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The effect of Aleppo pine (*Pinus halepensis*) invasion on nests predation

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By

Asaf Ben David

Supervisors:

Prof. Tamar Dayan

Prof. Ido Izhaki

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Abstract

The invasion of pine (*Pinus Halepensis*) to the Mediterranean scrubland and natural woodland, changes the composition and height of the vegetation. These changes may alter the movement of predators and thus increase predation pressure on prey. Predation in the nesting season is one of the most significant factors influencing the size of the population of song birds. In this study, I examined how the invasion of pine trees affects the populations of the Sardinian warbler (*Sylvia melanocephala*) in the Mediterranean scrubland. My hypothesis was that the invasion of pine may benefit to avian predators, like the Eurasian jay (*Garrulus glandarius*), thus, increasing predation pressure on the Sardinian warbler. The research question was examined in four habitats that differ in pine densities of pine using two methods:

 1) Placing dummy nests with eggs to identify signs of predators according to predation marks on the eggs.

2) Acoustic monitoring of mobbing calls of the Sardinian warbler and calls of the Eurasian jay.

Nest predation was highest in the scrubland with scattered pine trees (75% of the nests were preyed) and open pine forest (60%). Predation pressure was lowest in the scrubland without pines (42%) and dense pine forests (32%). Acoustic analysis showed the presence of jays different among the four habitats. Their calls were most frequent in the scattered pine forest and scrubland with scattered pine trees. Furthermore, the mobbing events of the Sardinian warbler were most frequent in the open pine forest (13.6 events per 40 cycles recording) and the scrubland with scattered pine trees; the lowest was in the scrubland (an average of 4.5 events). A model was developed to predict the chances of a nest to be preyed. It showed that habitat with scattered pines and progress of the nesting season have a significant positive effect on the chances of a nest to be preyed. I found no significant influence of environmental variables such as the pine count, vegetation cover and vegetation height on nest predation.

Although I have identified vary nests predators such as rodents and reptiles, I suggest that the high predation in the scrubland with the invading pines is associated with jays. I assume jays use vantage points in the pine trees in the areas of scrubland thus increasing predation pressure on nesting songbirds in the invading pine areas.

1. **Introduction**

1.1. **Nest predation**

The breeding season is critical phase in the annual life cycle of organisms including birds, with important consequences to population growth, body size and population survival. Nest predation in the breeding season has significant negative influence on the songbird populations worldwide (Ricklefs 1969; Yom-Tov 1974; Gates & Gysel 1978; Fuller et al. 1995). Predation rates can vary from 44% to 86% in different habitats (Martin 1988a). Predation is not limited only to eggs, nestlings and chicks as active adults are exposed to predation as well, especially during the nesting season (Martin et al. 2006). Studies documented that the incubation stage is exposed to higher predation than the nestling stage (Ricklefs 1969; Schaefer 2004).

A review (Chalfoun et al. 2002) of 120 papers on nest predators showed that 64% of the papers reported that mammals, mainly rodents, were the main predators, than (32%) avian (Corvidae only), and only 4% reported snakes (*Elaphe obsolete*) as nest predators. However, papers of this review were biased to forest habitats in North America. This study also found that avian predators were mainly associated with forest edge and small patches (Chalfoun et al. 2002).

Previous studies showed that small to medium-sized predators (e.g. Canidea, Felidea, Mustelidae) have a minimal impact on nesting success whereas relatively large nests rubbers (corvids, hawks, owls) have a significant impact on nesting success (Conner, 2010). A study conducted in a deciduous forest in Germany with surveillance cameras showed that the Eurasian jay (*Garrulus glandarius*) was a significant predator of Blackcap

warblers (*Sylvia atricapilla*) nests (Schaefer 2004). This study showed that Eurasian jays were responsible for 60% of the attempts of nest predation events (eggs and nestlings) and for 46% of all the events that led to nesting loss of the Blackcap warbler (Schaefer 2004). Another research from Sweden showed that shrub nest predation was dominated by Corvids and on the ground nest was dominated by mammals (Fox/Badger/Rodent) (Söderström et al. 1998). A study on nest predation from Denmark showed that the Euraisian jay was foraging mostly within the forest and avoided the conifer forest edges and the agriculture lands while the Hooded crow (*Corvus cornix*) foraged in both the forest and the agriculture lands (Møller & Moller 1989).

1.2. Vegetation structure and nest predation

In a global perspective, the proportion of predated nests is similar in tropical and temperate forest (Söderström 1999). Nest predation decreases with the increase of forest cover (Chalfoun et al. 2002) and is not affected by edge effect (Lahti 2001; Hartley & Hunter 2008).

The location of the nesting site is varied among bird species. The fact that not all birds are nesting in the thickest brush may suggest that there are at least two main factors that affect nest site selection: food availability and the ability to avoid potential predators (Martin 1993; Martin 1988b).

Studies indicated that the habitat type affects nesting success. For example, a study on American gray flycatchers (*Empidonax oberholseri*) nesting in the California Klamath National Forest which dominated by coniferous forests showed that foliage density of the bush decreased predation pressure. Thus, as the nest was more hidden in the foliage, the nestling survival was greater. Nest who were preyed by avian had significant less nests concealment, they were placed in smaller shrub patches, were closer to the patch edge, and had fewer surrounding seedlings and saplings compared to nests depredated by mammals. Positive correlation was found between the size of the shrub

patch in the forest and nesting success (Liebezeit & George 2002). Those observations might be explained by the lower ability of the predators to forage and locate the nests in the dense foliage (Martin 1993).

Members of the Corvidae family are known for their cognitive abilities. They may use high observation stands in order to identify nests of songbirds. A research in the US (Aiken County, South Carolina) has shown that high voltage power lines have a negative impact on nesting success in their vicinity. It was found that birds from the Corvidae family used voltage lines as observation points on the nesting areas and therefor detected the nests much more easy (DeGregorio et al. 2014). Another study from the Negev in Israel (Hawlena et al. 2006) showed a negative impact of tree planting on the Beer Sheva Fringe-Fingered lizard (*Acanthodactylus beershebensis*). This study also showed that the planted trees were used as observation posts for Great grey shrike (*Lanius excubitor*) as an observation post when foraging for prey. This paper showed that a structural change in the environment without relation to vegetation diversity can affect the predation pressure by avian predators and cause a local extinction of the preyed species (Hawlena et al. 2006). Furthermore, a clear positive correlation between the distance from the tree line and the daily survival rate of ground nests was reported in the Italian alps (Masoero et al. 2016).

1.3. The fear effect

In addition to the direct effect of predators on the breeding success of birds, they also have an indirect effect on their prey population through their mere presence that creates fear stress (fear of predation). A study on blue jay (*Cyanocitta cristata*), Cooper's hawk (*Accipiter cooperii*) and eastern screech-owl (*Megascops asio*) in north-central Florida, USA has shown that the fear factor led to a significant reduction in clutch size and in the number of fledglings. The Hawk calls led to 42.3% decrease in fledglings and the jay calls led to shorten the nestling period in 10.2% (Hua et al. 2014). A study from northern Finland found that clutch size and the nestling weight, wing and tarsus length of the black-

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necked flycatcher (*Ficedula hypoleuca*) were negatively correlated with the distance from sparrowhawk (*Accipiter nisus*) nests of up to 334 meters. Furthermore, this study also found that the hatching date of the first egg was earlier by 4 days in 300-400 meters from the sparrowhawk nest. The researchers suggested that the proximity to the hawk's nest led to a decree in foraging efficiency due to the fear effect (L. Thomson et al. 2006).

1.4. Mobbing calls

The acoustic behavior of passerines is shaped by physical and physiological constraints. The evolution of the physical structure of alarm calls was shaped by the detectability and localizability by the predator and the potential prey (P. Marler 1955; Klump, Kretzschmar, et al. 1986).

When prey birds identify a potential predator, they perform a noisy behavior - which is also called mobbing. This behavior is an act of self-defense against predator which neutralizes the effect of surprise by forcing the predator to move from the mobbing site (Klump, Kretzschmar, et al. 1986; Pettifor 1990). This behavior occurs most intensively during the breeding season. Some argue that this behavior interferes with the predator's ability to locate the nest (Krams & Krama 2002). Mobbing calls have a cost and can increase the ability of the predator to locate the nest (Krama & Krams 2004). The mobbing sounds of birds have a wide range of frequencies around 4.5 KHZ. They differ from Hawk alarm calls that are characterized by a high single voice ranging 7-8 KHZ and thus reduces the ability of the warning bird to be located by the avian predator (Klump, Windt, et al. 1986).

Mobbing can give information about the predator and its distance from the mobbing bird. In a study of black cap tit (*Poecile atricapilla*) mobbing calls consider as index for assessing the size of the predator (Templeton et al. 2005). The Arabian babblers (*Turdoides squamiceps*) distinguish between mobbing calls of a short-eared owl (*Asio flammeus*) and a cat (*Felis silvestris*) (Naguib et al. 1999). In addition, there was a negative correlation between the intensity of the mobbing calls and the distance from the danger in

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small songbirds (20 grams or less) in coniferous and mixed forest habitat (Forsman & Mönkkönen 2001). From an ecological point of view, mobbing calls can be used to assess predator's activity. A research from Costa- Rica used Ferruginous pygmy-owl (*Glaucidium brasilianum*) calls to imitate the presence of a predator and mobbing calls of passerines to simulate a mobbing activity. The results showed that the mobbing response of birds to the mobbing playback was correlated with the presence of the Ferruginous pygmy-owl (Sandoval & Wilson 2012).

1.5. Aleppo Pine (*Pinus halepensis)* invasion

The Aleppo Pine (*Pinus halepensis*) is a widespread pine in the Mediterranean forests (Richardson et al. 2000). The Israeli native populations inhabited only restricted areas (Carmel and Judea mountains) in a soft Rensina soil (Rabinowitch A 1985). In the late 20th century it had been planted in 50% of the planted forests in Israel which covers over 100,000 ha in a wide variety of habitats (Liphschitz & Biger 2001). The seed sources for most of these planted forests were exotic (שילר, 2013). In recent years, a wide spread invasion of planted pines into natural habitats was observed in many ecosystems across the globe (Richardson & Rejmánek 2004) as well as in various habitats in Israel (Lavi et al. 2005) including Ramat Hanadiv Park (Osem et al, 2011). The invasion can be explained by natural factors such as global and anthropogenic activities including fires and grazing (Sheffer 2012; Osem et al. 2011). Presumably new growth of pine trees in natural habitats has varied ecological impacts on different groups of organisms. Studies showed that plantations of pines in Israel had a significant effect the on avian community (Shochat et al. 2002);201 ,ברוש2). Most of the planted Aleppo pines in Israel will keep reproducing seeds for the next 30 years (Osem et al, 2011). Therefore, we can assume that their invasion into natural scrublands will dramatically change their floral and faunal structure in the next 30 years. Hence, a study of the effect of these changes on bird's communities is needed. The current study is focused on the effects of the invasion of Aleppo pine on nest predation.

1.6. Research hypothesis

I hypothesize that the invasion of pines and their establishment in the scrubland causes a change in the structure/infrastructure habitat for Eurasian jay (*Garrulus glandarius atricapillus*), a potential nest predator. I hypothesize that the jay uses high pines as observation points to detect nests and thus the presence of pines will increase the risk of nest predation, especially of song birds that build an open nest. Furthermore, even if no actual predation occurs the increased presence of predators on the pines will create stress on birds as a result of the "fear effect".

1.6.1. Research question

Does the pine invasion affect the predation pressures of Eurasian jays on songbirds in the nesting period?

1.6.2. Study goals

1. Examine whether there is a correlation between predation of eggs of songbirds with open nests and (a) pine density, (b) vegetation structure (see details in the methods).

2. Examine whether there is a correlation between predation of eggs of songbirds with open nests and the presence and activity of jays.

2. Methods

2.1. Study Site

The study was carried out in Ramat Hanadiv Park in the Southern Mount Carmel, Israel (32° 30' N, 34° 57' E) in an area of 4.5 km^2, surrounded by suburbs and agricultural fields. An intensive cultivated memorial garden (70 hectares) is located in the park center.

The area is a plateau with a mean elevation of 120 m above sea level. A series of rock cliffs are located in its west borders that descend gently to the east side. The parent

rock formations consist of limestone and dolomite, with a volcanic tuff layer below the upper limestone layer. The soil in the area is mainly Xerochrepts, developed on hard limestone or dolomite (קפלן, 1989). The climate of the study site is typical Mediterranean with an average maximal temperature of 25.6ºC and minimal temperature of 16.4ºC, humidity is 83.8% max and 45.7% min, the average wind speed archives 9.78 m/s, rainfall averages 493 mm annually, and occurs mainly from November to March. The climatic data are available to download in Ramat Hanadiv climate station (http://www.meteo-tech.co.il/hanadiv/hanadiv_periodical.asp#).

2.1.2. Plant communities

The main plant species in the study site are carob (*Ceratonia siliqua)*, Palestine oak *(Quercus calliprinos)*, mastic tree (*Pistacia lentiscus)*, spiny broom (*Calycotome villosa)*, prickly burnet *(Sarcopoterium spinosum)*, broad-leaved phillyrea *(Phillyrea latifolia)* and Palestine buckthorn (*Rhamnus lycioides)* and as planted trees such as Aleppo pine (*Pinus halepensis)*, Turkish pine (*Pinus brutia)*, Canary Island Pine (*Pinus canariensis)* and cypress trees (*Cupressus sempervirens*) (הדר, 1989).

