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Influence of Habitat and Food Resource Availability on Common Raven Nest Site Selection and Reproductive Success in Mediterranean Forests

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Simple Summary: A central goal of life history studies is documenting traits related to reproduction. Bird nest selection is influenced by the abundance of food resources and determines reproductive success. In Mediterranean forests threatened by human influences and by global change, studies of Common ravens are limited, despite this generalist species being able to exert strong pressure on targeted species such as the Spur-thighed tortoise. Our study demonstrated that (i) tree height, the absence of vegetation cover and the abundance of tortoises influences the selection of raven nest sites; (ii) that the spatial distribution of raven nests is clustered; and (iii) that young tortoise abundance plays a part in raven reproductive success. We discuss in depth how the key structural elements and resources of the forest might affect the interaction between the population dynamics of Common ravens and sensitive species on which they prey. Bearing in mind the positive increase in the number and distributional range of Common ravens, we recommended conducting long-term studies of reproductive parameters and appropriate conservation actions.

Abstract: Bird nest selection in forests can be influenced by the composition of key structural elements and resources. This has important consequences in terms of species population dynamics since it can determine reproduction success. Here, we assessed Common raven nest-site selection and reproductive success, and how these might be determined by foraging behavior and habitat structure. A previously documented breeding raven population that exerts high predation pressure on young Spur-thighed tortoises (*Testudo graeca*) in a Mediterranean forest was monitored. Generalized linear mixed models were performed to determine the singularities of the trees with nests and the drivers of reproductive success of breeding pairs of ravens. The results showed a high density of breeding pairs in the study area (0.8 pairs/km^2), which selected taller trees in areas with higher bare ground cover and a high density of tortoises for nesting. Nests were spatially aggregated; breeding pairs occupied smaller territories and intraspecific competition seemed relaxed, reflecting the abundance of food resources. Most breeding pairs occasionally predated on young tortoises. Tortoises seem to play a part in raven reproductive success in our study area, which might be associated with the availability/catchability of young tortoises. The study illustrates that Spur-thighed tortoise distribution and abundance plays a role in the breeding behavior of ravens and is mediated by habitat structure. Understanding the drivers of nest-site selection and the breeding behavior of ravens is pivotal to implementing appropriate habitat management and conservation strategies across their distribution range, particularly in areas where ravens potentially affect threatened species.

Keywords: tree height; bare ground cover; Spur-thighed tortoise density; predation; conservation

1. Introduction

Bird nest-site selection in forests can be influenced by the availability of suitable conditions, the abundance of food resources being indicated as the most important factor [1,2].

For a variety of forest nesting birds and raptors, large wide-trunk trees of mature forests—with open understory, high stem and foliage—are preferred for nest-building [3–5] because they provide a greater accessibility to and availability of food resources [6]. In addition, trees in areas affected by a shortage of food resources—especially at the beginning of the breeding season—and that are favorable for predators are related to breeding failure and therefore tend to be avoided for bird nesting [7]. Therefore, the selection of particular habitats for nesting might be associated with reproductive success and it could be hypothesized that if nest-site selection is a heritable trait, then natural selection should favor individuals that choose nest sites that confer a greater reproductive success [8].

The Common raven *Corvus corax* is considered both as an opportunistic species, which appears to have a generalist diet at the population level [9], and as a forest specialist well adapted to exploiting forest food resources (e.g., predation on forest birds [10]). Their feeding habits may gather at local food resources showing different degrees of site fidelity for varying lengths of time depending on whether they are single birds (highly vagrant and with lower site fidelity) or territorial breeding pairs [11,12]. They are mainly omnivorous, and while they are considered predators, they are also quite dependent on carrion and resources from rubbish dumps [11,13]. Nest-site selection might therefore be determined by a pair's specific foraging behavior [8,14,15], which in turn is related to the availability of food resources. For instance, cereals will dominate in raven diet in intensive agricultural areas [16], while water birds and their eggs will predominate in marshland [17] and rats and rabbits on certain islands [18,19]. In addition, certain anthropogenic features such as roads, that provide an easy and dependable source of road-kill and increase the visibility of prey, might confer an advantage in terms of reproductive success if the nest is close to them [20,21]. On the other hand, in natural ecosystems, ravens naturally breed in trees [15,21,22] and prefer high trees, which therefore suggests that forest structure may be a key feature in raven breeding behavior [8,14,15].

