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Goshawks *Accipiter gentilis* nest-tree and stand preferences in the Dadia-Lefkimi-Soufli forest, north-eastern Greece

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Abstract – Goshawk *Accipiter gentilis* preferences in terms of nest tree and nest stand (0.2 ha circle centred at nest tree) were studied at 23 nests in north-eastern Greece. Nest-tree and nest-stand characteristics were compared to those measured at paired, randomly selected plots. Goshawks usually nested in Calabrian pines *Pinus brutia* that were always dominant in the canopy. Trees at nest stands were taller, had greater diameter at breast height and were older than trees at random plots. The total tree density in goshawk nest-stands was lower, but the total tree basal area was greater compared to random plots. Goshawk nests were found at gentle and north-facing slopes in mature stands with high canopy closure. The importance of mature forest is emphasised for the maintenance of a stable goshawk population in the area.

Riassunto – *Selezione del sito di nidificazione nell'astore, a livello di albero e di struttura del bosco, nella foresta Dadia-Lefkimi-Soufli, Grecia nord-orientale*. Sono state studiate le preferenze a livello di albero e di struttura del bosco (in 0.2 ha intorno al nido), comparando 23 nidi con altrettanti siti selezionati casualmente. L'astore usualmente nidifica su pino bruzio (*Pinus brutia*), sempre in alberi dominanti. Il bosco nei pressi del nido è formato da alberi più alti, di maggior diametro, e più vecchi rispetto ai controlli. La densità del bosco è risultata invece minore, ma l'area basimetrica maggiore. I nidi si trovano su versanti dolci, esposti a nord, con copertura continua del bosco. Viene infine enfatizzata l'importanza dei boschi maturi per mantenere una popolazione stabile di astore nell'area.

INTRODUCTION

The goshawk is one of the most intensely studied species worldwide in terms of nest stand preference. Many studies have been concentrated on microhabitat features of nesting sites such as trees density, canopy closure, nesting tree species (e.g. Reynolds *et al*. 1982, Rosenfield *et al*. 1998) or macro habitat characteristics such as distances to human habitation, water and forest opening, slope location and slope orientation (e.g. Speiser and Bosakowski 1987, Bosakowski and Speiser 1994, Penteriani *et al*. 2001, Greenwald *et al*. 2005). However, few studies have analyzed goshawk nesting habitat selection in Mediterranean regions (e.g. Spain: Mañosa 1993; Italy: Penteriani and Faivre 1997) and so far none have occurred in Greece.

Goshawks generally prefer sites for nesting within mature and old-growth forests (Speiser and Bosakowski 1987, Squires and Ruggiero 1996, Penteriani and Faivre 1997), although more recent research has shown that they select stands with large-diameter trees and high canopy closure regardless of forest age (De Stefano 1998). The knowledge of a species' nesting requirements is an important ecological component for managing forests in order to maintain suitable sites and/or to influence the structure to create desired forest condition.

In this study, we describe: (1) the characteristics of the nest tree; (2) the structure of the forest around the nest tree; and (3) the features of the landscape surrounding goshawk's nest sites in the Dadia-Lefkimi-Soufli area (hereafter D-L-S).

METHODS

The D-L-S forested area is located in the central part of the Evros Province, northeastern Greece (southeastern

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ridge of the sierra of Rodopi; 40° 59'-41° 15' N, 26° 19'-26° 36' E). The area is characterized by the succession of small and large valleys, steep and gentle slopes and many streams and gullies (with elevations ranging from 10 to 700 m). The climate is sub-Mediterranean with a strong continental character of dry summers and cold winters. Mean monthly temperatures in the area range from 25°C in July to 4°C in January; mean annual precipitation is 664 mm.