In recent decades, the Ramat Hanadiv Park has suffered forest fires and disease and therefore was managed with intensive forestry work. The consequence is a very fragmented ecosystem that includes various habitat types including low open fields in the volcanic tuff soil, medium sparse scrubland with broad-leaved *Phillyrea* and mastic tree as the dominant shrubs, sparse trees grooves that were planted in the volcanic tuff soil, medium sparse scrubland with broad-leaved phillyrea and mastic tree as the dominant shrubs, medium dense scrubland with dense shrubs as the broad-leaved phillyrea and mastic tree as the dominant shrubs and tree dense are planted pine and cyprus groves above 5 meter height and with 75% or more cover (Table 1) (Massada et al. 2012).

Table 1: The properties of the habitat types in Ramat Hanadiv Park (after Bar Masada 2012).

Habitat type	% of the park area	Typical plants	Structure
Low open\Low	9.6%	Annual local Herbarium and wheat fields	<0.5 m tall, < 25% cover
Medium dense	31%	Broad-Leaved Phillyrea and Mastic tree.	0.5–2 m tall, >75% cover
Medium sparse	35 %	Broad-Leaved Phillyrea, Mastic tree.	0.5–2 m tall, 25–50% cover
Tree sparse	4%	Pine trees with Mastic shrubs	height > 5 m, <75% cover
Tree dense	7.4 %	Pine and Cyprus trees	height > 5 m, >75% cover
Tall dense	13%	Carob tree, Palestine Oak and Mastic tree.	Height> 2.5 m, >75% cover

Since 1990, the park under cattle grazing management in (>70% of the park) from March to the end of May and goat grazing in 32.9 hectares all year around (Rosenfeld 2004). Another study on the vegetation structure in the study site showed that in recent decades there's a considerable increase in the woody vegetation in all of the park (Perevolotsky 2013).

2.1.3. Bird community

The nesting bird monitoring program at Ramat Hanadiv Park is a long-term ecological research (LTER) (2012 ,ברוש). The program began in 1988 as a comprehensive survey of the site's avian biodiversity, and continued with significant modifications approximately every 3-4 years (1989, 1994, 1995, 1996, 2001, 2004, 2007, 2010, and 2013). The resident birds have been surveyed during the breeding

season (April - May). Since 2001 there were almost no variation in the survey methods. The length, time of the transects and the data collection methods were fixed. All data starting with the 2001 survey are currently available from Ramat Hanadiv's online data portal (http://ramathanadiv.maps.arcgis.com/).

These surveys detected 45 bird species, 35 of them nesting in the Ramat Hanadiv Park; the most common species were the Sardinian warbler (*Sylvia melanocephala*) and Eurasian collared dove (*Streptopelia decaocto*) (ברוש, 2012, Table 2).

Table 2: The common all-year resident bird species in Ramat Hanadiv (based on the last three surveys, (ברוש 2012; אדר 2013). The numbers are the sum of the birds that were located by visual/vocal.

Common name	Latin name	2007	2010	2013
Sardinian warbler	*Sylvia melanocephala*	312	441	408
Eurasian collared dove	*Streptopelia decaocto*	193	170	136
Graceful prinia	*Prinia gracilis*	65	142	84
Common blackbird	*Turdus merula*	81	106	99
Spectacled bulbul	*Pycnonotus xanthopygos*	144	103	78
European turtle dove	*Streptopelia turtur*	86	66	32
Great tit	*Parus major*	66	58	36
Palestine sunbird	*Nectarinia osea*	51	52	48
Euraisian jay	*Garrulus glandarius*	44	45	58
Chukar partridge	*Alectoris chukar*	21	28	34
Laughing dove	*Senegale Streptopelia*	9	28	15
Hooded crow	*Corvus corone*	17	23	21
Common kestrel	*Falco tinunculus*	16	12	18
Common whitethroat	*Sylvia communis*	1	11	0
Eurasian sparrowhawk	*Accipiter nisus*	13	8	7

Great spotted cuckoo	*Clamator glandarius*	8	7	5
Eurasian hobby	*Falco subbuteo*	8	6	4
Syrian woodpecker	*Dendrocopos syriacus*	7	6	4
European goldfinch	*Carduelis carduelis*	29	5	2
House sparrow	*Passer domesticus*	3	5	NA
Short-toed snake eagle	*Circaetus gallicus*	12	5	5
Rose-ringed parakeet	*Psittacula krameri*	0	4	0
European greenfinch	*Carduelis chloris*	28	3	3
Hoopoe	*Upupa epops*	2	3	1
white-throated kingfisher	*Halcyon smyrnensis*	5	3	0
Eurasian stone-curlew	*Burhinus oedicnemus*	0	2	3

2.1.4. Reptile and mammal communities

The reptile community in Ramat Hanadiv comprises 29 species as found in a survey during 2003-2004. Significantly higher richness was detected in the scrublands than in the pine groves(2004 ,שחם). The medium-sized mammals in Ramat Hanadiv have been described in a recent study that found the following predators: golden jackal (*Canis aureus*), Euraisian badger (*Meles meles*), Egyptian mongoose (*Herpestes ichneumon*), rare sighting of red fox (Vulpes *vulpes*) and wild boars (*Sus scrofa*) (Shamoon 2016). The small rodent community in the park comprises the black rat *(Rattus rattus),* Cairo spiny mouse (*Acomys cahirinus*), *house* mouse *(Mus musculus),* Wagner gerbil (*Gerbillus dasyurus),* Tristram's jird *(Meriones tristrami),* yellow-necked mouse *(Apodemus flavicollis),* broad-toothed field mouse *(Apodemus mystacinus) and* Social vole (*Microtus socialis)* (Rosenfeld 2004). This study also showed that the woody vegetation cover was the only environmental parameter that was associated

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with high rodent diversity in the open scrubland, probably due to the increased food availability and nest concealment (Rosenfeld 2004).

2.1.5.Study habitats

The main goal of my study was to find out if there is a correlation between nest predation and pine tree density. I studied the nest predation in four different habitat types that differ in pine density: (1) Medium sparse – an open shrub habitat without any pines or other higher trees, (2) Medium dense – an open shrub habitat with a few pine trees (>3 meters high) (different from the definition in Table 1 in the pine trees presence), (3) Tree sparse – planted groves of pines with significant distance between the trees and (4) Tree dense – densely planted pine groves. In each of the study habitats I chose randomly 16 research sites of 0.2 square kilometer for the artificial nest experiments and the acoustic monitoring (see below).

2.2. Birds communities

The study of bird community during the breeding season at Ramat Hanadiv within the four-habitat typed was based on (1) analyses of data from the long-term surveys (ברוש, 2012; אדר 2013) and (2) acoustic monitoring of birds from field recordings:

2.2.1.Birds communities in the four habitats

I used the data from Ramat Hanadiv bird surveys for the period of 2001-2013. From the raw data, I chose the 19 most common bird species. With ArcGIS 10.3 I registered the habitat type that each of the sight was made. The data were transformed with logarithmic transformation to reduce the effect of rare and common birds. Then I used NMDS ordination and Adonis test to characterize the bird communities in each of the four habitat types with R 3.2.3 programming 'environment' with the 3.3.2 package "vegan" (Wagner 2016).

2.2.2. **Mobbing bird community**

The comparison of the bird communities during mobbing events among the four habitat types was based on the field recordings (16 plots, 4 in each habitat type in the northern research site). The recording was made with a mobile recording device (TASCAM DR-07mk2). Each recorder was placed for 5 days from mid-April to May in the first two hours of the day and recorded at least six hours of omnidirectional sound. With parameters of 16-bit rate and 44.1kHz. from this data, I chose 75 files from microphones that were stationed in the center of habitat plot and from the middle of the nesting season. 8-17 hours for each habitat type (the Tree dense had low sample size due to continuous low activity). From each of the recordings I manually chose one hour from each recording that were made in the morning hours. To identify the bird species during the mobbing's, I registered any mobbing event of the five most common passerine mobbing calls, that are potential prey for the Eurasian jay and have a distinctive mobbing call (Sardinian warbler, common blackbird (*Turdus merula)*, graceful pirinia (*Prinia gracilis*), spectacled bulbul (*Pycnonotus xanthopygos*) and Palestine sunbird (*Nactarinia osea)*. I compared the mobbing community among the four habitat types using Chi square analysis.

2.3. **Direct evidence for nest predation**

Locating nests of passerines is a difficult task. Out of 20 days of nest search in the scrublands I managed to locate only 10 live nests, four of Sardinian warbler. To be able to assess the predation on Sardinian warbler nests with a good amount of data I established field experiments with artificial (dummy) nests.

2.3.1. **Dummy nests with Quail and Plaster eggs**

To assess predation pressure, I used dummy nests, although this method has some drawbacks (Moore & Robinson 2004). One of them assume to be related to lack

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of parental activity. However, a research from conifer and deciduous forests in Arizona found that this was not a significant parameter. It showed that the increased parental activity around the nests did not associate with increased predation, on the contrary, the highest predation occurred during the incubation period mostly because to the quality of the nesting site (Martin et al. 2000). Therefore, I feel I addressed most of the expected problems caused by this methodology by imitating the Sardinian warbles nest with high visual similarity, a thoughtful placement of the nests and making minimal disturbance as possible as being described in the methods below.

The nests were built from local weeds, flax and Raffia palms fibers in diameter of 10 -15 cm in a coiling basket wreathing method (Paul Shaw 2009). The size and the material choice of the nests were made by examining Sardinian warbler nests from the Steinhardt Museum of Natural History nest collection in from Tel Aviv University (Fig. 1).
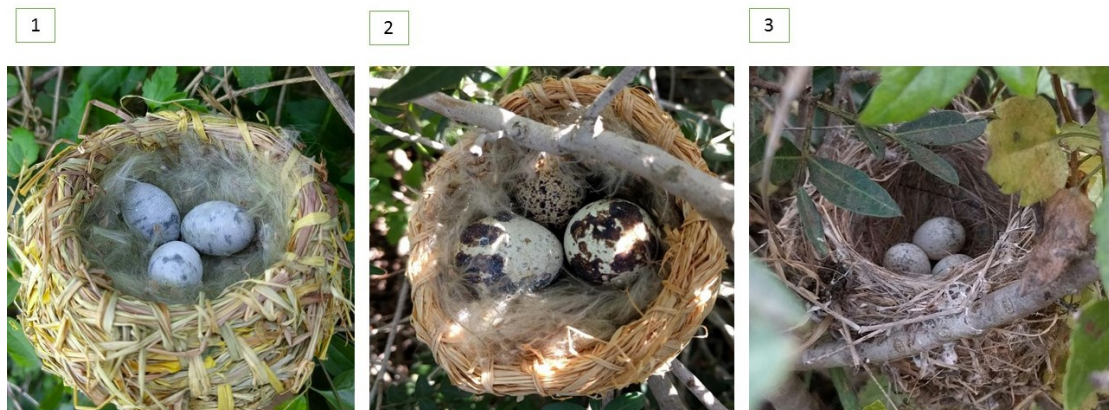

Figure1 : Dummy nest with Plaster eggs [1], dummy nest with Quail eggs [2], Sardinian warbler (*Sylvia melanocephala*) nest) [3].

To estimate nest predation of the Sardinian warbler I placed in the second year of the study 48 nests in the southern research site with 3 plaster eggs in each nest. The experiments had to types of eggs: One contained Quail (*Coturnix coturnix)* eggs

that were boiled in order extend their freshness. The other contained plaster eggs with 1.5 cm height that were made with a 3D plaster printer model Projet® CJP 660Pro by 3D Systems (Venuvinod & Ma 2004). Each egg decorated by the printer with a texture of passerine eggs. The artificial eggs were covered with white bee wax and mixed with soil from a chicken (*Gallus gallus domesticus*) droppings to fade the smell of the wax. The wax function was to track predator signs such as reptiles and avian predators with weak bite marks. The nests were placed in the thickest shrub in each plot and were reinforced to the branches with a zip tie at a height of 50-120 m from the ground, similar to descriptions of the nesting of a Sardinian warbler (Shirihai et al. 2001).

2.3.2. The dummy nest experiment

The dummy nest experiment assumed that the ability of the Euraisian jay to detect passerine nests is different among the four habitat types due to their different vegetation cover and tree height. A total of 128 dummy nests were stationed, 21-24 in each of the four habitat types (five fall of the shrub/ lost) from March to May in two seasons 2015 and 2016 (Table 3). Each nest was stationed in a distance of 20 meters from a road or a trail in a random coordinate in the four plots that were chosen in each of the four habitats. Each plot was at 25-100 meters apart. In the plots (0.2 square kilometer in size) I randomly selected a thick shrub to place the dummy nest. I used two types of eggs in the dummy nests. In two nesting seasons, I placed 80 nests (16 nests in each cycle) in five different cycles (two in 2015,3 in 2116) with three boiled Quail eggs in each nest in the northern research plots at the four habitat types. In 2016, for the Plaster egg experiment, I located the same four habitat types in the southern park with four plots in each of them (16 in total). The nests with the plaster eggs were placed in three cycles. This was made to geographically isolate the two experiments and not to over populate the plots with dummy nests that would lead to more human visits and by that we might uncover the nest array to potential predators.