Generally, works that investigate ravens' choice of forest nesting sites and their reproductive success are limited [8,14], and there are few studies concerning the ways in which ravens adapt to exploit forest food resources [10]. In Mediterranean forests, e.g., cork oak forests, which have traditionally been subject to human exploitation through forestry activities [23] but have managed to maintain great biodiversity [24–27], studies of raven nests are lacking. Maamora forest, a cork oak forest in northern Morocco, is the largest single stand of cork oak in the world [28] and is an area with one of the highest densities of Common raven breeding pairs (0.8 breeding pairs/km^2; [29]). In a previous study, high predation on hatchlings and young tortoises (<75 mm carapace length) by Common ravens has been documented in a protected area of Maamora [29] that has the highest density of Spur-thighed tortoises documented to date (23 indiv/0.01 km^2 [30]). Predation risk was mediated by vegetation structure and proximity to Common raven perches, and decreased in areas with lower bare ground cover and longer distances to perches. However, the importance of tortoises in the reproductive behavior in breeding pairs of ravens has been not documented, despite breeding pairs showing a higher degree of specific foraging when nesting [12]. Given the potential significance of young tortoises as resources for ravens, here we assessed the relative weighting of habitat features and tortoise abundance on nest-site selection and reproductive success of the Common raven. Within this context, our specific objectives were: (i) to identify the factors (habitat characteristics and food availability) that might determine the selection of nest-sites by breeding pairs of raven; (ii) to explore the spatial distribution of raven nests; and (iii) to identify the drivers (habitat characteristics and food availability) that determine their reproductive success. Our results are also discussed from the perspective of the potential risk Common ravens pose to populations of Spur-thighed tortoise, a threatened species, and the application of our findings in management strategies for this generalist predator.

2. Materials and Methods

2.1. Study Area

The study was conducted in an area of low elevation (72–185 m a.s.l.) and sandy soil within the Maamora forest (northwest Morocco; 34°02′54.19″ N, 6°27′19.24″ W). The climate is Mediterranean, with hot, dry summers, and the annual range of rainfall is between 300 and 500 mm. The Maamora forest is dominated by cork oak trees, *Quercus suber,* with scattered endemic wild pear, *Pyrus mamorensis,* wild olive *Olea europaea*, green olive *Phyllirea latifolia* and mastic *Pistacia lentiscus,* and a sparse understory comprising bush and scrub species such as Mediterranean brooms *Genista linifolia, Cytisus arboreus, Stauracanthus genistoides*, dwarf palm *Chamaerops humilis*, French lavender *Lavandula stoechas*, sage-leaved rockrose *Cistus salviifolius, Halinium halimifolium* and *Thymelaea lythroides*. A dense cork oak forest (more than 200 trees/ha) covers only 4110 ha, whereas 54,000 ha are classified as medium-density and open forest [31].

The study itself was conducted on private protected land (2500 ha) dominated by 80–198 cork oak trees/ha (see Figure 1). It is characterized by a considerable and varied undergrowth (i.e., high species richness and cover) when compared with other unprotected sites in Maamora. There are high densities and a diversity of breeding forest raptors (4 breeding pairs/km^2 pertaining to seven species including Booted eagle *Hieraaetus pennatus* and Long-legged buzzard *Buteo rufinus*; A. Segura, unpublished data) and Barbary partridge *Alectoris barbara*, and a low density of small carnivores (e.g., 0.16–0.36 individuals/km^2 of Red fox *Vulpes vulpes*; A. Segura, unpublished data). It has a good road network and the closest village is 5 km away (Sidi bou Kalkal, 7200 inhabitants).
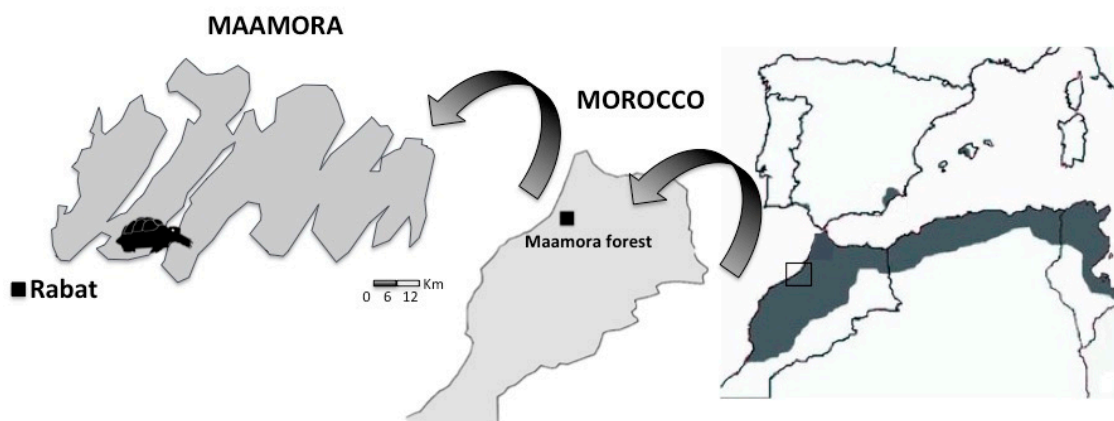