The study area is composed by many different habitat types, such as agricultural lands, grasslands, shrub lands, rocky areas, pine forests (mainly Calabrian pine *Pinus brutia* and black pine *P. nigra*), oak forests (*Quercus frainetto*, *Q. pubescens*, *Q. sessiliflora* and *Q. cerris*) and mixed pine-oak forests (Bakaloudis *et al.* 1998). During the 2002 and 2003 field seasons, we found 23 Goshawk nests (10 pairs with 1 nest, 2 pairs with 2 nests and 3 pairs with 3 nests) by extensive exploratory surveys on foot (Fuller and Mosher 1987), although some nests were located due to the information from foresters and villagers.

All the data on nest-stand characteristics were collected during August and September of 2003, after fledging. We defined the nest stand as a circular plot of 0.2 ha (25 m radius) centered on the nest tree. We selected tree, stand and landscape parameters on the basis of their importance in the large birds of prey literature on the topic, as well as their use by forest managers. The data were grouped into three categories: (1) nest-tree and nest features, (2) stand characteristics at the nest-stand scale (0.2 ha) and (3) landscape characteristics. The same number (23) of randomly selected 0.2 ha plots were established in the neighboring area in order to compare nest-tree features, stand and landscape characteristics within the same forest stand. A "forest stand' was defined as the surrounding suitable wood covered area centered on the Goshawk tree. The same measurements were made on the randomly selected plots as in nest stands, except for variables concerning nest features. Each random plot was situated from 50 m to 400 m from the nest tree; a minimum distance of 50 m was taken to avoid overlap between the nest stand and random plots. In order to establish each random plot three steps were followed. Firstly, the forest-stand centered on the nest tree was divided into four quadrants (1=northeast, 2=southeast, 3=southwest and 4=northwest) and one of these was randomly selected. Secondly, two randomly selected numbers between 0 and 400 were taken to calculate the distance of the random plot along the NS and the EW axis accordingly. The intersection of the lines extending from these points identified the location of the center of the random plot. Finally, the closest dominant tree to this centered point similar in DBH size with the nest tree was selected. This tree was defined as the random nest tree and the center of the random plot was shifted so as to correspond with the location of this tree (Titus and Mosher 1981, Bakaloudis *et al.* 2000, 2001). When the random points identified a plot in non-forested areas, such as grasslands, shrublands and cultivated areas or in an area with only young trees, they were rejected and the above procedure was reinitiated.

Nest-tree and Nest Features

The nest tree was described by six parameters: (1) tree species; (2) diameter at breast height (DBH); (3) tree height; (4) trunk height to live canopy; (5) height of trunk without branches; and (6) tree age. The DBH was measured using a diameter tape and the age was measured using an increment-core by counting growth rings. All heights were measured with a Blumme-Leiss altimeter (accuracy ± 0.25 m). Canopy height of nest trees was estimated by subtracting the height of the bottom of the canopy to the ground from the tree height.

The height of nest above ground was also measured and the relative nest height (%) [(height of nest above ground / height of nest tree) * 100] was estimated.

Stand Characteristics

All tree species within nest plots were identified and categorized into nine diameter classes (10-14 cm, 15-20 cm, 21-25 cm, 26-30 cm, 31-35 cm, 36-40 cm, 41-45 cm, 46-52 cm, and > 52 cm). All saplings < 10 cm DBH and > 1.2 m tall were sampled.

We randomly selected three dominant trees in each plot in order to describe the structure of the habitat. Each tree was aged and measured for DBH, height and canopy height above ground. Each plot was divided into four quadrants using four cardinal directions for quadrant boundaries and a point-centered quarter method was used to measure distance to the tree (> 10 cm) nearest the nest tree in each quadrant.

In order to estimate canopy closure, a straight-line transect centered on the nest-tree was oriented randomly to avoid potential bias that might result from a systematic orientation of transect with respect to physiographic characteristics (Stumpf 1993). Ten points at intervals were sampled along the 50 m transect in each nest stand plot. At each point, percentage tree canopy cover (dominant, intermediate and suppressed) was estimated using a Geographic Resource Solutions vertical densitometer.