I recorded the height and the shrub species on which the nest was placed. To compare the number of events of egg predation in artificial nests among the four habitats types I used Chi square test.

I compared the predation upon the plaster and the quail eggs and found no significant difference in Chi square with Monte Carlo simulation due to the small sample (n= 123, df = 3, p=0.86). Therefore, results of these experiments were combined.

Table 3: Details on the different experiments of the dummy nests that were conducted during the research: egg type that were used, the year in was placed, the month that the experiment was stationed and the place of the research site.

Cycle No	Eggs Type	Year	month	North/South
1	Quail	2015	April	North
2	Quail	2015	May	North
3	Quail	2016	March	North
4	Quail	2016	April	North
5	Quail	2016	May	North
6	Plaster	2016	March	South
7	Plaster	2016	April	South
8	Plaster	2016	May	South

2.3.3. Environmental parameters around each nest

To assess the impact of environmental conditions around each nest on egg predation, a 50 meters' buffer polygon was created around each of the 123 nests with Arc GIS 10.3 software. The following environmental parameters were calculated:

- Pine frequency - (pines and cyprus) density by manually counting the trees from an arial photo by distinguishing the shade length and the color of the trees.

- NDVI – Normalized Difference Vegetation Index-based on 38 images from Landsat satellite during 2003 – 2012. Describes the proportion of green vegetation in the polygon which has being successfully used to assess bird diversity (Oindo et al. 2000).

- Vegetation height – based on LAIDAR - Light Imaging, Detection, And Ranging, was taken to describe the vegetation structure (Goetz et al. 2007).

- Classification - Bremen and Cutler's "Random Forests" for rock, soil, vegetation and shade (Wiener 2002).

2.3.4. Predation events documented by trail cameras

To identify the nest predators in the four habitats types I placed 48 trail cameras (32 Bushnell Trophy cam 8MP and 24 Bushnell Trophy cam HD) near the dummy nests. In 2015, 32 cameras, eight for each habitat type, were placed at the northern research plots. In 2016, 16 cameras were placed in the Tree dense (8) and the Medium dense (8) in the northern research plots. Each camera was stationed for three weeks between March and April. The cameras were placed within 1 - 1.5 meters from the dummy nests. Each camera was built with an infrared motion sensor that detects movement in a second and shoots three images and 10 seconds' video in each "event". A comparative study from the US on the bias of placing cameras on nests showed that there was no significant difference between the breeding success in nests with or without camera (Herranz et al. 2002). Thus, I assume that the cameras in my study had no significant effect on nest predation.

The cameras had a lot of technical difficulties such as slow trigger time that missed the predator, cameras that drained their batteries on moving twinges and some of them missed placed by cattle and wild boars (*Sus scrofa*). Therefore, the results from the cameras in this study were mainly used to identify the various nest predators.

I assumed that that the potential predators which are associated with pine invasion are from the Corvidae, known regarding their high intelligence (Emery & Clayton 2004; Shaw et al. 2013). Therefore, I singed the nests in the field with only broken twinges and GPS coordinates and avoided visiting the nests during the experiment. This was the reason why I didn't use the nest survival model (Mayfield 1961) that requires four nest visiting during the nesting season. Instead the nests were left for three weeks, a normal nesting season for a small passerine (Ferguson-Lees et al., 2011) without any disturbances by the research team. After three weeks, the nests were taken out of their location. For each nest, I registered the fate of the eggs and the fate of the nest. When I approached a nest in which I put plaster eggs I looked for eggs on the ground around and below the nest. Each mark that was found on the egg wax was documented and measured for identification. To identify tooth marks I measured incisors of the common rodent's species and canines of the common carnivore family. In the reptile case I consulted with a reptile specialist and made a bite of plaster eggs with alcohol preserved specimens in the Steinhardt Museum of Natural-History skull collection in Tel Aviv University.

2.4. Indirect evidence of nest predation

I used indirect monitoring to documents the presence and the encounters of the Sardinian warbler and the Euraisian Jay in the four habitat types.

2.5. Mobbing calls of Sardinian warbler

At 16 plots, four in each habitat type in the northern research site I performed an acoustic monitoring of the Sardinian warbler mobbing calls (Fig. 2).
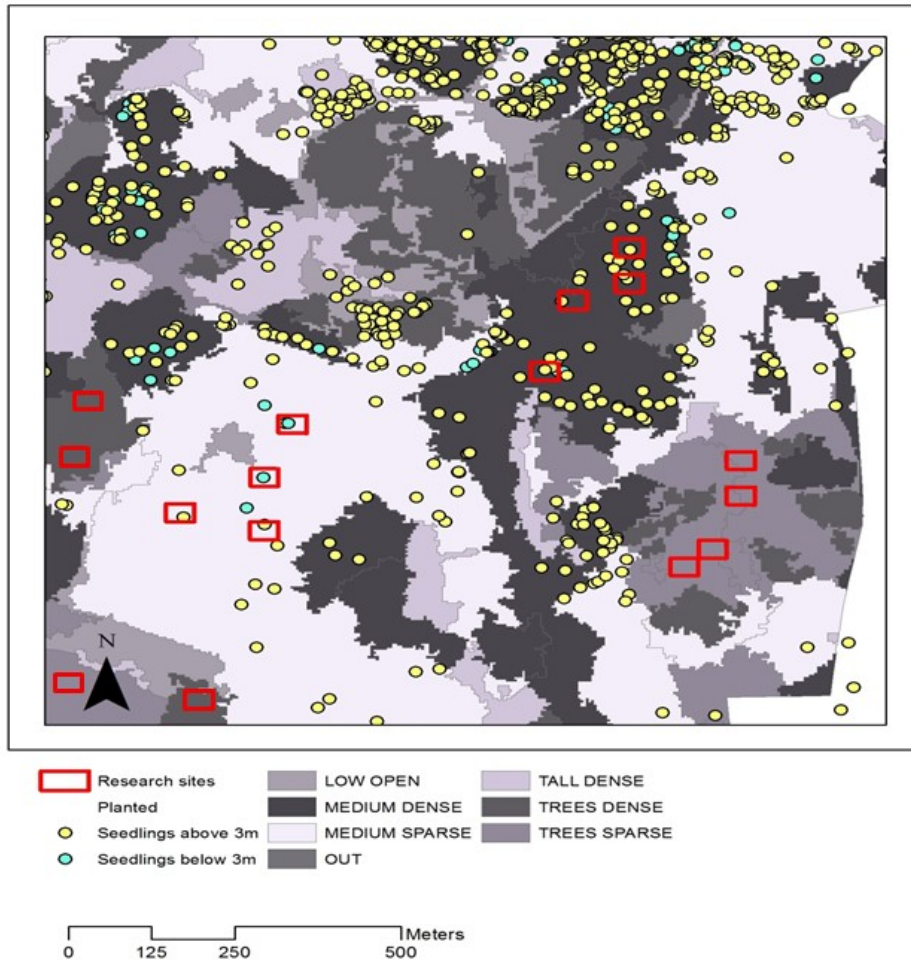
Figure 2: Map of the northern site in Ramat Hanadiv with the distribution of the microphones among the four habitat types. Yellow - pine trees > 3 meters tall, green- pine lower than 3 meters, red squares- the research plots.

The monitoring was carried out using a mobile recording device (TASCAM DR-07mk2). Each recorder was placed for five days from the mid-April to May. The recorders were placed in the first two hours of the day and recorded at least six hours of omnidirectional sound. The recordings parameters were made at a 16-bit rate and 44.1kHz.

The acoustic analysis was conducted with Raven Pro 1.5 software -from the Bioacoustics lab of Cornell's University. The spectrogram parameters that the detecting of the mobbing calls were made in 592 window size and with 80% overlap in the window method Hann. The Sardinian warbler alarm calls are made from repeating tk-tk-tk-tk notes (Shirihai et al. 2001) (Fig. 3).
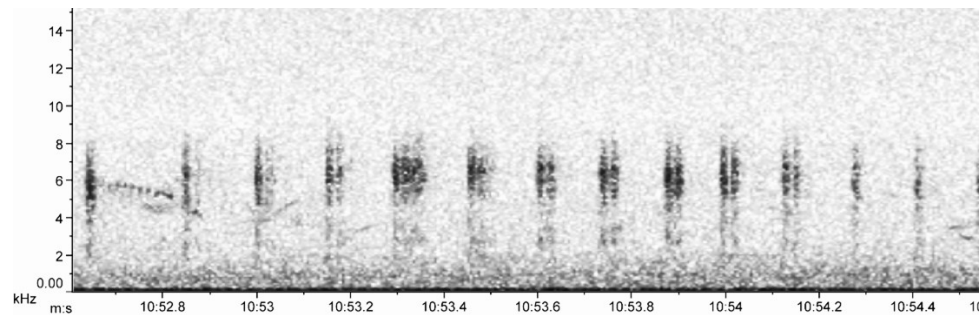
Figure 3: Sardinia warbler (*Sylvia melanocephala*) mobbing calls [window size = 592, method: Hann]

I also used recordings from the field of observed mobbing events to describe the calls. To detect the mobbing calls automatically I created a detector with the Raven software to detect the single notes of the mobbing calls in the frequency range of 4500 to 6000 Hz duration of 0.01-0.04 seconds with a minimal time interval of 0.008 seconds. This detector plot was imported into R 3.2.3 programing 'environment' and was rearranged to find sequences of 20 or more notes. Then the plot was imported back to the Raven software and was scanned by hand for any mistakes of the algorithm. All the mobbing calls within a 20 minutes' interval were counted as a mobbing event. In total, I scanned 220 hours of recordings. I conducted Kruskal-Wallis Test with R 3.2.3 programing environment with "stats" package (R Core team 2015) to find if the number of mobbing events per two hours were significantly different among the four habitat types.

2.6. Jay presence monitoring

During the two nesting seasons, once a week I conducted 10 routine trails in the first two hours of the morning in each of the four habitat types. I recorded Euraisian jay presence with Arc pad app indicating the bird height and the description of its activity (e.g., flying, foraging, observing). I compared the number of jay presence among the four habitat types with Chi square test.

2.6.1. Euraisian jay acoustic monitoring

I characterized the Euraisian jay's calls with recordings from the field (Fig. 4). To detect the calls automatically I created a detector with the Raven Pro 1.5 software in frequency range of 1000 to 6000 Hz duration of 0.3-0.5 seconds with a minimal time interval of 0.5 seconds. The spectrogram parameters that the detecting of the mobbing calls were made in 592 window size and with 80% overlap in the window method Hann.
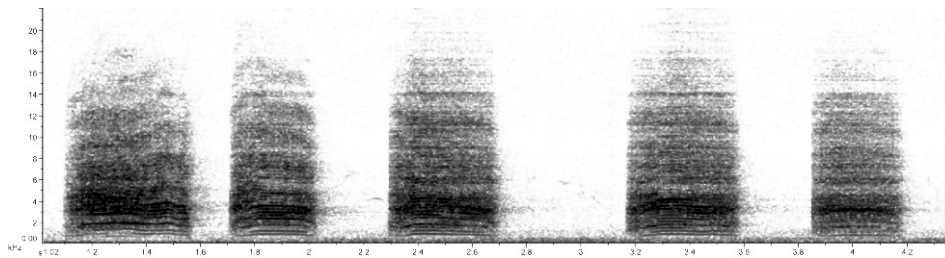
Figure 4: Euraisian jay (*Garrulus glandarius*) companion calls [window size = 592, method: Hann]

I scanned the field recordings (see section 2.5) with the detector and then manually checked the detector to verify its fidelity. Then I summarized the events in each habitat and tested the results with Kruskal-Wallis Test. I crossed the detectors of the Sardinian warbler mobbing's and the Euraisian jay calls and looked for events interval of less than 10 minutes between the jay's calls and the Sardinian warbler mobbing's.

2.6.2.The correlation between jays and tree height

The Pine and Cyprus trees > 3 meters were mapped with ArcGIS 10.3 geographic information system by identifying the trees with Osem Aleppo pine invasion layer (Osem et al, 2011). The planted grooves of other pine species and Cyprus were mapped with Ramat Hanadiv Park planted grooves polygons and the arial image. With those two layers, I could characterize the pine trees on the arial map by their distinctive light green color and the length of their shade. The results were crossed with field observations.

The density of the trees is different among the four habitat types (Table 1). To calculate the correlation between the jays and the density of high trees I calculated the number of pine/cyprus trees > 3 m? and the number of the Euraisian jay sights within a 50 meters' buffer from each nest. Because I assumed that the effect of the pine density on the jays was not linear and the data was zero inflated, I performed a Poisson GLM regression with R 3.2.3 programing 'environment' with "stats" package (R Core team 2015).

2.7. Logistic regression model of nest predation

To predict the most significant variables that affect the probability of a nest to be preyed I conducted a Logistic Regression with R statistical programing environment with package "stats" (R Core team 2015). The model was chosen with AIC goodness of fit test.

The variables that were chosen to this analysis were: the four habitat types (categorical), the pine density within a buffer of 50 meters around each nest, a "Random forest" classification of the research area by rock, shade and perennial cover, the mean vegetation height within a 50-meter buffer, and the month that the nests ware placed (categorical). In a few cases I observed that the cattle eliminated large portions of the shrubs with the nests that were placed in them. Because cattle grazing was not considered

as nest predation in this study, I excluded the cattle predation from the model to calculate a model that predicts only wildlife activity.