Figure 1. The location of the study area (represented by the tortoise) in Maamora forest, northwestern Morocco, close to Rabat city. The distribution range of *Testudo graeca* according to Giménez et al. [32] is also shown (dark gray).

Starting in 2018, three sampling seasons were carried out (in spring), and the mean average temperature of the period March–May was 15.5, 16.6 and 18.6 °C for 2018, 2019 and 2020, respectively.

2.2. On the Study Species

The Common raven is a territorial and social species. Breeding pairs are long-term monogamous and defend a territory, often larger than 10 km^2, all year round [33]. Young ravens join non-breeder groups for foraging and roosting after they become independent from their parents during their first summer [7,34]. Non-breeder groups can be highly vagrant or can show preferences for certain foraging techniques and sites [35,36]. Breeding pairs (mature at 3–4 years) produce only one brood of 3–4 fledglings per year and they may use a particular nest site for several years or change site each year depending on the availability of nest sites within the nesting range as well as predator density [37]. Nests are built in trees, on crags and in gorges, but also in human-made structures including buildings and bridges, among others.

Despite, during a long period of persecution, ravens almost becoming extinct in the US and central Europe in the late nineteenth/early twentieth century [38], raven populations have increased dramatically over the past several years throughout the US, Europe and North Africa [39] due to the growing human activity footprint and its associated anthropogenic food subsidies, as well as the species having been afforded protection (EU bird directive in Europe and federal laws in the US). However, recent increases in raven populations have threatened some vulnerable species, including Desert tortoises *Gopherus agasizzii*, Spur-thighed tortoises, Sandhill crane *Antigone canadensis*, Marbled Murrelet *Brachyrampus marmoratus*, Snowy plover *Charadrius nivosus* and Least Terns *Sternulla antillarum* [29,40,41]. Currently, management techniques, such as lethal removal, behavioral modification and habitat modification, have been employed to protect threatened and endangered species from raven predation in certain states in the US [21] but in the Maamora forest, no control measures have as yet been implemented.

2.3. Sampling Common Ravens and Tortoises

Common raven nests were sought out across the study area each spring (March to May) between 2019 and 2020. Nests were visited approximately once a week after an adult was observed in an incubation position or young could be seen in the nest. The location of the active nests and the number of breeding pairs were recorded, along with their reproductive success, quantified as the number of fledglings that left the nest between May and early June. Raven behavior was observed at a distance of 30 m from the nest, from dawn till 11.00, once every 15 days throughout the breeding season in order to spot ravens caching young tortoises. In addition, in 2018 an opportunistic survey provided the same information, but only for four nests.

Tortoise population density in the study area was estimated following the methodology described in Segura and Acevedo [30]. Briefly, population densities were estimated in four zones using a capture-recapture approach that assumed both a closed population and the fact that adult tortoises are highly philopatric and remain localized during breeding. The study populations were surveyed for 10 days in both the 2019 and the 2020 breeding seasons, with areas of 12/17 ha, respectively, being covered, resulting in average densities of 37.1, 24.7, 21.8 and 15.9 indiv/0.01 km^2. Because breeding pairs spend 90% of their time within 400 m of their nest [42], the area within a 400 m radius of each of nest site was intensively surveyed in order to detect dead tortoises with signs compatible with predation by Common ravens (recent holes in the carapace or plastron; see [29]). The surveys to detect dead tortoises were carried out on two days each month throughout the raven breeding season in both 2019 and 2020 (for further details see [29]). Each dead individual was georeferenced using a GPS and the carapace length (CL; mm) was measured using a vernier caliper (accuracy ±1 mm). All predated tortoises were removed from the field on each survey day to avoid double counts. These data were used to derive the number of dead tortoises attributable to each nest.