Landscape Characteristics

Percentage slope and slope orientation were measured using a clinometer and a compass, respectively. Elevation

of the site above sea level and position of site on slope (lower 1/3 of slope, middle 1/3 of slope and upper 1/3 of slope) were estimated by plotting the nests on 1:5000 scale topographic maps. Nest distance to water, nearest paved road and nearest rain water gully was estimated in the same way.

Statistical Analysis

All variables were tested for heterogeneity of variances using Bartlett's test (Zar 1996), and for normality using the Anderson-Darling test. Variables that did not meet the assumptions of homoscedasticity and normality were log-transformed prior to parametric analysis. Normally distributed variables were analyzed using paired-sample t-test, but those not meeting normality assumptions after transformation were analyzed using the non-parametric equivalent Wilcoxon matched-pair test. Nominal variables were compared using chi-squared analysis. Variables expressed as percentages were arcsine transformed to standardize variance. Circular variables were analyzed using Rayleigh's Z test for circular uniformity, and Watson-Williams test for comparing paired angular distributions (Zar 1996). All statistical analyses were performed using the Minitab statistical software (release 13.3) and differences were considered significant with $\alpha = 0.05$.

RESULTS

Nest-tree and Nest Features

All goshawk nests were found in Calabrian (82.6%) and black pines (17.4%). All nest trees were alive and dominant in the canopy (mean DBH = 45.6 cm, mean height = 19.6 m). Crown diameter, canopy height and DBH of nest trees were not different from random trees (Tab. 1). However, tree height, height to live canopy and tree age were significantly greater compared to random trees (Tab. 1). The mean height of nest above ground was 11.6 ± 0.5 m (range = 7.3 - 16 m) and the relative nest height was 59.3 ± 1.6% (range = 46.2 - 79.5%, CV = 13.3%).

Stand and Landscape Characteristics

Goshawk' s nest stands were generally found on gentle slopes 18.5 ± 1.8% (range = 7 - 40%), and this was significantly different from the slope of random plots 25.1 ± 2.5% (range = 5 - 48%) (t = 2.58, P = 0.017). Nest trees were significantly more likely to be found on a north-facing slope (mean aspect = 7.6°, mean angular deviation *s* = 60.4°, measure of concentration *r* = 0.44) than the randomly selected trees (mean aspect = 82.2°, mean angular deviation *s* = 68.4°, measure of concentration *r* = 0.29) (Watson-Williams test: F = 7.29, P < 0.01). Moreover, the distribution of slope orientation where the nesting trees were found deviated significantly from a random distribution (Rayleigh's test: z = 4.55, P < 0.01).

Nest stands were found at a wide range of elevations with a mean of 150.6 ± 14.5 m (range = 40 - 254 m), which did not differ from random sites 159.5 ± 15.2 m (range = 40 - 278 m) (t = 1.06, P = 0.30).

All nest plots were in pine stands dominated by Calabrian pine or black pine in the upper and middle storey and various oak species in the lower layer. The three randomly selected dominant trees in nest stands were significantly older, taller and had a larger DBH compared to those in random sites (Tab. 2). However, the three dominant trees had similar canopy height between nest and random stands.

Total tree density and the density of deciduous species were significantly lower in nest stands than in random stands (t = 3.35, P = 0.003 and t = 3.33, P = 0.003, respectively, Tab. 3). However, there was no difference between the total conifer density in nest and random stands (Tab. 3). Nest stands contained significantly fewer 10-25 cm DBH trees than random sites (P < 0.001, Tab. 3). There were no significant differences in the densities of 26-30 cm diameter or 31-35 cm diameter trees in nest and in random stands

Table 1. Characteristics (mean ± SE) of 23 Goshawk nest trees and 23 randomly selected trees in the D-L-S forests, northeastern Greece – *Caratteristiche (medie ± ES) dei 23 alberi nido comparate con quelle di alberi selezionati casualmente, nella foresta Dadia-Lefkimi-Soufli (D-L-S), Grecia nord-orientale*.

