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Goshawk nesting habitat in Europe and North America: a review

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I review Goshawk *Accipiter gentilis* nesting habitats in Europe and North America. The aims of this review are to (1) summarise the knowledge on Goshawk nesting habitats, (2) identify habitat features common to the Nearctic and Palearctic, and (3) assess the need for further research describing Goshawk nest sites and propose future directions for research on its habitat needs. Goshawks generally select a tall tree that offers good support for the nest within a mature stand. The diameter at breast height of the nest tree was the only parameter significantly different in the nest tree *vs.* nest stand trees comparison among studies. The investigated Holarctic populations are similar in nesting habitat preference, and there seem to be no features that distinguish nesting habitat preferences in the Nearctic from those in the Palearctic. Further studies on Goshawk habitat use and preference may be justified only if they cover a wide range of levels, to better understand the factors guiding the nesting habitat selection of the species. The evidences of such a review can help to preserve the stands in which Goshawks reproduce. For example, the data provided by my work could be considered: (a) in the conservation or creation of the goshawk's nesting stands and (b) in the planning of buffer areas of old trees around the nest tree during logging.

1. Introduction

Goshawk *Accipiter gentilis* has a Holarctic distribution, occupying a wide variety of forest habitats from sea level to tree line. Their range includes forests below the arctic tree line, south to temperate regions. Only at the border of the arctic region, where tall trees are not available, are nests placed quite low, even on rocks (Pleske 1886) or on the ground (Wattel 1973).

Over the past two decades, ornithologists have described more than 300 variables in their studies on Goshawk nesting habitat use (quantitative and qualitative descriptions of nest sites) and preference (descriptions of nest sites compared with available resources, Hall *et al.* 1997, Jones 2001). Because of Goshawks' possible vulnerability to structural alterations of forest stands (Reynolds 1983, Kennedy 1988,1997, Crocker-Bedford 1990, Penteriani 1997, Widén 1997), much research has focused on providing practical advice to forest managers to safeguard Goshawks and their habitat (Reynolds *et al.* 1992, Penteriani 1993, Graham *et al.* 1994, Braun *et al.* 1996, Iverson *et al.* 1996, Penteriani & Faivre 2001).

The impressive amount of literature produced by European and North American researchers lacks Nearctic *vs.* Palearctic comparisons of habitat features, and is difficult to summarize because of the variable behaviour of Goshawks. To improve the global perspective on the species, here I summarise and analyse literature on Goshawk nesting habitat.

This paper reviews European and North American studies of Goshawk nesting habitat use and preference at several spatial scales, and aims to (1) summarize the existing knowledge of nesting habitats; (2) compare nesting habitat preference in North America and Europe; (3) evaluate the need and future directions for research describing Goshawk nesting habitat.

2. Methods

I reviewed 43 published accounts, such as articles, theses and technical reports (28 from North America and 15 from Europe), of data on Goshawk nesting habitat use and preference. To my knowledge, the scientific literature and unpublished reports I used for this review constitute the main body of studies on Goshawk nesting habitat that is possible to obtain during standard bibliographic inquiry (e.g., Zoological Record, Biological Abstract, CD-ROMs of bibliography, references within articles, etc.). Sometimes, several publications dealt with a pertinent subject, but not in a manner suitable in my comparisons (e.g., qualitative description only). I did not use a minimum sample size as a "quality control" for including studies in the review because the subjectivity of the threshold I could decide and to avoid losing information for countries in which the studies were carried out on a small sample size of nests (range = 10–74 nests, $\bar{x}$ = 29.2 nests per study, n = 43 studies reviewed).

Because of considerable variation in parameters and number of categories used to describe nesting habitats, I selected the most frequently used for the review. For each habitat variable, I calculated the mean of the different study means (in these cases, n = number of studies). Mann-Whitney U-tests were used to determine whether (1) nest tree and nest stand characteristics may differ between North America and Europe, (2) frequently measured tree parameters, which are often different between the nest trees and the nest stand trees, may also differ in the comparison among studies, (3) frequently used nest site parameters, which are often significantly different from local control sites, may also differ in the comparison between nest site and control plots of the various studies. The nest stand is defined as the portion of forest in which a species reproduces and that is characterised by a homogeneous structure and age. More generally, the nest stand is also defined as nest site.

3. Results and discussion

3.1. Study designs

From the 43 studies reviewed, only nine compared nest site habitat with habitat availability (Fig. 1, bold numbers). Descriptions of nesting habitat alone provide information on what a species uses for nesting, but data concerning availability are needed to determine habitat preferences, i.e., whether the chosen resources are used in a way disproportionate to their availability (see Jones 2001).