3. **Results**

3.1. Environmental conditions characterizing the four habitat types

The comparison of the environmental conditions among the four habitats was carried out using LDA analysis. The model included all parameters that ware calculated with in a 50 meters' buffer from the nest. The variables that were included in the final model were the following: percent of shade, soil, rock and perennial vegetation cover, number of pine trees, minimal, maximal, standard deviation and mean of a vegetation cover, the minimal, maximal, standard deviation and mean of vegetation height.

The Wilks' Lambda test showed a significant difference (P<0.001) between Tree dense, Tree sparse and the Medium sparse habitats. No significant difference was found between Medium sparse and Medium dense habitats (Fig. 5).
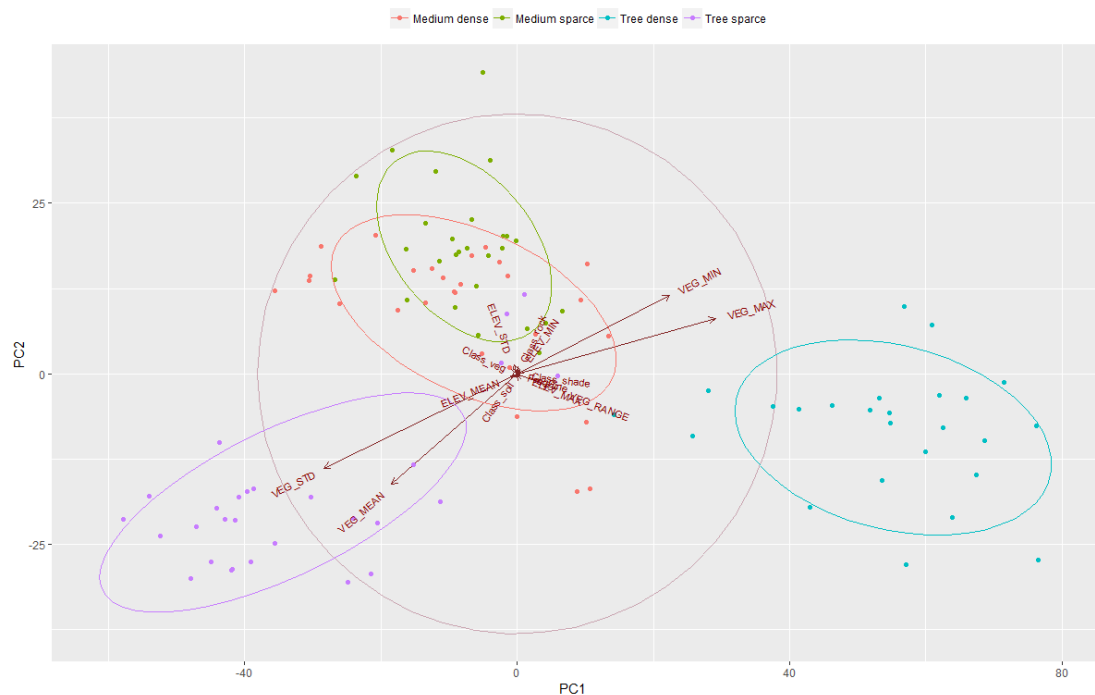
Figure 5: LDA analysis of the environmental parameters of the four habitat types based on measurements around (50-meter buffer) each nest location. The Tree dense (cyan) and the Tree space (purple) were significantly separated from the Medium space (green) and the Medium dense (red).

The six variables that contributed the most to the model were: shade classification, pine density, soil classification, standard deviation of the vegetation height, classification of rocks and the NDVI standard deviation (p<0.001, Fig. 6).
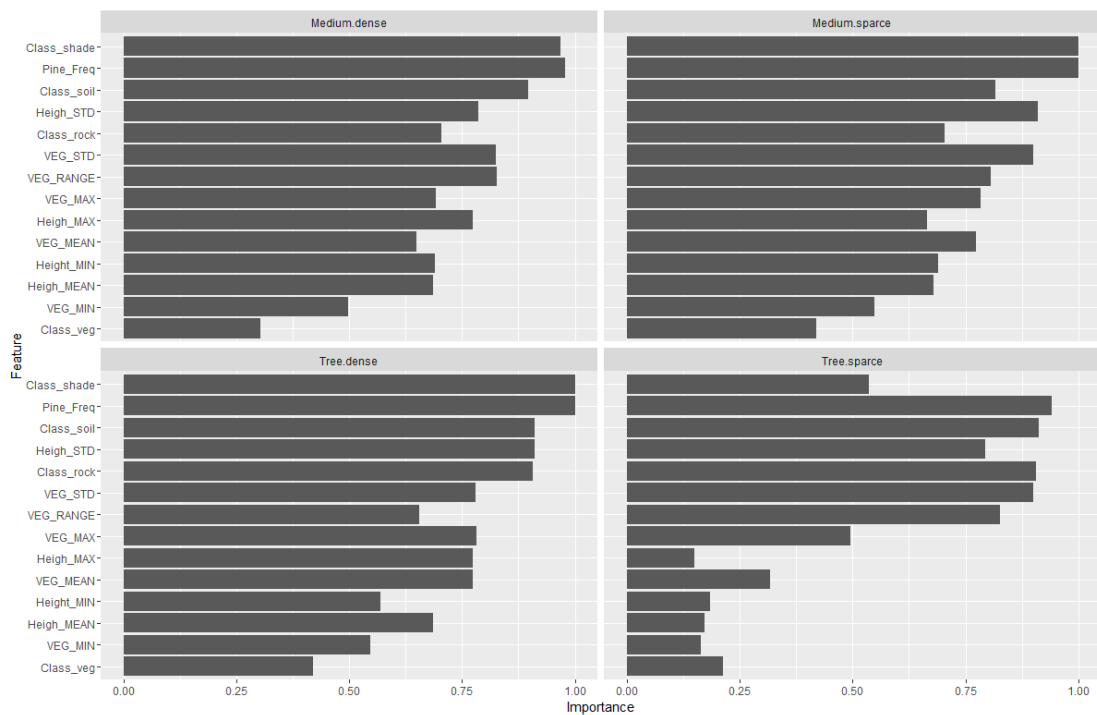
Figure 6: The importance of each environmental variable in each of the habitat types on the LDA model. Pine density (Pine_Freq) is the most important variable. The shade classification (Class_shde), soil classification (Class_soil_ and the standard deviation of the height (Heigh_STD) are also highly important. The minimum and average vegetation height (Heigh_MEAN, Heigh_MIN), minimum vegetation growth (VEG_MIN) and the vegetation cover classification (Class_veg) were the least in their importance.

3.2. Bird communities

The results of the NMDS analysis of bird community showed differences in community structure between the pine groves (Tree dense), open pine grooves (Tree sparse) and the natural scrubland habitat (Medium sparse, Medium dense) (Fig. 7).

3.2.1. Birds community in the four habitat types during the nesting season at Ramat Hanadiv.

To describe the bird communities during the breeding season in the different habitat types I analyzed the presence of the 19 most common bird species in our study site among the four habitat types based on the "Long term ecology research nesting birds survey of Ramat Hanadiv" (2012 ,ברוש) with NMDS ordination. The data were log transformed to reduce the noise of the common species. The results were tested with Adonis test for their significant. I found that the bird community composition was significantly different among the four habitat types (P= 0.01, R^2 = 0.62, stress= 0.14). Although the model is significant, there was partial overlap between bird communities of the Medium dense and the Medium sparse habitat types (Fig. 4). The jays were more common in the Tree dense and the Tree sparse habitats (Fig. 7). Other potential nest predators such as the Eurasian sparrow hawk (*Accipiter nisus*) and the Hooded crow (*Corvus corone*) were also related to the Tree dense habitat. The Sardinian warbler was more common in the Medium sparse and the Medium dense habitat.
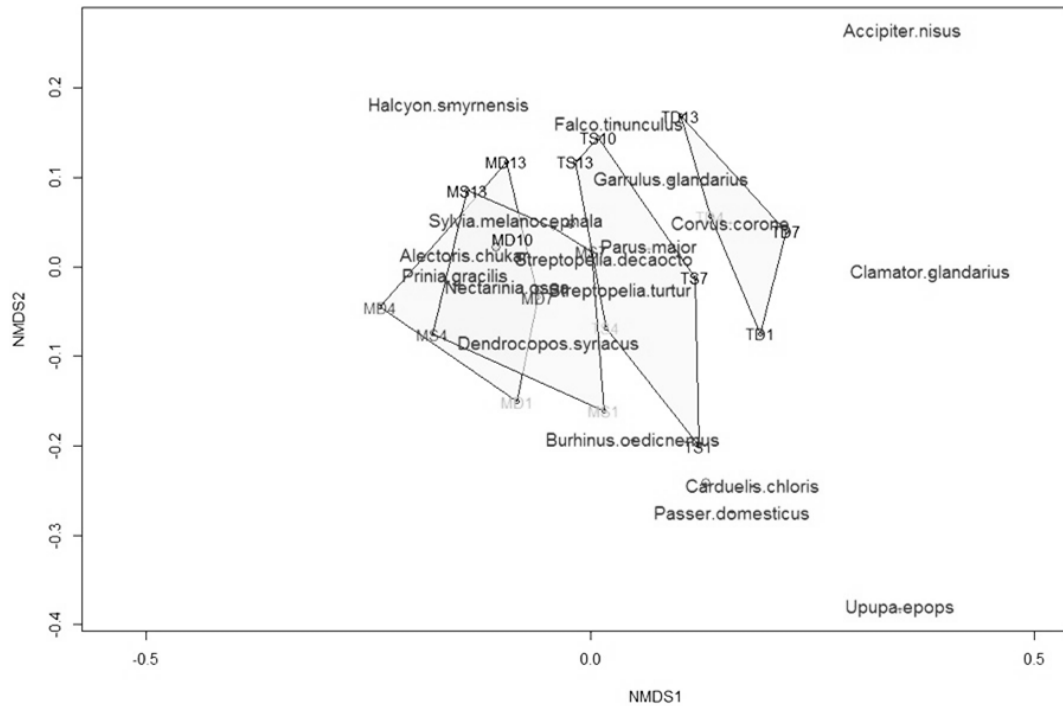
Figure 7: The bird community structure in the four habitat types in Ramat Hanadiv analyzed with NMDS. Each polygon represents different habitat types (TD= Tree dense, TS= Tree sparse, MS= Medium space, MD= Medium dense). Each point in the polygon represents a different year (2001-2013) in the survey.

3.2.2. Mobbing bird communities in the four habitat types

The results of the acoustic monitoring of 75 hours of recording showed that the mobbing calls of the Sardinian warbler were the most common (80% - 100%) in all four habitat types (Fig. 8). In the Tree dense I also recorded 20% Common blackbird mobbing's. In the Medium dense 10% of the mobbing's were of Bulbuls and one event was of Graceful Pirinia. In the Tree sparse I recorded one event of Eurasian blackbird, Spectacled bulbul and Palestine sunbird. No significant difference was found among the four habitat types regarding the number of calls of each bird species (Chi^2 = 13.16, df=15, P= 0.19).

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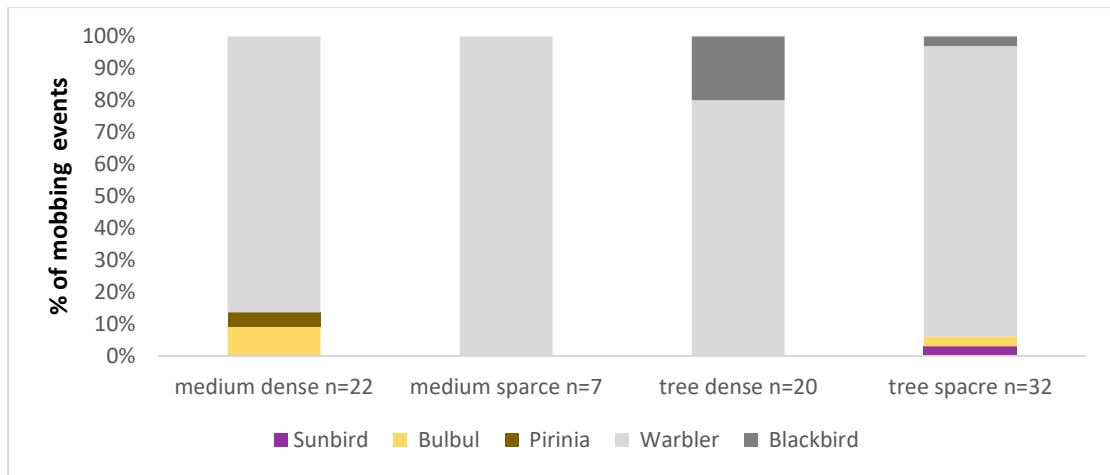Figure 8: The mobbing community of common Passerines - bird community structure in each of the four habitat types based on the number of mobbing calls during 75 hours of random morning recordings during the breeding season. n= number of mobbing calls.

3.3. Direct evidence for nest predation

The dummy nests with quail and plaster eggs were preyed upon by variety of birds, reptiles and mammals. A large portion of the predators' identification remained unknown.