VARIABLES	NEST TREE	RANDOM TREE	t-*test*	p-VALUE
DBH (cm)	45.6 ± 1.89	42.1 ± 1.47	1.87	0.074
Height (m)	19.6 ± 0.67	17.5 ± 0.66	2.63	0.015
Height to live canopy (m)	9.80 ± 0.46	8.3 ± 0.62	2.59	0.017
Canopy height (m)	9.87 ± 0.58	9.16 ± 0.60	1.02	0.318
Height of trunk without limbs (m)	8.20 ± 0.42	6.9 ± 0.54	2.01	0.057
Age (yrs)	80 ± 3.50	68 ± 2.50	2.91	0.008

Table 2. Characteristics (mean ± SE) of three dominant trees selected from 23 Goshawk nest stands and 23 randomly selected plots, in D-L-S forests, northeastern Greece – *Caratteristiche (medie ± ES) di tre alberi dominanti prossimi a nidi di astore, comparate con quelle di altrettanti alberi selezionati casualmente, nella foresta D-L-S, Grecia nord-orientale.*

VARIABLES	NEST STAND	RANDOM SITE	t-*test*	p-VALUE
DBH (cm)	41.3 ± 0.9	36.1 ± 0.9	5.21	< 0.001
Height (m)	20 ± 0.4	16.9 ± 0.5	7.50	< 0.001
Canopy height (m)	9.9 ± 0.3	9.6 ± 0.4	6.47	0.312
Age (yrs)	78.4 ± 2.9	65.6 ± 2.3	3.64	0.001

(Tab. 3). Nest stands contained significantly more large (36-40 and 40-45 cm) and mature trees (46-52 cm) diameter classes (Tab. 3), which formed three of the four largest diameter classes and were only composed of Calabrian and black pine. The mean number of saplings was significantly lower in nest stands than in random stands (Tab. 3).

The average basal area of all trees at goshawk nest stands was significantly higher than at random sites ($P < 0.05$, Tab. 4). However, only the basal areas of large trees (36-45 cm DBH) and mature trees (46-52 cm DBH) were higher on nest stands than on random sites (Tab. 4). Total trunk basal area and trunk basal area of the conifer species were significantly higher on sites selected by goshawks for nesting compared to randomly selected sites, whereas the trunk basal area of the deciduous species was significantly lower on nest stands compared to the random ones (Tab. 4). Mean inter-tree distance around the nest tree was significantly larger at nest sites (6.3 ± 0.3 m) compared to random plots (5.3 ± 0.2 m) ($t = 2.71$, $P = 0.013$).

Mean canopy closure immediately adjacent to goshawks nest trees was significantly higher compared to that near randomly selected trees. Canopy cover in the dominant tree layer at nest stands (range = 33.2 - 90.1%) was significantly higher than that at random stands (range = 18.4 - 56.8%, matched-pairs Wilcoxon test: $W = 276$, $P < 0.001$). Canopy cover in the intermediate layer was lower at nest stands compared to the random ones but not significantly so, whereas canopy cover in the lower layer

Table 3. Tree and sapling density (mean ± SE) /0.2 ha at 23 Goshawk nest stands and 23 random plots in D-L-S forests, northeastern Greece – *Densità di alberi e di semenzali (medie ± ES) negli 0.2 ha intorno a nidi di astore, comparate con quelle di altrettanti siti selezionati casualmente, nella foresta D-L-S, Grecia nord-orientale.*