I reviewed six studies quantifying nest site preference at the stand level where plot size was large enough to describe stand structure (Fig. 1, underlined numbers). Generally, a standard 0.04 ha plot (James & Shugart 1970) or a 0.08 ha plot was used in the majority of Goshawk stand evaluations. I agree with Santana *et al.* (1986) and Speiser and Bosakowski (1987) that 0.04 and 0.08 ha plots are not large enough to provide an accurate assessment of stand structure surrounding nest tree. Actually, Goshawks often use stands where the distance between trunks and crown diameter are larger than this plot radius (Penteriani & Faivre 1997, Penteriani *et al.* 2001). This makes the sample of stands to be described too small to be reliable for several of the study purposes (e.g., forest management). Researchers have rarely used control plots (i.e. randomly selected plots) that are useful for nest stand management practices (i.e., non-random, outside or within the same stand as the nest tree one, like Hall 1984, Ingraldi & MacVean 1995, Squires & Ruggiero 1996, Penteriani & Faivre 1997, Penteriani 1999a, Daw & DeStefano 2001, Penteriani *et al.* 2001). When control plots are selected close to the nest tree, and in the same nest stand, it is possible to deter-

Sources: 1 = Bartelt 1977, 2 = McGowan 1975, 3 = Allen 1978, 4 = Nore 1979, 5 = Perco & Benussi 1981, 6 = Reynolds *et al.* 1982, 7 = Saunders 1982, 8 = Moore & Henny 1983, 9 = Benussi & Perco 1984, 10 = Hall 1984, 11 = Kalabér 1984, 12 = Bloom *et al.* 1986, 13 = Fischer 1986, 14 = Kostrzewa 1987, 15 = Speiser & Bosakowski 1987, 16 = Crocker-Bedford & Chaney 1988, 17 = Kennedy 1988, 18 = Anonymous 1989, 19 = Hayward & Escano 1989, 20 = Joy 1990, 21 = Patla 1991, 22 = Zanghellini & Fasola 1991, 23 = Mañosa 1993, 24 = Bosakowski & Speiser 1994, 25 = Bull & Hohmann 1994, 26 = Younk & Bechard 1994, 27 = Lilieholm *et al.* 1994, 28 = Titus *et al.* 1994, 29 = Ingraldi & McVean 1995, 30 = Siders 1995, 31 = Iverson *et al.* 1996, 32 = Siders & Kennedy 1996, 33 = Squires & Ruggiero 1996, 34 = Penteriani & Faivre 1997, 35 = Selås 1997, 36 = Squires & Reynolds 1997, 37 = Toyne 1997, 38 = Daw *et al.*1998, 39 = Rosenfield *et al.* 1998, 40 = Bosakowski 1999, 41 = Bosakowski *et al.* 1999, 42 = Penteriani *et al.* 2001, 43 = Daw & DeStefano 2001.

Figure 1. Location of Goshawk study areas in the Holarctic region. Bold numbers refer to studies (n = 9) comparing nest site habitat with habitat availability. Underlined numbers refer to studies (n = 6) that quantified nest site preference at the stand level by using plot size large enough to describe stand structure. When the same study considered both the above the cited element is bold and underlined.

mine whether Goshawks choose only a limited portion of the stand, characterized by a specific structure (Penteriani & Faivre 1997, Penteriani *et al.* 2001).

Few studies rely on systematic nest searches in order to avoid biased habitat characterizations (except for Crocker-Bedford & Chaney 1988, Squires & Ruggiero 1996, Penteriani & Faivre 1997, Daw *et al.* 1998, Penteriani *et al.* 2001). Too frequently, researchers seek out specific stand structures they believe Goshawks use before they begin searching for nests (Daw *et al.* 1998). To avoid biases in describing nesting habitat (Schaffer & Holroyd 1996), nest searches should be based on a rigorous sampling protocol that accounts for the full range of possible habitat use by Goshawks.

One of the most evident features of nesting habitat studies is the huge number of parameters used to describe the nesting habitat. This approach has some intrinsic problems. The arbitrary and complicated nature of some parameters (i.e., tree density classes, grass cover on the ground, diameter of dead limbs) makes it very difficult to compare studies and to get an overall picture of the nesting habitat features that are genuinely important.