3.3.1. Dummy nests with quail and plaster eggs

From the 123 nests that were stationed all around the Park, 65 (52.8%) had been preyed (Fig. 9). The number of predation events was not equal among the four habitat types (Chi^2= 13.4, df =7, P <0.05). The highest predation (19.5 %) was recorded in the Medium dense and the lowest (7.3%) in the Tree dense habitat (Fig. 9). The largest difference between the observed and expected predation (at random) was in the Medium dense where the highest number of predations (24) was recorded (Fig. 10). The lowest predation was detected in the Tree dense with the largest negative difference between the observed and expected predation. Chi square tests between pairs of habitat types showed a significant difference in the number of predation events between the Tree dense and the Medium dense (Chi^2= 11.08, P=0.008) and between the Medium sparse and the Medium dense (Chi^2=7.1, P=0.007) (Fig. 9).

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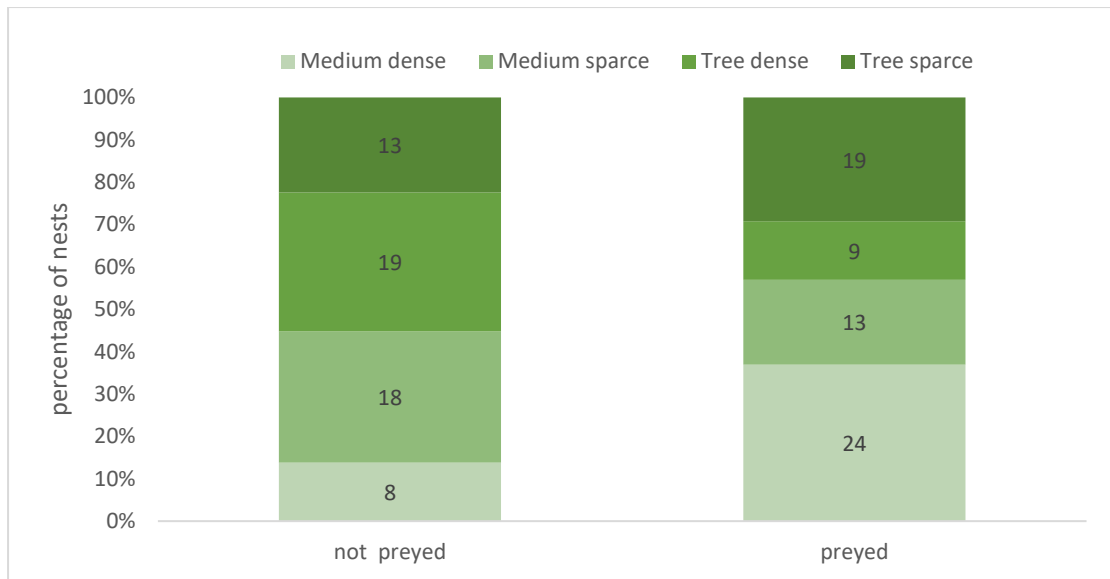
Figure 9: An overview of all the 123 nests in the predation experiment and their fate in the four different habitat types. The number of nests in each habitat type that had been preyed is marked.
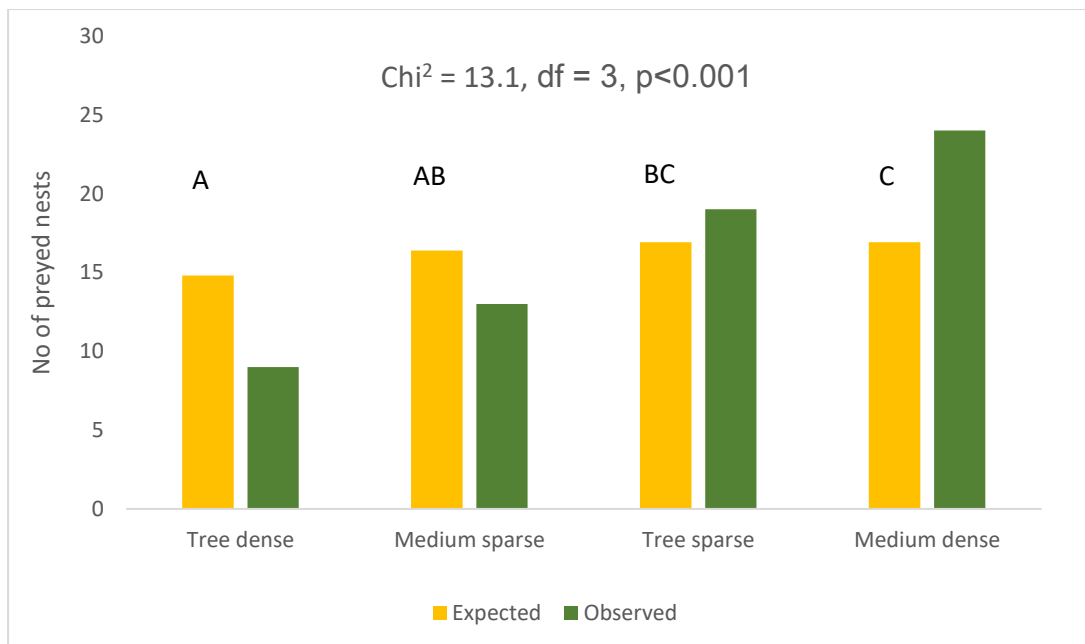
Figure 10: Observed and expected nests predation - The observed (green) and the expected (yellow) predation of nests (at random) in the four habitat types with the results of Chi square test. [A], [B], [C] are the groups of significant difference. Tree dense is different from the Tree

sparse and the Medium dense, Medium dense is different from Medium sparse and the Tree

dense (n= 123).

| Figure 11: the artificial nest distribution in Ramat Hanadiv Park and their fate (Red=prey, Green=un preyed) in each habitat type. | |
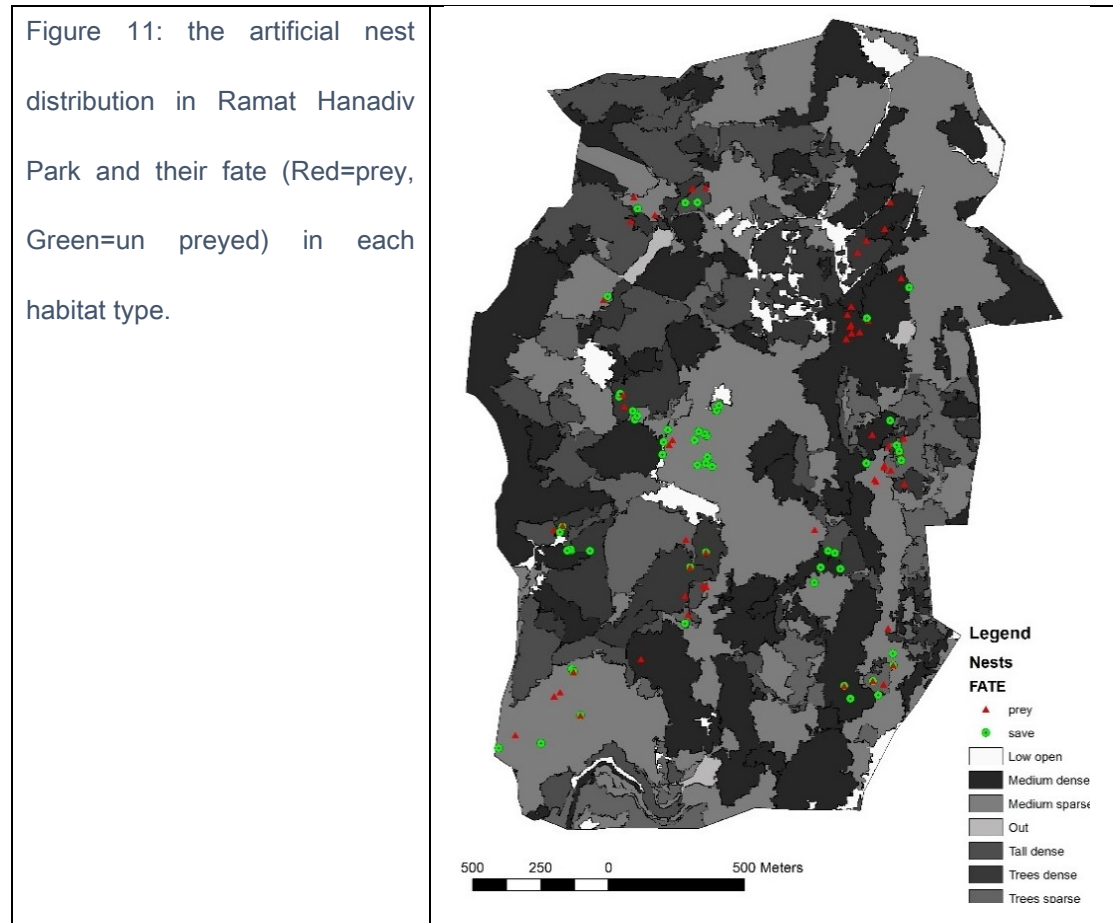
3.3.2. Predation events documented by trail cameras

I placed cameras on 48 artificial nests, 8-16 in each habitat type. I successfully

identified the predators in nine predation events (Fig. 12). The most common predator

identified from the cameras was the Eurasian jay (n=4) and the second (n=3) was

rodents from the *Muridae* family (it was difficult to make a clear identification). There

was also one observation of European glass lizard *(Pseudopus apodus)* and one of

undefined animal. In the preliminary experiments, I also observed Egyptian mongoose

(*Herpestes ichneumon*) preying on the eggs.

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Most of the identified predators were documented in the Medium dense (4) and were made by Euraisian jays. One event of the European glass lizard (*Pseudopus apodus*) was documented in the Tree sparse and three events of rodents were Identified in the Tree sparse and the Tree Dense habitat.
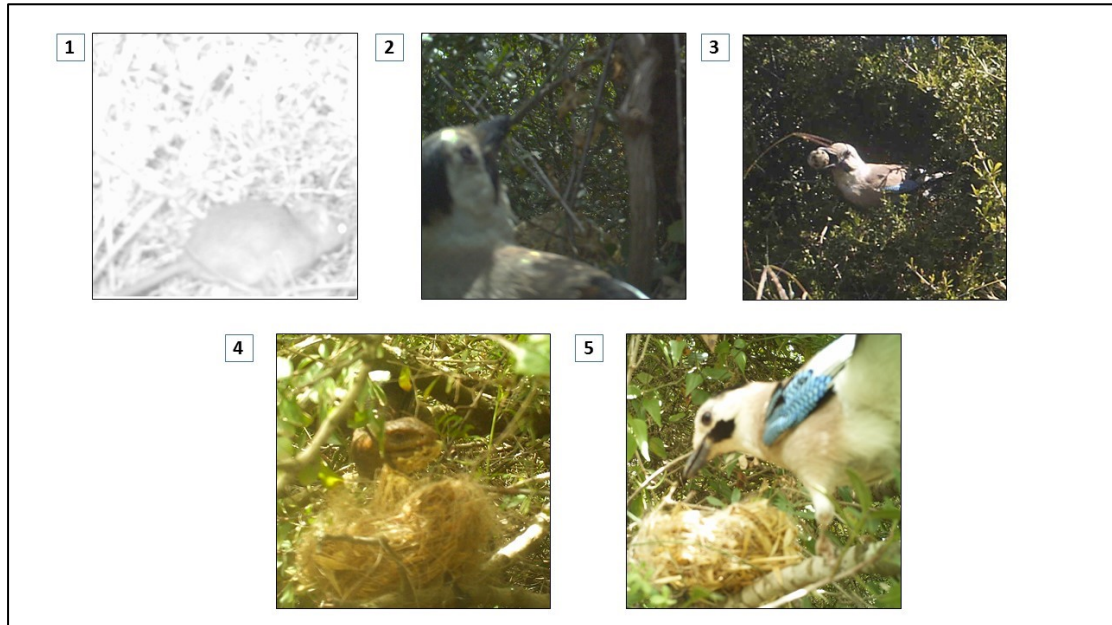
Figure 12: Pictures from the trail cameras from different predation events. [1] Black rat (*Rattus rattus*). [2,3,5] Eurasian jay (*Garrulus glandarius*), [4] European glass lizard (*Pseudopus apodus*).

3.3.3. Predation events based on remained signs

The plaster eggs were used in 48 nests during the second year of the research. I was able to identify four predators according to their marks on the eggs (Fig. 13). Another egg was unmeasurable due to too many tooth marks.

Figure 13: Plaster egg with teeth marks of: [1] white-breasted hedgehog (*Erinaceus concolor*) -clear mark of the canine, [2] different rodents (marks of the insectivores especially on the tip of the egg), marks of an avian predator. [3] triangle marks of bird's nails. [4] triangle marks of a wide beak and teeth marks by a European Glass Lizard (*Pseudopus apodus*) [5] marks of row symmetric teeth similar in size.

The main predator group that were identified from their signs on the plaster eggs were medium size mammals (8) and rodents (7). Avian (2) and reptiles (1, probably a Euraisian Glass Lizard) signs were also recorded. Some nests close to the cattle corral, disappeared with the shrubs around the nest site (3) (Fig. 14).