VARIABLES	NEST STAND	RANDOM SITE	t-*test*	p-VALUE
Total conifer density	42.2 ± 3.1	48.6 ± 6.1	0.29	< 0.774
Total deciduous density	20 ± 3.5	31.3 ± 4.4	3.33	< 0.003
Total tree density	62.1 ± 2.8	79.8 ± 5.5	3.35	0.003
Saplings	135.1 ± 17	185.3 ± 19.3	3.30	0.003
Thin pole trees				
Tree density 10-14 cm	12.9 ± 2.5	22.6 ± 3.3	5.14	< 0.001
Tree density 15-20 cm	8.5 ± 1.1	19.8 ± 2.9	4.84	< 0.001
Thick pole trees				
Tree density 21-25 cm	3.6 ± 0.6	10.9 ± 1.8	4.69	< 0.001
Tree density 26-30 cm	6.1 ± 1.1	8 ± 1.2	1.66	0.112
Large trees				
Tree density 31-35 cm	8.9 ± 1.3	6.3 ± 0.8	1.76	0.093
Tree density 36-40 cm	9.6 ± 1.1	4.7 ± 0.6	3.98	0.001
Tree density 41-45 cm	6.2 ± 0.7	3.1 ± 0.3	5.05	< 0.001
Mature trees				
Tree density 46-52 cm	4.3 ± 0.6	2.5 ± 0.5	2.11	0.04
Tree density > 52 cm	1.5 ± 0.3	1.8 ± 0.6	0.46	0.654

Table 4. Trunk basal area (mean ± SE) (m^2/0.2 ha) at 23 circular Goshawk nest stands and 23 random plots, in D-L-S forests, northeastern Greece – *Valori di area basimetrica (m^2/0.2 ha; medie ± ES) negli 0.2 ha intorno a nidi di astore, comparati con quelli di altrettanti siti selezionati casualmente, nella foresta D-L-S, Grecia nord-orientale*.

VARIABLES	NEST STAND	RANDOM SITE	t-*test*	p-VALUE
Total conifer BA	4.4 ± 0.2	3.4 ± 0.3	3.05	0.004
Total deciduous BA	0.4 ± 0.1	0.7 ± 0.1	3.95	0.001
Total tree BA	4.8 ± 0.2	4.1 ± 0.2	2.50	0.02
Thin pole trees				
Trees BA (10-14 cm)	0.1	0.3	4.29	< 0.001
Trees BA (15-20 cm)	0.2	0.5 ± 0.1	3.79	0.001
Thick pole trees				
Trees BA (21-25 cm)	0.1	0.4 ± 0.1	4.69	< 0.001
Trees BA (26-30 cm)	0.4 ± 0.1	0.5 ± 0.1	1.66	0.112
Large trees				
Trees BA (31-35 cm)	0.8 ± 0.1	0.5 ± 0.1	1.76	0.093
Trees BA (36-40 cm)	1.1 ± 0.1	0.5 ± 0.1	3.98	0.001
Trees BA (41-45 cm)	0.9 ± 0.1	0.4	5.05	< 0.001
Mature trees				
Trees BA (46-52 cm)	0.8 ± 0.1	0.5 ± 0.1	2.11	0.04
Trees BA >52 cm	0.4 ± 0.1	0.4 ± 0.1	0.46	0.654

was significantly lower at nest stands compared to random plots.

DISCUSSION

Goshawks in the D-L-S forests generally used the tallest trees available, which were usually also the oldest. Other researchers (e.g. Squires and Ruggiero 1996, Bosakowski *et al*. 1999, Penteriani and Faivre 1997, Penteriani *et al*. 2001) have also noted that goshawks tend to nest in the largest trees available. Goshawks were found to use mostly Calabrian pine trees, which generally have only a few, thick branches and often have triple or multiple primary crotches. Goshawks seem to prefer these tree characteristics for building their nests, as noted in previous studies (e.g., Speiser and Bosakowski 1987). In general, trees with forked or whorled branching seem to offer a suitable site for goshawk nest building (Reynolds *et al*. 1982, Squires and Ruggiero 1996).

The height of nests above ground was consistent with that reported in Penteriani's (2002) review of goshawk nesting habitat in Europe and North America (4.5 - 30 m). The mean relative nest height of goshawks in our study was 59.3% (range = 46.1 - 79.5%), which is consistent with those reported in previous studies (60.9% Penteriani 2002, 53.7% Speiser and Bosakowski 1987). The nests were built either against the trunk on a large branch or in crotches and were located within the foliage of nest trees, at the bottom of the crown. Many researchers (e.g., Speiser and Bosakowski 1987, Penteriani and Faivre 1997, Zawadzka and Zawadzki 1998, McGrath *et al*. 2003) have noted the location of the nests at the lower part of the crown. This may be associated with larger branches that can support the large goshawk nest and easier accessibility to goshawks approaching the nest below the canopy (Speiser and Bosakowski 1987). Furthermore, this location possibly provides protection to incubating females, eggs and nestlings from aerial avian predators (e.g., eagle owls *Bubo bubo*, common ravens *Corvus corax*, and hooded crows *Corvus cornix*, which are common in the study area (Bakaloudis *et al*. 2001).

