighting the relationships between (**a**) small mammals' overall body condition (SMI; gray box), and (**b**) rodent SMI (gray box) and the tested factors. Habitat features (green box) are divided into variables, representing the site level (1 m buffer) and landscape level (50 m buffer); Interspecific relationships (brown box) include the abundances of wild boar, deer, and carnivores; Weather conditions (blue box) are represented by precipitation; and health condition (pink box) is represented by ectoparasite abundance. Black and red arrows represent significant relationships, while light gray arrows are non-significant. Positive interactions are represented with black values and negative interactions with red values. The values are near the influential variable, and the arrow direction indicates the affected variable.

Ultimately, for the white-toothed shrew, we were not able to determine the effect of the selected variables on the SMI due to the reduced number of samples (i.e., the models did not converge).

4. Discussion

Our results demonstrate that small mammals' body condition response to *Eucalyptus* plantations is species-specific. Although the overall community outcomes do not indicate any significant effect of habitat type, *C. russula* had better individual conditions in native habitats. This result contradicts those obtained by [12], where no differences were detected in small mammal body condition between *Eucalyptus* stands and native woodland. This difference may be related to the greater spatial and temporal scale of our study, which contributes to a better perception of the relationship of this type of altered landscape to the health of the small mammal communities. The literature shows that *Eucalyptus* plantations tend to have an adverse impact on the diversity and abundance of the native understory [7,54]. Moreover, disturbance varies throughout the production cycle and with management intensity [7,16]. The combined effect of disturbance and limited understory vegetation (and thus, reduced food and shelter and higher predation risks [31]) may explain the lower health conditions of individuals inhabiting these altered landscapes. However, this pattern does not hold for the wood mouse, on which plantations seem to have a negligible effect. This rodent is a bigger species, and has wider territories than the other two studied species [55]. Such characteristics may allow the wood mouse to move in a wider radius and find resources farther away, which may attenuate the effect of plantations' resource shortages on its body condition.

Additionally, *C. russula* females exhibited higher values of SMI in native areas when compared to *Eucalyptus* plantations. This species presents a female-biased dispersal, mostly related to reproductive opportunities [56,57], although with typically short ranges [58]. The abundance of this species is positively correlated with the understory vegetation [31], which may lead to greater breeding success (e.g., females may have more options due to the higher density of individuals). *Eucalyptus* plantations' management often leads to a drastic understory reduction [59], which may result in a smaller abundance and, consequently, mating choices. In such a context, *C. russula* females inhabiting these landscapes must have greater dispersal movements to increase reproductive success, thus leading to a lesser body condition. Another reason that may explain this result could be linked to the fact that the body condition index of reproducing females changes with their reproductive status, since after birth, females experience weight loss [60]. Hence, in unsuitable habitats such as exotic plantations, this species might have a slower recovery due to the lack of optimal conditions to thrive (e.g., food availability).

The SEM suggested a lack of a direct relationship of *Eucalyptus* with small mammals' body condition, a fact that is probably linked to the dominance of the wood mouse in our dataset. Such results do not support our hypothesis that plantations have a direct deleterious relationship with small mammals' body condition. However, our results support the hypothesis that forest landscape integrity index (FLII), ungulate abundances, and climatic conditions directly relate to small mammal body conditions, whereas rodent SMI is related only to climatic conditions and wild boar abundance.

Well-conserved forests (e.g., those with high forest connectivity and low degrees of human pressure) have been previously described as a key factor in small mammals' abundance [37,61], providing suitable conditions and resources for small mammals to thrive. The sampled *Eucalyptus* plantations showed a strong human presence (e.g., due to forestry activities), revealing impacts even on generalist and disturbance-resilient species (e.g., red fox and wild boar; [11,62]). Therefore, it is expected that regions with higher FLII values (i.e., native areas) provide better environmental contexts (i.e., more resources and less disturbance), which may enhance small mammal populations' health conditions.

Precipitation revealed a strong positive influence on SMI, i.e., animals inhabiting areas with a higher average monthly precipitation had better body condition values. Higher rain levels increase water availability (a limiting environmental factor in Mediterranean regions; [63]), thus promoting vegetation regeneration [64]. This is the main determinant of primary production, a process often associated with species body size [65]. Higher precipitation values may increase food availability by promoting shrubs that produce fruits (e.g., *Myrtus* sp.) and attract pollinators [66], which are often a food source for rodents and insectivores [50,67]. Vegetation development due to water availability development [32] will also provide better refuge conditions that will limit predation risk and disturbance effects. Both factors will concur to promote suitable conditions for small mammals to achieve better health conditions. Nevertheless, our model did not reveal a link between precipitation and the understory (i.e., shrubs and herbs), most likely due to the different scales of variables (e.g., precipitation–1 km resolution, and understory–field observation).