As was found with the quail eggs, many (n=12) nests ware disappeared / empty from all their eggs. Three more nests were lost because of cattle grazing (Fig. 13). One of the nests fall due to clumsy placement and the eggs were found with a Southern white-breasted hedgehog (*Erinaceus concolor*) tooth marks (Fig. 12). Eight nests were found with rodent's tooth marks with three size categories: 0.1 cm (3 nests), 0.2 cm (3 nests), 0.3 cm (1 nest). Two nests had distinctive avian marks with triangle bill shape. One of the nests had eggs with reptile tooth marks.
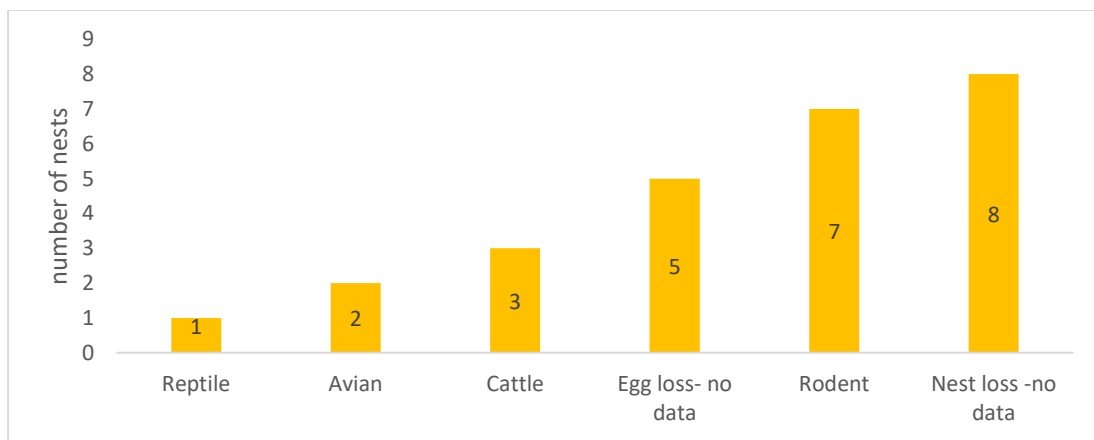

Figure 14: Nest predator guild as detected from the plaster eggs.: Egg loss – no egg were found in or around the nest, Rodent – rodent incisors teeth found on one of the eggs, Avian – claws or beak marks shown on one of the eggs, Reptile – reptile teeth marks were shown on one of

the eggs, Cattle – all the shrub that the nest was placed was eaten by the cattle, Nest loss- no data – all the nest disappeared.

Summary of all the predation events in this study (Fig 15) shows that the predators of almost half (43%) of the predation events were unidentified. The medium size mammals and rodents were the most common egg predators, then avian (ca. 10% of the identified predation events); reptiles were the rarest predators.

	Raptile	Cattle	Avian	Rodent	Nest loss-no data	Egg loss- no data
Series1	0.02739726	0.054794521	0.095890411	0.191780822	0.191780822	0.438356164
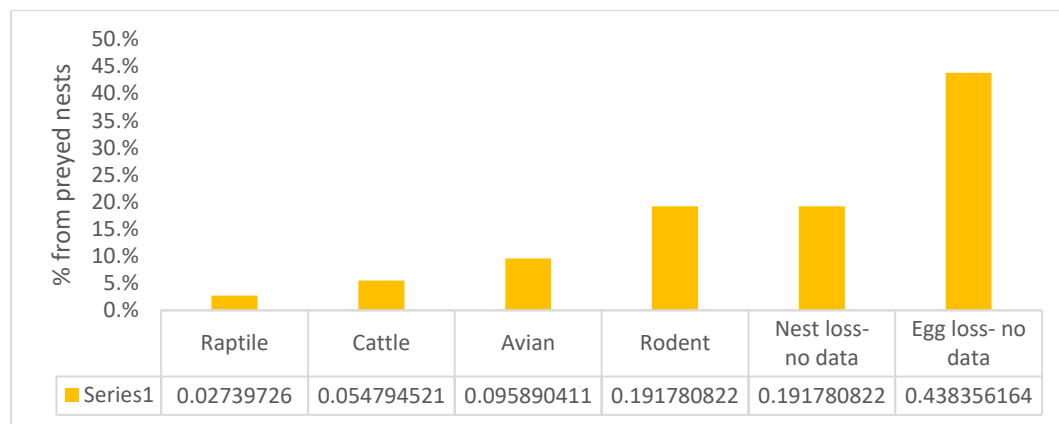
Figure 15: Predator guild - The fate of all documented preyed nests based on cameras, teeth marks on plaster eggs and the presence/absence of the preyed nest.

The proportion of the predator's guild in the four habitats are significantly different in Pearson's Chi squared test with simulated p-value (Chi^2 = 30.98, df = NA, P < 0.001) Most of the avian predation events were found in the Medium dense habitat. The portion of the nests that disappeared was highest in the Tree sparse habitat. Predation events by rodents and the Egg loss were almost evenly distributed in all the four habitats with a slight preference to the Medium dense. The eggs disappeared category (nest that were found without the eggs) had the lowest events in the Tree Dense habitat (Fig. 16)
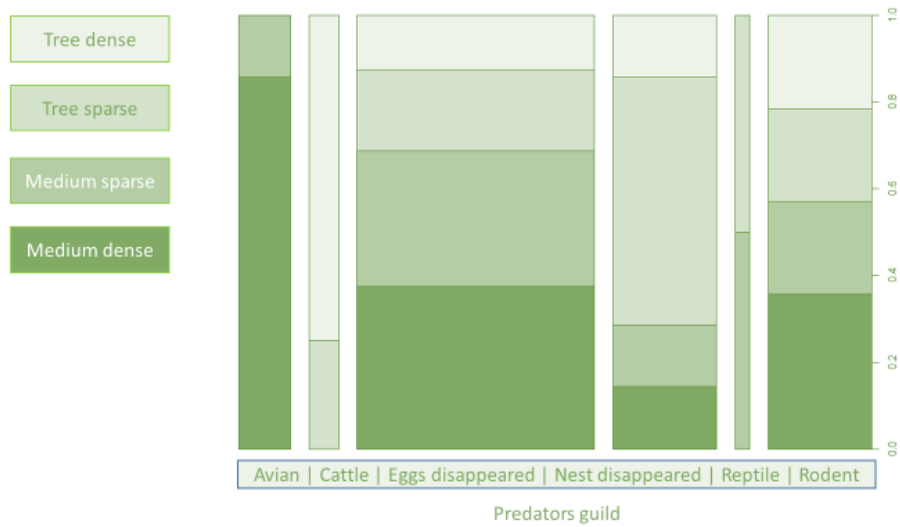
Figure 16 : The percentile of the predator guild in the four different habitat types. The Avian evidence were found mainly in the Medium dense, Cattel were found mostly in the Tree dense, Eggs disappearance mostly in the Medium sparse and the Medium sense. Nest disappearance was the highest in the Tree sparse and Rodents predation was the most evenly distributed predation in all the habitats with a slight preference to the Medium dense (Chi^2 = 30.98, df = NA, P < 0.001).

The proportion of the predator's guild in the three months of the three months of the experiments were significantly different in Pearson's Chi-squared test with simulated p-value (Chi^2 = 27.847, df = NA, P= 0.002). The Avian predation was mainly documented during March. Most nest disappearance occurred in April and the rodent predation was evenly spread along the breeding season (Fig 17).
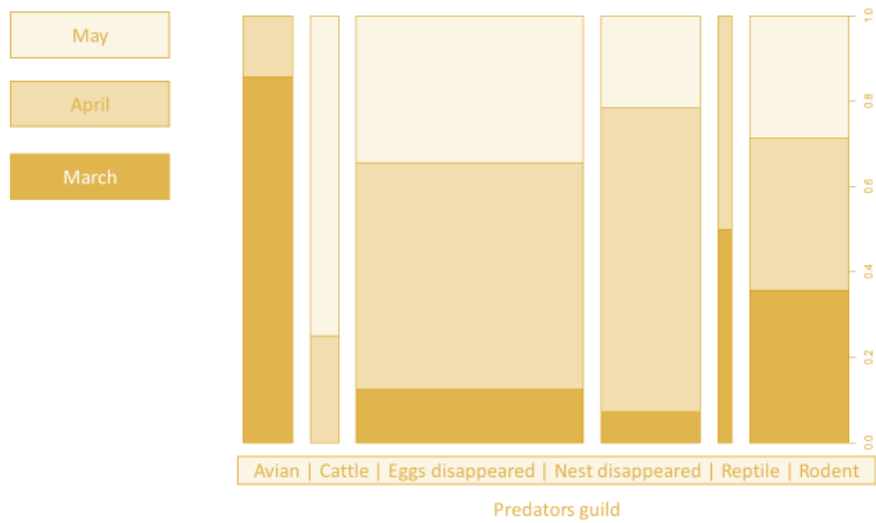
Figure 17: The proportion of predator guilds o all dummy nests and the month that the nest was stationed. Most of the avian predation occurred in March, most of the disappearance of eggs occurred in April and the rodent predation was spread evenly (Chi^2 = 27.847, df = NA, P= 0.002).

3.4. Indirect evidence of nest predation pressure

The Sardinian warbler mobbing calls and the Euraisian jay monitoring may indirectly indicate the predation pressure in the four habitat types.

3.4.1. Mobbing calls of Sardinian warbler monitoring

The number of mobbing calls was significantly different among the four habitat types (Kruskal-Wallis, Chi^2= 15.564, df=3, P=0.0014) whereas post-hoc with Wilcoxon tests and Bonferroni correction showed significant difference in the number of mobbing calls between the Medium sparse and the three over habitats Tree dense, Tree sparse and Medium dense (P= 0.0264). The highest number of mobbing calls was in the Tree sparse habitat and the lowest was in the Medium sparse (Fig. 18).
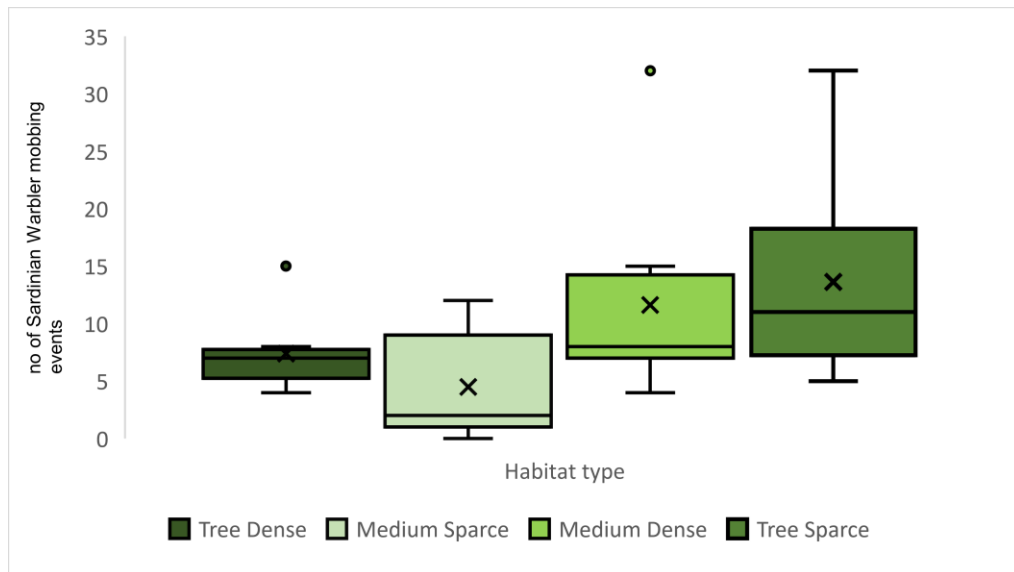
Figure 18: Mobbing events in the four habitat types - The distribution of Sardinian warbler mobbing events (X= mean, line=median) in each habitat type during 220 hours of recordings from 06:00-10:00 AM (n=88).

3.4.2. Jay presence in the different habitat types

During the two nesting seasons, I documented 67 sights of jay presence. In most of them the jays were on observation post (25) and flight (24). In 10 events, I documented the jays foraging in and around shrubs while other passerines were mobbing on them. In one case I recorded a jay that preyed on graceful pirinia nest (Fig. 19). I also found six nests of jays during the research, all of them were stationed on trees > 4 meters and four of them were stationed on pine trees. The number of sights was significantly different among the four habitat types (Chi^2 = 21.5, df = 3, P=0.01, Fig. 19). Most of the sights in the Medium Sparse were in flight and no nest robbing activity was documented. It was also the habitat with the lowest count of jays (12).

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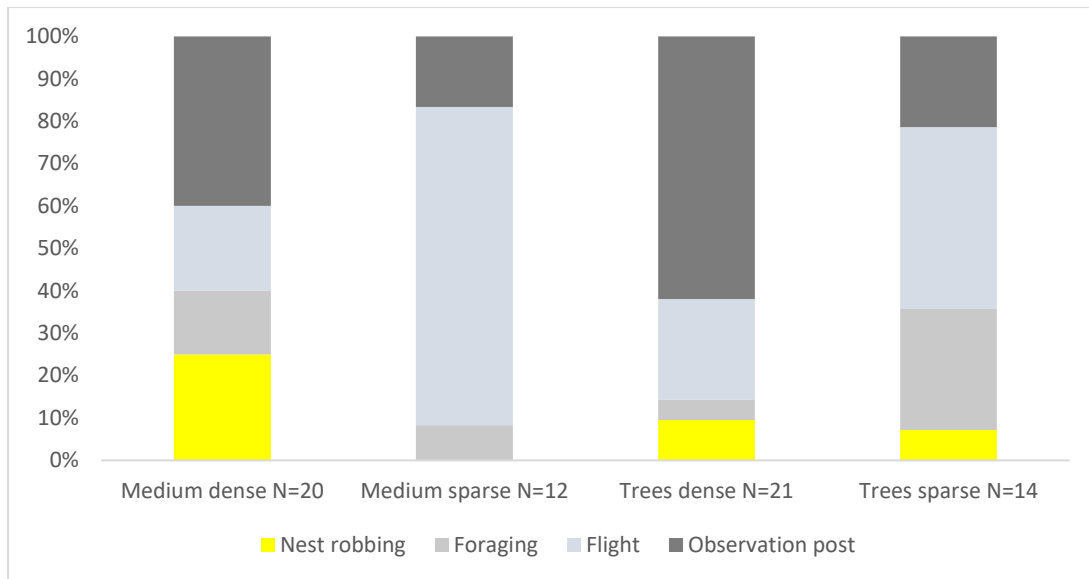
Figure 19: A summary of the Euraisian jay (*Garrulus glandarius*) observed during the study and their behavior in the four habitats. Most of the observed jays were on observation posts. In 10 cases the jays were forging in the shrubs with birds mobbing on them.