2.4. Environmental Characteristics and Anthropogenic Influence

Each Common raven nest was georeferenced and the height (H; m) and diameter at breast height (DBH; m) of the tree in which it was located were measured. The density of mature trees (>30 cm DBH) in the 20 m radius buffer of each nest was also estimated [43], measurements being made in the year each nest was monitored but after the young had fledged. We also estimated the cover of scrub and bare ground (percentage) and quantified the scrub richness in the 200 m radius buffer around each tree [8]. To measure anthropogenic influence on foraging behavior, we estimated the distance from the nest to the nearest road using ArcGIS [44]. Finally, the shortest distance to the nearest conspecific nest was estimated, again with ArcGIS, to characterize the spatial distribution of the nests.

2.5. Modeling Nest Site Selection and Reproductive Success

To determine nest-site selection, we randomly sampled 70 trees without a raven nest. They were separated by at least 200 m [8] and the same environmental and anthropogenic variables ascertained for those trees with nests were estimated. To examine collinearity among predictors, the Variance Inflation Factor (VIF) was calculated prior to modeling. The singularities of the trees with a nest were identified using generalized linear mixed models, with a binomial distribution and logit link function (response variable: presence or absence of nest). The most parsimonious model was selected using a forward stepwise procedure based on Akaike Information Criteria (AIC, [45]). Nest ID was considered as a random effect factor since the same nest was used in more than one year, and tree height, DBH, density of mature trees, scrub and bare ground cover, scrub richness, distance to road and tortoise density were considered covariates.

To examine reproductive success we performed generalized linear mixed models (response variable: number of successful fledglings), in this case with a negative binomial distribution and logarithmic link function. Nest ID and year were used as random effect factors and number of young tortoises predated, scrub and bare ground cover, scrub richness and distance to road as covariates. In both cases, the most parsimonious model was selected using a forward stepwise procedure based on AIC. All statistical analyses were performed using R 3.6.1 software [46].

3. Results

3.1. Tree Selection for Nesting

All nests ($n = 41$) in all three years were located in cork oak trees ($n = 4$ in 2018, $n = 19$ in 2019 and $n = 18$ in 2020). Some nests were reused between seasons ($n = 6$), but new ones were also built each year. All of them were located in the top part of the tree. Interestingly, there was one area where six nests in 2019 and four nests in 2020 were located within less than 200 m of each other (see Figure 2). The trees with and without nests were characterized by heights of 12.2 ± (SD) 1.7 m and 9 ± 1.7 m, respectively, and bare ground cover of 10 ± 7.3 and 3.9 ± 5.6%, respectively (see also Table 1 for differences between years and nest habitat features).

Table 1. Characteristics of trees with and without (random tree) Common raven *Corvus corax* nests: height (H) and diameter at breast height (DBH), density of mature trees (>30 cm DBH within a radius of 15 m), scrub and bare ground cover in 200 m radius, nearest road distance and nearest conspecific nest distance in the study area for the three seasons included in this study. Finally, descriptive results concerning raven and tortoise sampling are also provided. When possible, standard deviations for each parameter are included.