We also detected a positive relationship between deer abundance and small mammal body condition. This pattern contradicts our initial expectation, since small mammals frequently avoid areas with higher deer abundances due to trampling and reduction in vegetation [68]. Thus, small mammals inhabiting areas with higher deer abundance may be subject to higher food competition and disturbance that will induce lower body conditions. This unexpected result may be related to two distinct factors. High deer densities may be a suitable ally against shrub encroachment [69], which facilitates access to food (by assuring landscape heterogeneity) that can promote small mammals' density [70,71] or increase the body condition of individuals. This mechanistic link is confirmed by the negative relationship between shrub cover and deer abundance (i.e., areas hosting more deer have less shrub cover). Another possible explanation may be related to the relationship between the small mammals' parasitic load and deer densities. In Italy and Slovakia, Cagnacci and colleagues [72] revealed that the parasites feeding on rodents, after an initial increase, reached a peak and then decreased with increasing deer density. As the authors described, this factor could be attributed to the dilution effect hypothesis, that is, non-competent hosts (deer) divert ticks from competent hosts (rodents), thus decreasing the prevalence of parasites on small mammals, increasing their body condition. Nevertheless, we were not able to determine the deer parasite load to test this hypothesis. This result needs to be carefully interpreted, since the spatial scale of sampling for the two groups differed; thus, the measures of SMI and deer abundance may not necessarily match (i.e., the relationship of SMI to deer abundance might have been very different for other capture grids in the same forest patch).

Inversely, we detected a negative relationship between wild boar abundance and the small mammal SMI in our study sites. This negative trend has already been observed elsewhere in Europe [73–75]. It is documented that the wild boar may focus their subterraneous foraging efforts near small mammals' burrows [75]. Moreover, wild boar rooting disturbs soil dynamics and habitat vegetation [38], reducing food availability and refuge. Such disturbances will induce a decrease in small mammals' abundance [73], and ultimately may lead to a reduction in small mammals' health conditions.

We could not confirm any direct link between *Eucalyptus* plantations and the body conditions of small mammals. Several studies have produced contradictory results regarding the effects of the presence of *Eucalyptus* plantations on wildlife [7,74]. Moreover, our findings are in line with Iberian studies that report a lack of evidence of the typically described direct negative effect of *Eucalyptus* on several mammalian taxa [18,22,33]. However, some indirect relationships may be deducted. *Eucalyptus* plantations have a negative influence on deer abundance, which, on the other hand, promotes small mammals' abundance. Therefore, by affecting deer abundance, plantations are indirectly reducing small mammals' body condition. This indirect relationship was captured by the inter-habitat comparison that clearly revealed a difference between SMI values in *Eucalyptus* plantations and native areas for two of the three studied species. SMI seems to be driven by forest connectivity (i.e., FLII), climatic conditions, and interspecific relationships.

Other drivers related to kinship levels [75], low food availability [76], endoparasite prevalence [77], or social rank [78], among others could also influence individual body conditions. However, no data were available for the studied small mammal populations regarding those factors, and thus no inferences could be made; however, these influences should also be considered in future studies.

5. Conclusions

Our findings provide evidence that small mammals' competitors, landscape integrity, and climatic conditions affect the health condition of the studied species. The first two factors are intrinsically linked to the management of *Eucalyptus* plantations. The forestry activities in these landscapes may jeopardize the integrity and connectivity of the landscape, namely by reducing the understory that is linked to functional small mammal communities [31]. Therefore, we conclude that the maintenance of the landscape integrity (e.g., by preserving native patches within plantations, somehow connected) and a reduction in the abundance of competitors (e.g., wild boar) may favor the body condition of small mammals, especially during the drier season, as due to climate change, the Mediterranean basin will become increasingly dry and warmer [79].

Given the existing link between body mass (and consequently, body condition) and reproductive success [80,81], it is possible that *Eucalyptus* plantations may be affecting the reproduction and life expectancy of *C. russula* populations (as they have a negative impact on the species' body condition). Thus, the implementation of a management regime that enhances forest integrity and food resources (e.g., conservation of native patches within plantations, which can buffer the deterioration of climatic conditions due to increased aridity in Iberia; [82]) may contribute to promoting small mammal communities' health.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su16010128/s1, Figure S1: Results of SEM highlighting the indirect relationships between (a) tested factors affecting small mammals' overall body condition (SMI), and (b) tested factors affecting rodent SMI. Habitat features (green box) are divided into variables representing the site level (1 m buffer) and landscape level (50 m buffer); Interspecific relationships (brown box) include the abundances of wild boar, deer, and carnivores; Weather conditions (blue box) are represented by precipitation and health condition (pink box) is represented by ectoparasite abundance. Black and red arrows represent significant relationships, while light gray arrows are non-significant. Positive interactions are represented with black values and negative interactions with red values. The values are near the influential variable, and the arrow direction indicates the affected variable.; Table S1: Small mammal capture period, number of traps used, and trap scheme (grid or line) for each study area.

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