I found a higher number of jay calls that I identified from the acoustic monitoring in the Tree sparse and the lowest number of calls was found in the Medium sparse (Fig. 20). Yet, the number of jay calls were not significantly different between the four habitat types (Chi^2 =6.888, df = 3, P= 0.076).
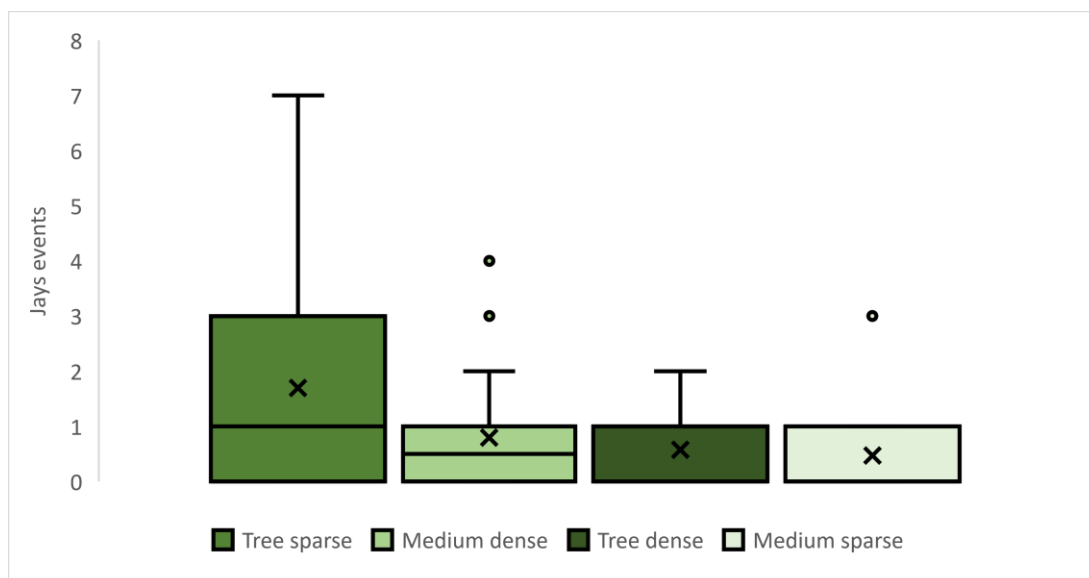
Figure 20: The distribution of Euraisian Jay (*Garrulus glandarius*) calls in the four habitats. The Tree sparse habitat with the highest presence of Euraisian Jay calls.

3.4.3. The association between jays and high trees

I calculated the correlation between the number of observed jays and the tree height within a buffer of 50 meters around the nests (pooling all habitat types). The results of Poisson regression model showed a significant (P<0.001) positive correlation between the number of pines > 3 meters' height and the number of observed jays in a 50-meter buffer around the nest (Fig. 21).
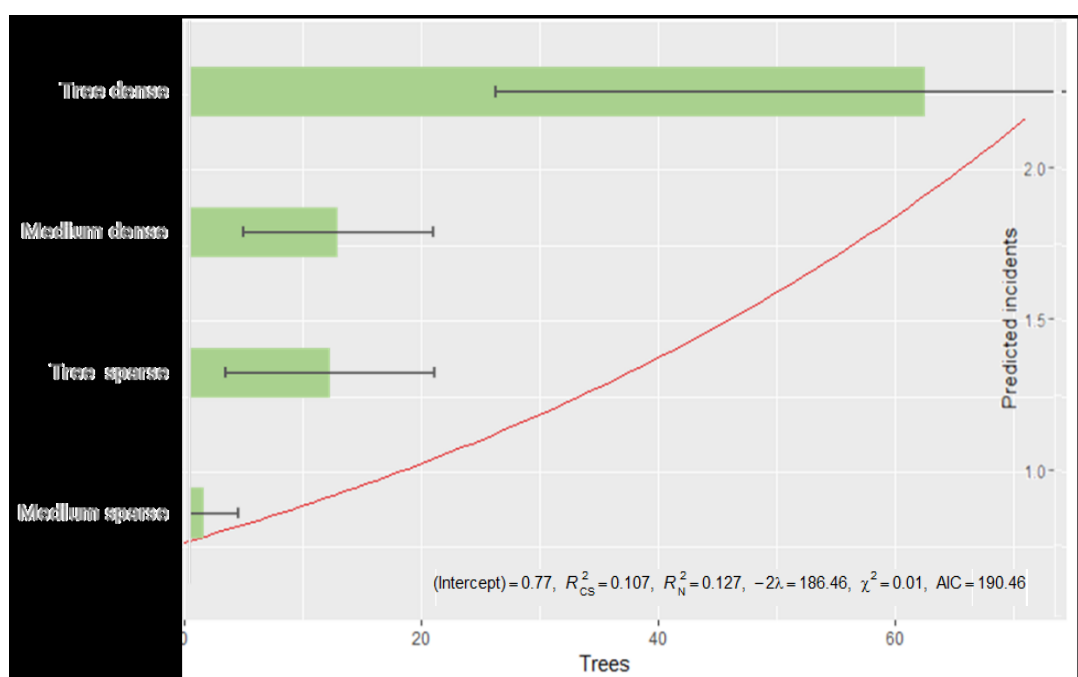
Figure 21: Predicted sighting of Euraisian jay (*Garrulus glandarius*) - The correlation between the number of jay's sighting and the number of trees above 3 meters analyzed by GLM with Poisson regression and the mean of the Pine and Cyprus trees count for each of the habitats.

3.5. A logistic model to predict the factors that affect nest predation

The logistic regression model showed that the Tree Dense (p=0.04) and the Medium sparse (p<0.001) habitats were the main variables that positively affected nest fate (less predation) whereas the Tree sparse had a negative effect on nest fate. The month in

which the nests were placed negatively affected nest fate (p=0.03), as we get deeper into the end of the nesting season the predation was higher (Fig. 22; Fig. 23).
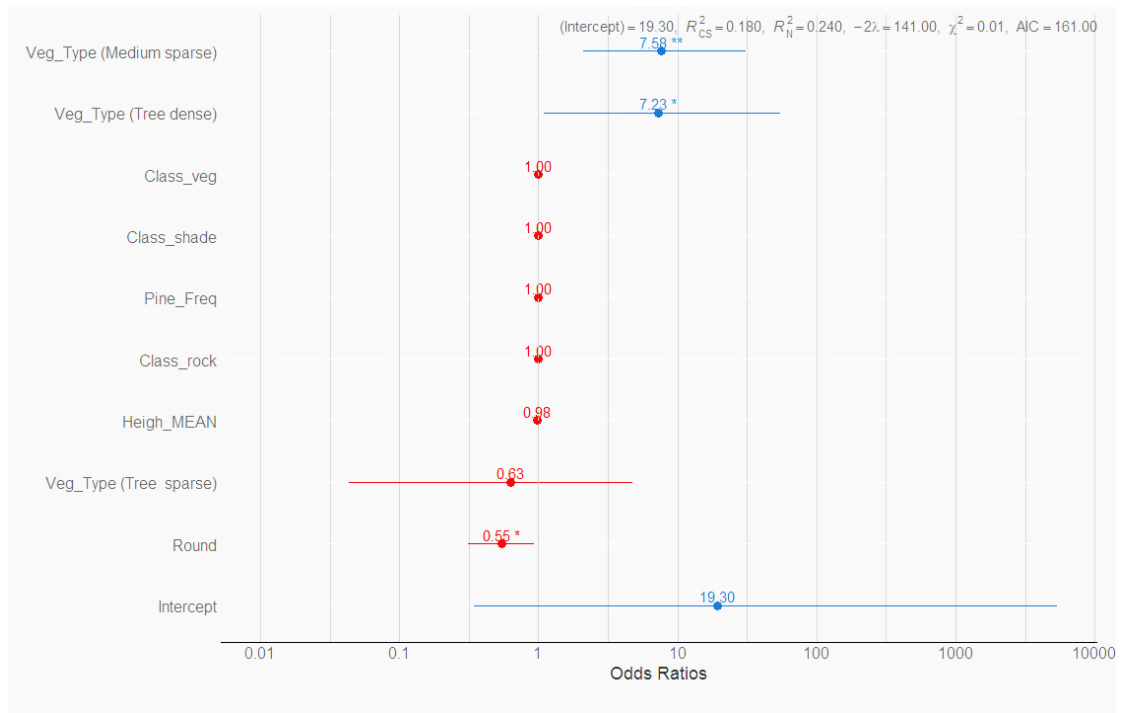
Figure 22: Summary of the different variables in the Logistic regression model and their effect on the odds of nests to be saved from predation. The blue variables have a positive effect on the model (increase the chance of a nest to be preyed). The red variables have a negative effect (increase the chance to be preyed). The * marks significant P value (P<0.05). Veg_Type =habitat type, Pine_Freq = number of pines in 50 meters' buffer from the nest, Class= classification from Ariel photo in 50 meters' buffer from the nest of Bremen and Cutler's Random forest classification, Heigh_MEAN= mean of vegetation height from LAIDR, Round= the months of the experiment.
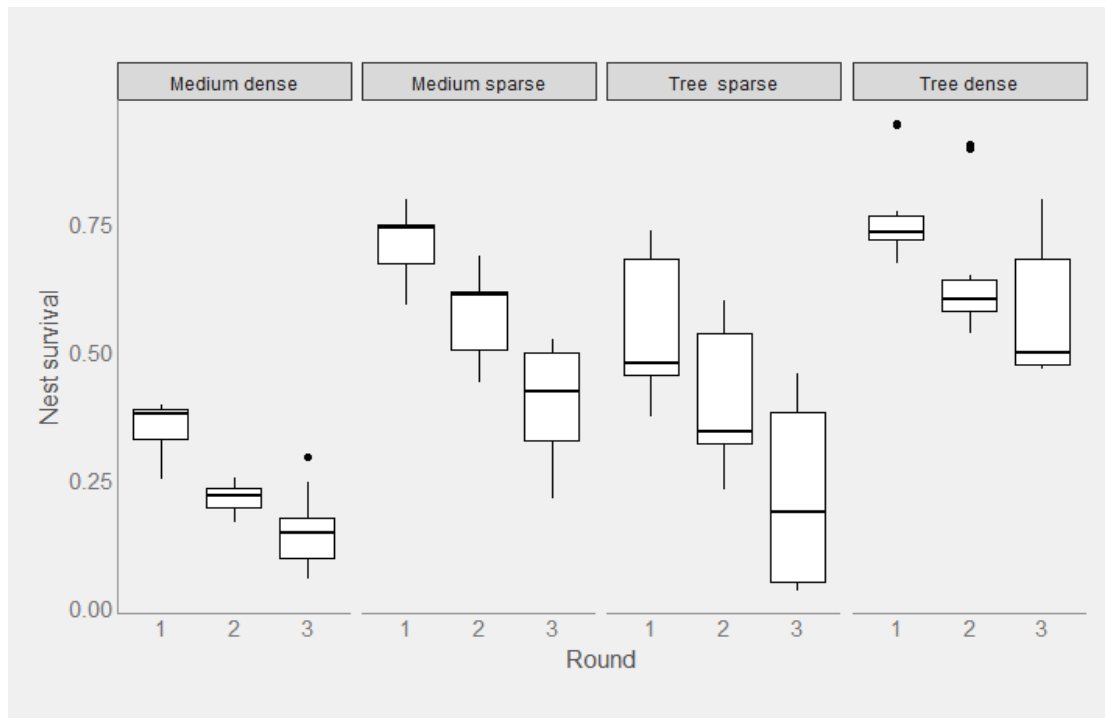
Figure 23: The predicted estimation of the nest survival of the model in the fore habitats and the three months of the experiments (Round) 1=March, 2=April, 3=May.

4. Discussion

The results show significant difference between the four habitats in the predation pressure and the mobbing events and a difference in the jay's activity in the four habitats.

4.1.0. Does the pine invasion influence the predatory pressures?

I showed a higher predation pressure in the Medium dense over the Medium sparse were the only significant difference between these two habitats were the density of 11.5 scattered standing pines in average around each nest in the Medium dense. The Tree dense habitat showed the least predations. The Tree sparse had higher predation than the Medium sparse but not significantly different than the Medium dense.

The highest predation pressure was observed in the Medium dense habitat. This can be explained by a combination of three different factors: food availability for the prey species, concealment and edge effect.