|	2018	2019	2020	Random Tree
Vegetation				
H (m)	12 ± 1	12.4 ± 1.7	12.4 ± 1.8	9 ± 1.7
DBH (cm)	96.3 ± 27.5	79.9 ± 27.2	70.9 ± 19.9	54 ± 26
Mature tree density	3.8 ± 1.5	3.8 ± 1.7	3.8 ± 1.3	2.7 ± 1.7
Scrub cover (%)	23.7 ± 10.3	30.5 ± 19.1	26.9 ± 20.6	41.8 ± 30.8
Bare ground cover (%)	13.7 ± 9.4	10.3 ± 8.7	8.6 ± 6.6	3.9 ± 5.6
Scrub richness	3.5 ± 1.3	2.6 ± 1.4	2.6 ± 1.4	2.2 ± 1.5
Distance to road (m)	48 ± 36.7	78.4 ± +60.1	76.1 ± 59.5	184.7 ± 177.2
Nest conspecific distance (m)		340 ± 225	325 ± 200	
Ravens				
Nests	4	19	18	
Breeding pairs	4	19	16	
Fledglings	3.5 ± 0.6 ($n = 14$)	2.6 ± 0.8 ($n = 50$)	2 ± 1.1 ($n = 36$)	
Predated tortoises	102	125	119	0
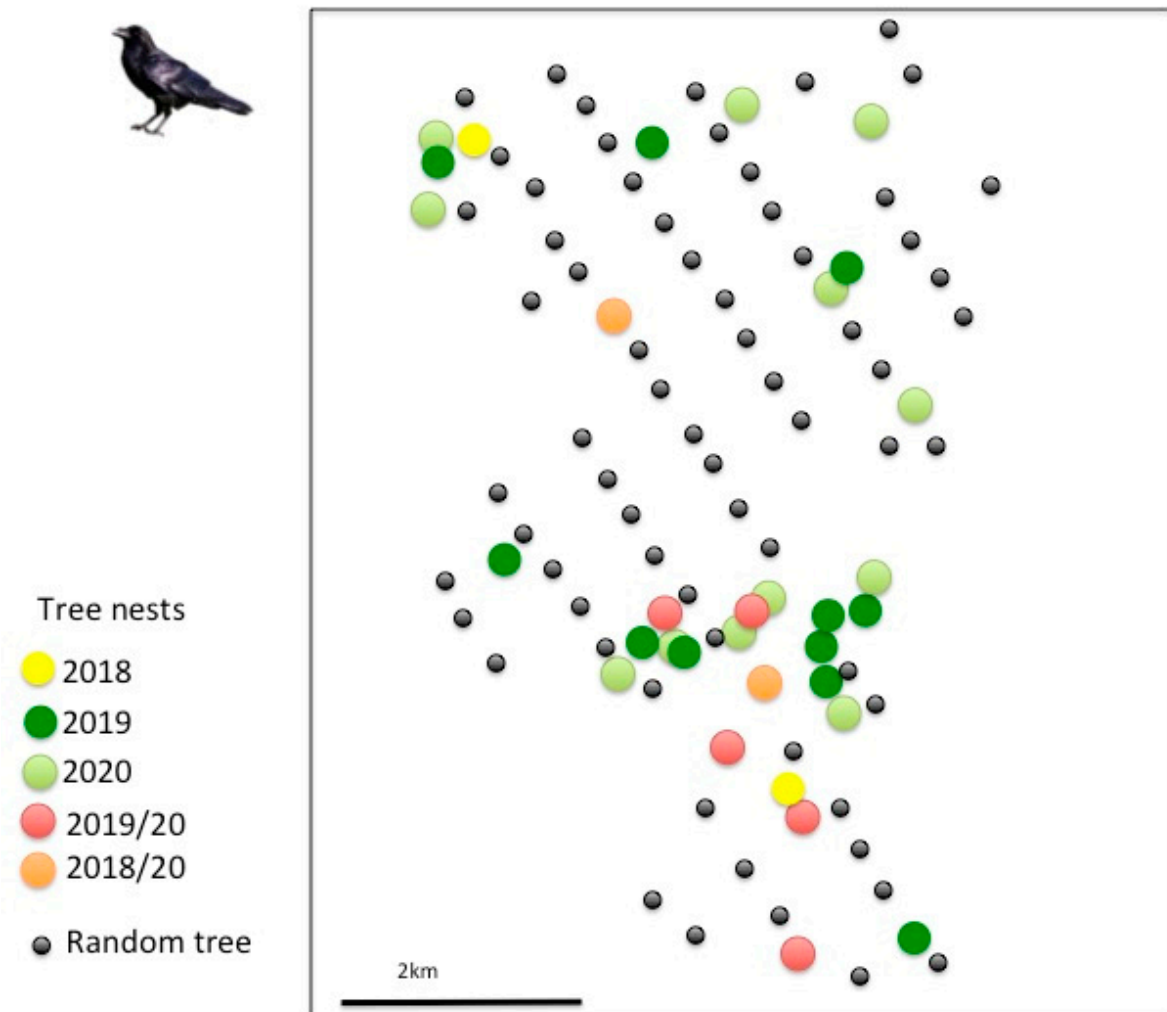
Figure 2. Location of trees with nests of Common raven *Corvus corax* within the study area by breeding season (*n*= 4, *n* = 19 and *n* = 18 in 2018, 2019 and 2020, respectively). A distinction is made between trees used for nesting in only one season (in yellow for 2018, dark green for 2019 and light green for 2020, respectively), those used in more than one season (in red those occupied in 2019 and 2020 and in orange those used in 2018, 2019 and 2020) and randomly selected trees without nests (in black, random tree).