3.2. Nesting habitat characteristics

3.2.1. Nest tree and nest stand

Research to date shows that Goshawks generally nest (1) in one of the largest trees among the available stand trees; (2) at two-thirds tree height and against the trunk; (3) at a wide range of elevations, from about sea level to over 3000 m; (4) in the lower or middle part of gentle northern slopes; (5) within the most mature portions (usually from 80 to > 200 yr) of a forest stand; (6) below a dense canopy; and (7) near natural or man-made flight corridors and/or in a stand with plenty of flight space (see also Tables 1 and 2).

A nest is typically built at about two-thirds of tree height, where large-diameter branches can provide a wide and stable nest support. The nest position below or within the lower canopy permits a wider view of the stand from the nest and may increase accessibility (Hall 1984, Speiser & Bosakowski 1987). Moreover, as noted by Crocker-Bedford and Chaney (1988), this typical nest position could benefit the microclimatic features present at the base of the overstory canopy (Geiger 1966).

Nest stands were generally found on gentle slopes (Siders 1995, Squires & Ruggiero 1996;

Table 1. Goshawk nest and nest tree characteristics in the Holarctic region.

Parameter		x̄ ± SD	Range	Sources[a]
Nest height in conifers (m)		15.7 ± 3.0	–	18, 21
Nest height in broadleaves (m)		17.7 ± 4.1	–	18, 21
Nest height in conifers or broadleaves (m)		16.6 ± 3.0	4.5–30.0	2, 5, 8, 6, 10, 11, 12, 14, 15, 16, 18, 22, 25, 28, 29, 33, 34, 39, 42
Relative nest height in conifers or broadleaves (%)		60.9 ± 6.4	53.7–69.4	15, 18, 33, 34, 39
Nest elevation (m a.s.l.)		1183.0 ± 931.8	129.0–3100.0	5, 6, 10, 11, 12, 15, 21, 22, 24, 28, 26, 30, 33, 34, 37
Nest tree dbh (cm)		53.1 ± 16.4	31.6–91.0	3, 6, 7, 8, 10, 14, 15, 17, 18, 19, 20, 23, 25, 28, 30, 32, 33, 34, 39, 41, 42
Nest tree height (m)		26.7 ± 7.6	14.0–43.0	1, 4, 6, 7, 10, 13, 14, 15, 17, 18, 19, 20, 23, 25, 30, 32, 33, 34, 39, 42
Canopy cover at nest (%)		76.0 ± 19.7	42.0–92.1	10, 25, 30, 32, 34
Mean distance nest tree-nearest tree (m)		7.6 ± 1.5	1.1–16.7	34, 42
Nest position on slope (%):	Flat ground	8.0 ± 5.5	1.0–15.8	21, 22, 23, 29
	Lower third	33.9 ± 26.7	3.0–75.0	21, 23, 25, 29, 34, 42
	Middle third	37.5 ± 20.6	3.0–76.6	21, 23, 25, 29, 34, 42
	Upper third	22.1 ± 18.2	0.0–53.0	21, 23, 25, 29, 34, 42
Nest exposure (%):	north	15.3 ± 5.7	8.8–19.0	8, 21, 22
	northeast	22.8 ± 20.7	5.9–52.9	8, 9, 21, 22
	east	15.0 ± 4.5	11.8–18.2	8, 21, 22
	southeast	23.3 ± 12.6	9.5–39.2	8, 9, 21, 22
	south	17.8 ± 12.3	9.1–26.5	8, 21, 22
	southwest	9.3 ± 3.6	5.9–14.3	8, 9, 21, 22
	west	14.8 ± 12.7	5.9–23.8	8, 21
	northwest	12.3 ± 5.8	8.8–19.0	8, 21, 22
Nest distance (m) to:	unpaved road	08.0 ± 15.3	97.2–118.8	14, 15
	path	394.6 ± 783.3	11.2–1794.9	14, 22, 31, 34, 42
	paved road	1139.9 ± 504.5	579.0–1784.2	14, 22, 24, 31, 34, 42
	built-up area	1919.0 ± 995.2	862.0–3304.0	9, 15, 22, 24, 34, 42
	water	277.4 ± 343.4	70.0–1291.0	6, 10, 14, 15, 21, 22, 24, 25, 26, 31, 34
	forest opening	600.9 ± 672.7	163.3–1375.5	14, 24, 31
	wood edge	474.0 ± 387.6	76.6–1002.5	14, 31, 34, 42

[a] Sources: see Fig. 1.