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1. Food availability for the Sardinian warbler (the most common passerine in the study area) is probably higher in the Medium sparse and Medium dense habitats with more insects to feed from and by that increase the quality of nesting sites in those habitats (Levanony 2005). I suggest that there are more seeds, fruits and more Arthropods for the birds, and more passerine nests to prey on for all predator types. All these increase the probability for encounter of predator and nest (Schmidt 1999; Barrio et al, 2015)

2. The higher foliage availability in the Medium dense and the Medium sparse habitats probably increases the available nesting sites for passerines and more nest concealment from predators.

3. The edge effect - predators may have benefited from the invasion of Aleppo pines and increase the predation pressure in a relative close buffer to the pines. Thus, we can look at each pine as a deformation of the habitat and the Medium dense and the Tree sparse as the most deformed and the most edge effected habitats. A recent study on the predation of nests in the European Alps found a positive correlation between the tree line and nest predation (Masoero et al. 2016). Furthermore, the Eurasian jay does not forage far from the forest patches. This may explain the low presence of the Eurasian jay in the Medium sparse habitat (Andren 1992). The research of Shochat et al. (2002) showed higher presence of the Euraisian jay in pine groves than in scrublands (Shochat et al. 2002). This research also showed the importance of the scrubland patch size to the presence of specialized scrubs warblers and might indicate an edge effect of the Euraisian jays on those specialized warblers.

The Logistic regression model shows that habitat type correlates with the odds of the nest to be preyed, the most significant out of the three habitats was the

Medium sparse. However, it could not be explained by any of the environmental parameters in separation of the habitat.

The fact that there was a correlation in the model between nest predation and the progress of the nesting season might be explained by declining nest concealment during the three months of the research which can be caused by cattle browsing and by the summer phenology of vines such as the Virgin's Bowe (*Clematis cirrhosa)* and the Common Madder *(Rubia tenuifolia.).* As we found in the preliminary results of this research and in the research of hooded warblers in (Howlett & Stutchbury 1996) the nest concealment is not the main nesting predation factor. I suggest that the main factor might be the probability of the predator to encounter the nest that might change by the preferred foraging habitat of the predator. Another study from Spain showed that nest predation in the Mediterranean forest increased with the leafing phenology in the vegetation (Santos & Telleria 1991). But it could be that the correlation that they show is just correlated with the nesting season and not truly correlated with the leafing phenology.

4.2. Does the presence of Eurasian jay's correlates with a higher predation pressure?

The results showed in more than one experiment that the presence of the Eurasian jay is correlated to pine trees especially in the Tree sparse habitat which also showed the highest mobbing events, but still not significantly different than the Medium dense. In the predator's guild, we see a high presence of mammals and avians.

My results on the identification of the main egg predators are different from findings that were reported for the European conifer forest (Andren 1992; Schaefer 2004) where corvids were found to be responsible for most (45-57%) predations and all mammals

together for less than 10% of the nest loss. My results are more like the results of studies from Spanish Mediterranean forests that reported a high proportion of rodents (> 50%) among artificial nest predators as well as corvids (>30%) (Carpio et al. 2016; Castro-Caro et al. 2014). The fact that the Sardinian warbler is nesting at 80 - 100cm height may also explain the large portion of mammals among its nest predators. The height of the nest enables medium sized mammals to reach the nest by bending the branches (Santos & Telleria 1991; Schmidt 1999). I can conclude that I found indications that the nest predator's guild in Ramat Hanadiv park is composed of a large portion of mammals.

The mobbing calls of the Sardinian warblers were more frequent in the Medium dense and in the Tree sparse habitats where I also detected higher egg predation. Although the difference between the Medium dense and the Tree sparse was not significant, the fact that the highest amount of mobbing calls was recorded in the Tree sparse habitat could be explained by the fear effect. In the current study, I also documented highest events of jay calls in the Tree sparse habitat. However, the mobbing calls may predict also the predator's presence and not preying attempts (Sandoval & Wilson 2012). The highest jay's presence was in the Tree dense and the tree sparse habitats. This fact shows that the jays presence is not the only factor that determine the predation pressure. In summary, the mobbing calls are positively correlated with the predation pressure and hence I suggest that the predation pressure in the Tree sparse and the Medium dense is the highest of the four different habitats (Table 4).

Table 4: A summary of the results of direct and indirect evidence for nest predation by Euraisian jays in the four habitats. The numbers within the table are categorical rank for each habitat in the difference experiments (1= lowest score, 3= highest score)

	Medium dense	Tree sparse	Tree dense	Medium sparse
Jay presence	3	2	3	1
Jay calls	3	3	2	1
Mobbing calls	3	3	2	1
Nest predation	3	3	1	2

Another direction that may explain this observation is the effect of the presence of the Euraisian jay on the predator's guild. Corvids aggressive mobbing behavior can affect the abundance of other predators especially near their nests (Baeyens 1981). Thus, their aggressive mobbing can decrease the foraging time of other predators in the Tree sparse habitat that will lead to decrease in nest predation.

The most unexpected result of this research was the positive? correlation between the nest predation and the progress of the nesting season. I explain this results by the cattle entrance to the study area in mid-March that might decrease nest concealment and introduce predators as golden jackals and Egyptian mongoose to the study plots (Grahn 1990; Shamoon 2016). However, I didn't find any statistical evidence for that. It could be also related to an increase mammal's presence as the kittens are growing and start to forage on their own.

The unknown predations could be divided into two categories: 1. Nest disappearance: the nests were tied to the branches with a zip tie.   to take the nest from its position should involve a great amount of force that can be ascribed to medium-large mammals (i.e. Egyptian mongoose, golden jackal, wild boar). 2. The eggs disappeared and

the nest was in his position. This predation can be ascribed to rodents/avian/reptile's predators. The high portion of the jay's predations and the nests where the eggs disappeared in the Medium dense may indicate that the excess predation was made by avian predators.

4.3. Conclusions

The results of this study indicate that there are three habitat categories in Ramat Hanadiv regarding egg predation: dense pine forest with the lowest predation, scrubland without pines with medium predation and sparse trees forest/scrubland with the highest predation. Although pine density is correlated to nest predation it seems that pine density alone does not govern as we have seen in the logistic regression model. It therefore seems that in the Medium dense habitat an optimal combination of these factors occurs (Hyper-Predation, Fig. 24).
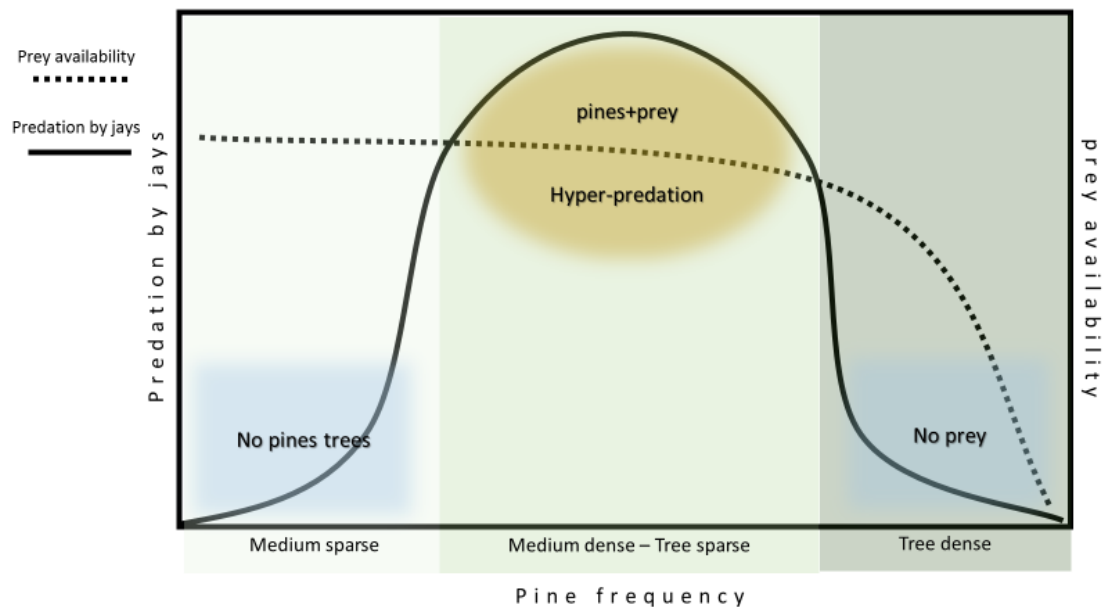
Figure 24: A theoretical explanation of the predation pressure by the Euraisian jay.

The fact that the habitat had such a strong significant in the model can indicate that the habitat size and its continuity are also important factors that helps to the jays to move with the "stepping stones" that the pines creates.

Schmidet (1999) suggested in a theoretical paper to look at the nest predation from an optimal foraging theory point of view (Schmidt 1999) and to the pine height as a factor that influences the foraging cost for the Euraisian jay. We can assume that in the Tree dense conceal the visual signals of active nest from the jays and in the Medium sparse the lack trees for high standing posts will increase the foraging cost/area.

As for the Aleppo pine invasion, the current study documented the first evidence of the trends that we might see in the passerine nesting population. In the near future, the invaded habitats can promote a larger and broader Eurasian jay's population and decline in the populations of open nest passerines. The mechanism of nest predation of passerines in the Mediterranean scrubland is yet to be understood. Further research should be made with 24/7 video monitoring on the nests to have a fully understanding of the predator's guild. I also recommend to study the optimal scrubland habitat for the Sardinian warbler. The patch sizes of the habitats were very small in our research and thus it would be wise to look on nest predation and correlation with pines in larger scales of 0.3, 1,2,5 kilometers as the foraging range of the Eurasian jay (Pons & Pausas 2008). We should also look on other avian predators as we might find that there are specialized predators to specific nesting niche (Martin 1988a) or that the behavior such as vigilance and food forging might affect the nest predation proportions (Schmidt 1999).

I can conclude from this research that there's a significant difference in the predation pressure on the artificial nests in close habitats that differ from each other only by presence of a few pines. I also show that the mobbing events of the Sardinian warbler differ significantly in the same way as the predation pressure in the four habitats and by indirect evidence we can assume the jays benefit from the presence of the pines.

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תקציר:

התנחלות אורן ירושלים (Pinus halepensis) לשטחי בתה, שיחייה וחורש טבעיים משנה את הרכב הצומח וגובהו. שינויים אלו עלולים לשנות את תנועת הטורפים ובכך להגביר את לחץ הטריפה על נטרפים. טריפה בעונת הקינון נחשבת לאחד מהגורמים המשמעותיים המשפיעים על גודל אוכלוסיית ציפורי שיר. במחקר זה בחנו כיצד התנחלות אורן ירושלים משפיעה על אוכלוסיות סבכי שחור ראש (Sylvia melanocephala) בשטחי שיחייה ברמת הנדיב. השערתנו הייתה כי התנחלות האורן עשויה להיטיב עם מין טורף, עורבני שחור כיפה (Garrulus glandarius) ובכך להגביר את לחץ הטריפה על סבכי שחור ראש. שאלת המחקר נבחנה בארבעה בתי גידול הנבדלים זה מזה בצפיפות האורנים באמצעות שתי שיטות: 1) הצבת קנים עם ביצי דמה וזיהוי טורפים על פי סימני טריפה על הביצים, 2) ניטור אקוסטי של קולות התגודדות של סבכי שחור ראש וקולות עורבני שחור כיפה. שיעור טריפת הקינים הגבוה ביותר נמצא בגריגה עם עצי אורן פזורים (75% מהקינים נטרפו) וביער אורנים פתוח (60%). לחץ הטריפה הנמוך ביותר נמצא בגריגה ללא אורנים (42%) ובחורשות אורן צפופות (32%). ניתוח הנתונים האקוסטיים מלמד על נוכחות שונה של עורבנים בין ארבעת בתי הגידול. קולותיהם נשמעו בתדירות גבוהה ביער אורנים הפזור ובגריגה עם עצי אורן פזורים. גם מספר קולות ההתגודדות של סבכי שחור ראש הגבוה ביותר היה ביער אורנים פתוח (13.6 אירועים בממוצע ל 40 מחזורי הקלטה) ובגריגה עם עצי אורן פזורים והנמוך בגריגה הפתוחה (4.5 אירועים בממוצע). מודל שנבנה לחיזוי הסיכוי לטריפת קן הראה כי תצורות הצומח עם אורנים פזורים והתקדמות עונת הקינון משפיעים באופן חיובי ומובהק על סיכויי הטריפה ונשללה השפעתם של משתנים סביבתיים בדידים כגון מספר האורנים, כיסוי צומח וגובה צמחייה. למרות שבין טורפי הקינים זיהינו מכרסמים וזוחלים אנו מעריכים כי הטריפה הגבוהה בשטחי הגריגה אליהם פלשו אורנים ובשטחי היער הפתוח קשורה לעורבנים. אנו מניחים שהעורבני משתמש בעצי האורן כנקודות תצפית על שטחי הגריגה ולכן גובר לחץ הטריפה על קני ציפורי שיר בשטחים אליהם פלשו אורנים.

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השפעת התנחלות אורן ירושלים (*Pinus halepensis*) על לחץ טריפה בקני ציפורים

עבודה זו הוגשה כעבודת גמר לתואר "מוסמך אוניברסיטה"

במסלול אקולוגיה וסביבה

ע"י

אסף בן דוד

מנחים:

פרופ' תמר דיין

פרופ' עדו יצחקי

פברואר 2017