VIF analyses did not exclude any predictor (VIF < 3) and therefore all were considered in the models. The final model for nest selection included H, bare ground cover and tortoise density (see Table 2). The probability of locating a raven nest is positively related to H, bare ground around the tree and the density of tortoises in the area.

Table 2. Statistical parameters of the generalized linear mixed model used to explain raven nest-site selection. See electronic Supplementary Materials Table S1 for model selection.

Predictors	Estimate	Std Error	Z Value	*p* Value
Intercept	−704.81	42.246	−16.68	<0.05
Height	45.91	2.952	15.55	<0.05
Bare ground cover	470.45	28.922	16.27	<0.05
Tortoise density	66.04	4.648	14.21	<0.05

3.2. Reproductive Success and Predation of Young Tortoises

On average in 2019 and 2020 when all the study area was surveyed, there were 0.8 raven breeding pairs/km². Most of the breeding pairs were successful (95%), rearing

2.4 ± 1 fledglings (*n* = 100) per breeding pair. Although in 2019 all the broods succeeded, in 2020 two broods failed completely likely due to the severe climatic conditions that year (strong rain and wind).

Over the three breeding seasons, 36 breeding pairs of raven were observed killing and consuming young Spur-thighed tortoises, with evidence of raven predation being found in 346 hatchlings and juveniles (signs of recent predation, fresh blood and flesh on the carapace). No significant differences were found between 2019 and 2020 (X^2 = 10.3, *p* = 0.248, *n* = 346), when, respectively, 125 and 119 young tortoises were predated and consumed by breeding pairs. Most of the breeding pairs (92%) fed on young tortoises, but only 10% consumed over 30 individuals per breeding pair. Of particular note is one pair that consumed 75, 33 and 64 young tortoises per season in 2018, 2019 and 2020, respectively (see Figure 3). The young tortoises predated by Common ravens ranged from 30 to 75 mm CL, mostly 41–60 mm (see Supplementary Materials Figure S1), and were located within 1 to 120 m of a raven nest.
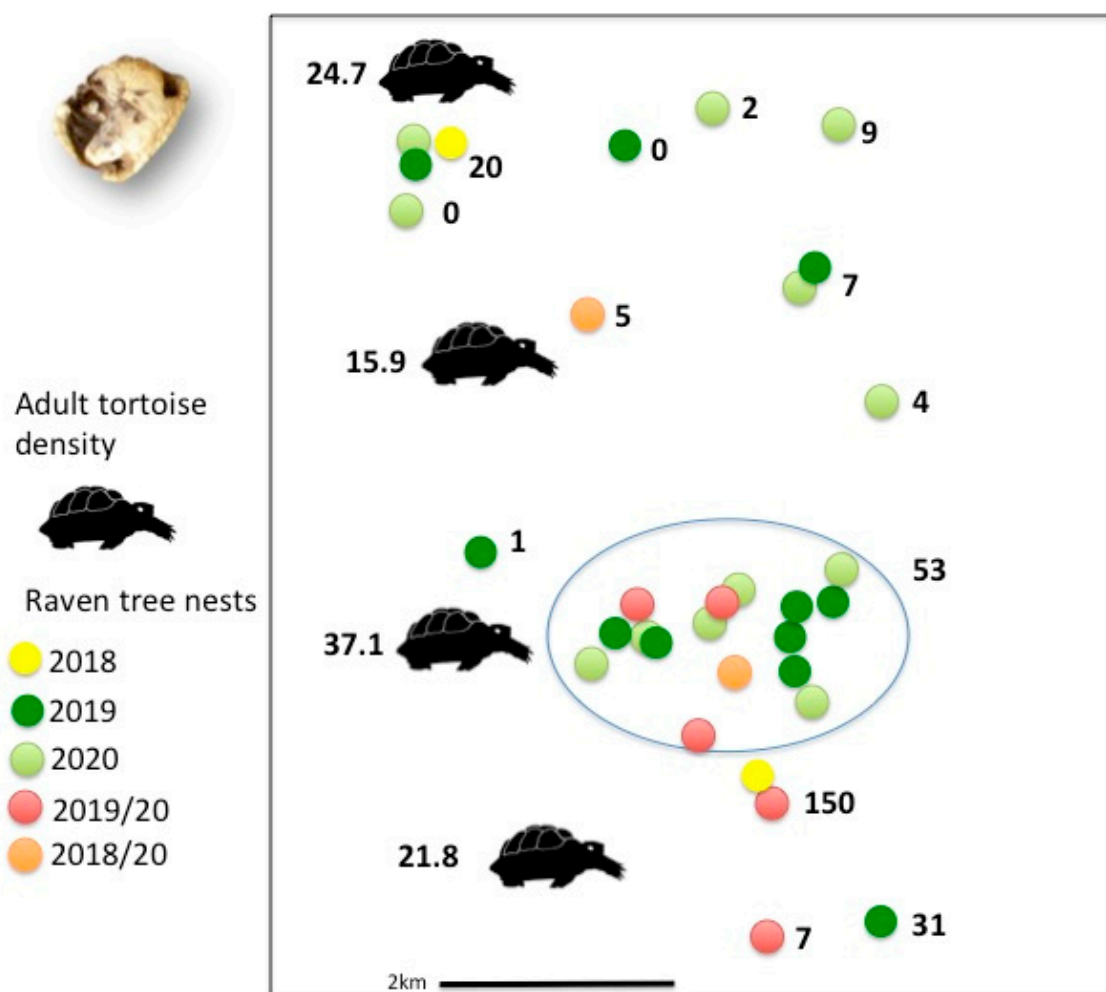