Table 2), significantly different from the ones in control plots (Penteriani & Faivre 1997). As Goshawks often fly below the canopy, available flight space is the area between the ground (or shrubs) and the lower canopy. When slopes are steep, the canopy of trees is at the same height as the trunks of the upslope trees, thereby reducing flight space.

Nest stands were recorded at a wide range of elevations (Table 1), probably because of a choice of the nest stand mainly determined by the forest structure (Penteriani & Faivre 1997), although in cold climates lower altitudes seem to be preferred (Titus *et al.* 1994).

Preference for exposure seems to be latitude and temperature dependent (Table 2). Actually, although (1) northerly slope use by Goshawk was higher than availability in Siders (1995), (2) it avoided southerly slopes in Speiser and Bosakowski (1987) and Hall (1984), and (3) the high occupancy percentages of northerly slopes (100% in Younk & Bechard 1994; 75% in Bull & Hohmann 1994; Reynolds *et al.* 1992, Penteriani & Faivre 1997, Penteriani 1999a), in Alaska and Norway did Goshawks prefer southerly exposures for nest stands (McGowan 1975, Titus *et al.* 1994, Selås 1997). This is probably due to the warmer temperatures on south-facing slopes. Moreover, Crocker-Bedford and Chaney (1988) found frequent nesting on southern aspects at high elevations in Arizona, which they attributed to larger trees growing on southern aspects at high, cool elevation. This likely also applies to the northern portions of the species range. Reynolds *et al.* (1982) and Kennedy (1988) suggest that northern and eastern exposures are characterized by a lower input of radiant energy, which results in a more stable environment than southern and western exposures, thereby minimizing the heat loading of nestlings (Kennedy 1988). Siders' (1995) landscape analysis of thermal conditions in which Goshawks were found confirms this preference for cooler areas.

Goshawks use several species of trees including 22 conifer species (13 studies) and 16 broadleaved species (11 studies). In most studies, comparisons of use with availability were lacking or these comparisons were made but researchers indicated that use is in proportion to availability, showing an opportunistic use of these elements (Siders 1995). Tree species use is likely to mirror

Table 2. Goshawk nest stand characteristics in the Holarctic Region.

Parameter		x̄ ± SD	Range	Sources[a]
Tree dbh (cm)		37.7 ± 25.8	14.8–122.0	6, 7, 8, 10, 13, 17, 18, 22, 23, 27, 29, 30, 32, 34, 39, 42
Tree height (m)		21.6 ± 3.5	15.3–25.9	6, 16, 22, 29, 30, 33, 34, 42
Trunk height (m)		11.1 ± 4.7	6.0–22.0	10, 22, 23, 34, 42
Canopy volume (m^3)		1654.2 ± 1501.9	188.4–5333.6	34, 42
Canopy cover (%)		71.9 ± 11.3	49.6–95.0	6, 7, 8, 10, 13, 14, 16, 31, 32, 34, 33, 38, 39
Basal area (m^2/ha)		38.3 ± 24.5	4.2–90.0	3, 8, 10, 15, 16, 19, 23, 29, 30, 32, 33, 34, 39
Distance between trees (m)		5.7 ± 1.7	3.0–7.8	10, 18, 22, 30, 32, 34
Tree density (stems/ha)		647.1 ± 441.1	16.4–1324.0	6, 7, 8, 10, 13, 17,19, 23, 30, 32, 34, 38, 39
Slope gradient (degrees)		13.0 ± 5.6	6.2–19.0	15, 21, 28, 24, 34, 39, 42
Slope exposure (%):	north	20.5 ± 18.8	2.4–50.8	8, 15, 21, 23, 24, 34, 42
	northeast	25.3 ± 25.6	4.3–73.3	8, 15, 21, 23, 24, 34, 42
	east	13.3 ± 8.6	0.0–23.5	8, 15, 21, 23, 24, 34, 42
	southeast	5.0 ± 6.3	0.0–13.0	8, 15, 21, 23, 24, 34, 42
	south	2.3 ± 4.5	0.0–11.8	8, 15, 21, 23, 24, 34, 42
	southwest	3.9 ± 3.8	0.0–8.7	8, 15, 21, 23, 24, 34, 42
	west	12.3 ± 9.6	0.0–23.5	8, 15, 21, 23, 24, 34, 42
	northwest	17.8 ± 15.1	0.0–35.7	8, 15, 21, 23, 24, 34, 42

[a] Sources: see Fig. 1.

the distribution of studies in the parts of the Holarctic region (mostly North America, central and northern Europe, see also Fig.1), where coniferous species are most abundant.