Stands used by goshawks had higher total trunk basal area, higher canopy closure, fewer saplings, lower total tree density and more trees in the large diameter classes (31 - 52 cm) compared to random plots. These findings agree with those reported earlier by Speiser and Bosakowski (1987), Squires and Ruggiero (1996), Penteriani and Faivre (1997), Daw and DeStefano (2001), Penteriani *et al*. (2001) and Lõhmus (2005).Trees >52 cm were few in both nest sites and random plots and therefore there was no significant difference. Nest stands had a total tree

density of 200 - 420 trees/ha and a total basal area of 18.6 - 31.2 m^2/ha. Trees at nest stands were significantly older than those at random sites. These characteristics of mature forests (large trees, high canopy closure, low shrub cover) make them important to goshawks, as they offer suitable trees for nesting and the lack of a dense understory provides free flying space facilitating nest access. Many researchers, both in Europe and North America, have confirmed the species' apparent preference for mature and old-growth forests as nesting habitat. For example, the maturation of eastern United States forests has been suggested as a major factor in the recent southern range extension of the goshawk (Speiser and Bosakowski 1987, Kennedy 1997).

The average basal area of all trees was significantly higher at nest stands compared to random plots and the difference between used and random was an average 4 m^2/ha. McGrath *et al*. (2003) report differences of 7 - 11 m^2/ha between nest sites and random plots in a review of six goshawk studies in North America. Basal area differences are probably due to the different limit in biomass that the ground can support (Penteriani 2002).

High canopy closure around the nest stand may be a prime factor in nest site selection by goshawks; it protects the nest from wind and rain, reduces thermal loss during nighttime, and reduces excessive heating due to solar radiation during the day (Walsberg 1985). High canopy closure may also provide protection from the eagle owl, which prefers hunting at more open areas (Mikkola 1983) and is the goshawks' main predator in our study area. However, high canopy closure is a characteristic of old-growth stands, so it could be just a simple consequence of nesting in such stands and not a preference.

Goshawks nesting in D-L-S woodlands preferred nest trees on moderate slopes compared to those available. Similar findings have been reported by other researchers (Reynolds *et al*. 1982, Speiser and Bosakowski 1987, Squires and Ruggiero 1996, Penteriani and Faivre 1997) and may be associated with the availability of flight space (Penteriani and Faivre 1997). The preference for northern slopes has been recorded many times at temperate forests (Reynolds *et al*. 1982, Hayward and Escano 1989, Bosakowski and Speiser 1994, Penteriani and Faivre 1997, Penteriani *et al*. 2001, McGrath *et al*. 2003). Northern and eastern exposures offer a more stable environment as the input of radiant energy is lower compared to southern and western exposures (Kennedy 1988). Our findings, that goshawks place their nests in mature forests, dominated by old Calabrian pine on north-facing slopes, stands with low tree density, high canopy closure and high basal area suggest the importance of mature forests for maintenance of stable goshawk populations in the area. Penteriani and Faivre (2001) in a study in two European areas concluded that goshawks have long-term fidelity to the nesting stand in the absence of severe habitat degradation and can tolerate some level of timber harvesting within the nesting stand. As the D-L-S forests are managed with the shelterwood system and given the fact that the area supports approximately 22 different breeding raptor species, most of which prefer mature forest stands for nesting, the primary goal of a management plan should be the conservation of mature forests in order to support their populations. Therefore, management should not be framed in terms of single species management, but rather in an ecosystem context considering as wide a range of wildlife species requirements as possible in the area.

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