Figure 3. Spatial distribution of the number of predated young Spur-thighed tortoise *Testudo graeca* surrounding raven nests. The nests are differentiated by color as follows: in yellow, 2018; in dark green, 2019; in light green, 2020; those occupied in both 2019 and 2020, in red; and those occupied in all three years, in orange. The adult tortoise density (indiv/0.01 km^2) in the study area is also shown. The blue ellipse highlights the aggregation of nests.

The final model of raven reproductive success only included the abundance of predated young tortoises (Z = 2.048, *p* < 0.05), i.e., the higher the number of predated tortoises, the greater the reproductive success of the raven.

4. Discussion

4.1. Common Raven Nest Site Selection

Common ravens select mature forests characterized by larger and taller trees for nesting due to the optimized breeding conditions this provides, namely more appropriate branch structure to hold the nest, an easier approach for the raven itself and a higher visibility for spotting potentially approaching terrestrial or aerial predators [8,14,15,47]. Maamora forest is not an exception, and breeding pairs selected taller trees and trees located in areas with more bare ground cover and a higher density of tortoises, the latter possibly offering a high number of detectable tortoise juveniles [29]. Other studies have documented the distance to the road as a factor related to nest-site selection; shorter distances being preferred for nesting [48] because they offer a higher availability of food resources, which may also be related to higher reproductive rates [49]. Nevertheless, acknowledging that in our study area all the nests were located close to roads, this factor does not seem to play a part in nest-site selection, likely due to the fact that it is private land where the passage of vehicles is quite reduced. Overall, our results suggest that nest-site selection can be explained by a hierarchical process whereby ravens select sites with suitable tree characteristics in areas where tortoises are abundant and detectable. Tortoises, therefore, could play an important role in determining the selection of breeding sites supporting the notion that tortoises are a significant resource for ravens in the study area. However, studies of raven diets are required to conclusively demonstrate their preference for tortoises among the other, alternative preys (amphibians, bird eggs or small mammals) that are also abundant in this Mediterranean forest [38]. Indeed, previous studies worldwide have shown that the richness of species found in the diet of ravens is mainly related to the biomass of the different resources [18,19,38,50], with no evidence of resource selection reported. Whether tortoises are a preferred food resource in the study area or not is worthy of further study.

Territory size and breeding density are strongly connected with food availability and intraspecific competition in ravens [51], i.e., where food resources are abundant the species occupies smaller territories and intraspecific competition is thus relaxed [7]. This was observed in Maamora, where densities of raven breeding pairs were high (0.8 pairs/km^2) and the average distance between Common raven occupied territories was short (333 m). Indeed, the territories of some breeding pairs even overlapped (<200 m). This fact might provide evidence that in our study area ravens did not randomly occupy the forest, which might be associated with the high food resource availability, an idea that is reinforced by the high values of raven reproductive success that have been found [8,19]. In addition, several nests were used in different breeding seasons and others were in locations close to a previous nest (<30 m from previous year), showing an undeniable preference for certain areas. Nevertheless, some studies state that there is no relationship between the success of the nesting attempt and the re-use of the nest the following season [37]. Individual identification and recognition of ravens would make a valuable contribution to future studies in this respect.

In addition to the acquisition of a better nest territory, temperature and rainfall might indirectly affect food resources and the timing of nesting, which will also play its part in nest-site selection. Further long-term monitoring studies—which will allow the effect of climatic variables to be taken into account—at the landscape scale are required to reveal additional factors that could potentially explain nest-site selection and other related patterns (e.g., nest fidelity and nest timing) in Maamora and in other Mediterranean forests.

4.2. Common Raven Reproductive Success and Predation on Young Tortoises

Acknowledging that several factors, such as weather conditions, shortage of food and nest predation, might play a part in the interannual fluctuations of breeding performance, in our study Common raven reproductive success (2.4) is similar or slightly higher when compared to that reported in other natural forests (2.4 and 1.8, respectively, [8,14]). There is a non-remarkable variation in reproductive success between years, which in part might

be related to the similar temperature values and the absence of predation observed in both periods.

Territorial breeding ravens rely more heavily on natural prey than on anthropogenic food subsidies in more naturalized areas [41]. Young tortoises seem to play a part in reproductive success in our study area. Indeed, most of the breeding pairs occasionally predated on young Spur-thighed tortoises (<75 mm CL), which might be linked to the availability of the young tortoises and to their detectability in areas with scant cover [29]. It is known that often a few breeding pairs disproportionately predate tortoises (e.g., [52]), which might be related to the Common raven's ability to remember specific feeding locations [53–55], as evidenced in this study by a couple of nests (<15 m apart) that were revisited in each of the three years and where over 150 young tortoises were predated. If this behavior were to be extended over a prolonged time, it might exert an effect on the tortoise population structure and therefore might threaten their viability. Nevertheless, despite the habitat features tested not favoring a higher raven reproductive success; they might play a part indirectly through increasing the abundance of food resources and refuge [29]. Kristan et al. [38] showed that fledging success was correlated with diet composition, i.e., breeding pairs whose diets were composed mainly of birds or road kill fledged a greater numbers of chicks. Other additional potential prey species will also play their part too in our study area and diet studies are necessary to identify and determine their weight in the diet. However, factors such as more severe winters might influence the body condition of breeding ravens and result in a delay in egg laying [8] or the timing of nesting, while a hot early June might reduce fledgling success and individual characteristics (age, body condition) might also have a role in reproductive success. Therefore, further research is required, which includes the study of biotic and abiotic factors in order to paint a bigger picture of the reproductive success of ravens in Maamora. Furthermore, understanding if and why particular ravens are more likely to predate tortoises will allow mechanisms to be designed by which these individuals could be characterized and managed through specific conservation actions.

4.3. Implication for Conservation

Bearing in mind the positive increase of the numbers and distributional range of Common ravens in the last 40 years worldwide [39,44,45], understanding the relationship between the ecology behind nest-site selection and reproductive success of this important predator will improve our ability to manage this species. Maamora is no exception to the increase in raven populations, and whereas low abundances of this corvid species can have a minimal impact on tortoise at the population scale, high raven abundance, and thus tortoise predation, will lead to tortoise populations being unsustainable, as has occurred in the Mojave desert [41]. This might be especially true in unprotected areas where tortoise densities are three times lower and juveniles are scarce, but is more easily detectable to predators due to the low vegetation cover [29]. Therefore, certain selective management strategies should be applied to mitigate the threat of ravens to the sensitive species that inhabit the Maamora forest, e.g., targeting breeding pairs that exert strong pressure on tortoise populations and trapping them (e.g., with ladder traps, [56]) or controlling raven fertility by applying oil to eggs [57] and reducing the growth rate of breeding pairs to 0.4 breeding pairs/km^2. In addition, more information on the raven population dynamic and spatial behavior is needed to support effective management actions, especially those that include both protected and unprotected areas. As such, ringing breeding pairs throughout different Mediterranean forests could provide key information on nest-site selection, foraging behavior and reproduction success of ravens that might reveal additional or different patterns. Establishing a long-term and large-scale Mediterranean network, which is very valuable in designing effective management programs, would allow raven population dynamics to be modeled for these unique environments, where sensitive species are facing threats such as global change.

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