Mean nest tree diameter at breast height (hereafter dbh) ranged widely among studies (Table 1), and was significantly greater than the mean dbh for nest stand trees by Mañosa (1993) and Penteriani and Faivre (1997). Mean dbh of nest stand trees also varied widely among studies (Table 2): Mañosa (1993), Penteriani and Faivre (1997), and Penteriani *et al.* (2001) found mean dbh of nest stand trees was significantly greater than in control plots.

Age of nest stand generally ranged from 80 to > 200 yr (Hall 1984, Zanghellini & Fasola 1991, Reynolds *et al.* 1992, Titus *et al.* 1994, Selås 1997, Penteriani 1999a). Nesting in young industrial forests (Speiser & Bosakowski 1987, Rosenfield *et al.* 1998, Bosakowski *et al.* 1999) is probably due to the high quality of soils at private industrial forest lands, in which young stands (40–70 years old) often have large trees useful for nesting (Crocker-Bedford pers. comm.). Penteriani and Faivre (1997) demonstrated for an Italian Goshawk population that this species requires only a limited portion of mature forest near their nests, sometimes only 1 ha in size within younger forest portion surrounding the nest stand (Penteriani *et al.* 2001).

Nest stand tree densities vary widely (Table 2), from very open stands (16.4 and 21.3 stems/ha in Daw *et al.* 1998), to dense stands with > 1000 stems/ha (Hayward & Escano 1989, Mañosa 1993, Siders & Kennedy 1996, Squires & Ruggiero 1996). In Selås (1997) and Mañosa (1993), tree density was significantly higher in nest stands than in control plots, whereas in Hall (1984), Squires and Ruggiero (1996), and Penteriani and Faivre (1997), density was significantly lower in the nest plots. Researchers have also found significantly greater values of basal area in the nest stands than in control plots (Speiser & Bosakowski 1987, Hall 1984, Squires & Ruggiero 1996). Basal area differences between studies are probably due to the different limit in the biomass that ground can support. Sites with similar basal areas may be composed of fewer numbers of larger dbh trees or larger numbers of smaller dbh trees: the lower limit of stand use by Goshawks is probably the densest site through which they can fly. In addition, it can access nests from above the canopy. I frequently observed Goshawks fly to and from the nest from above the tree canopy: and in such cases, they do not use flight space below the canopy. Hall (1984), Speiser and Bosakowski (1987), and Penteriani (1999a) have noted canopy openings adjacent to the nest tree. Such openings may facilitate nest access.

Mean height of nest stand trees ranged from 15 to 26 m (Table 2). Ingraldi and MacVean (1995), Squires and Ruggiero (1996), and Penteriani and Faivre (1997) reported significantly higher means for nest stand trees than for control plots. The comparison of the size of the nest tree with the trees around it indicates that the nest tree is often one of the largest trees within the stand (Tables 1 and 2; Mañosa 1993, Squires & Ruggiero 1996, Penteriani & Faivre 1997), but is not necessarily the largest (Bosakowski 1999, Penteriani *et al.* 2001). Goshawks probably choose larger trees to build their nests because of more stable nest support and more flight space around it. Penteriani (1999a) reported that a tree of smaller size than its neighbours might be chosen when it is located near a natural or man-made corridor that provides better access to the nest. Moreover, the mean distance between nest stand trees was significantly greater in the nest plots than in the control plots (Penteriani & Faivre 1997), and around the nest tree than within the nest stand (Penteriani & Faivre 1997, Penteriani *et al.* 2001). Comparison of tree dbh, tree height, trunk height, and canopy features between the nest trees and the nest stand trees shows a higher range of values for the nest tree. The choice of the nest tree is probably the best compromise between a set of its characteristics, such as nest support and flight space availability.

The mean canopy volume, as well as the canopy cover, was significantly greater in nest plots than in control plots (Hall 1984, Crocker-Bedford & Chaney 1988, Ingraldi & MacVean 1995, Iverson *et al.* 1996, Penteriani & Faivre 1997; Table 2). Siders (1995) showed preference for high-canopy cover (60%–80%) and avoidance of low-canopy cover (20%–40%), and Bosakowski (1999) reported a lower limit of canopy cover at about 50%. Some studies focused on the importance of canopy cover. High canopy cover at the nest sites might be only a consequence of Goshawk utilization of mature stands. In addition, we should consider that, in broadleaved forests, pairs only see the canopy cover about one month after egg-laying and one to two months after nest building and nest tree choice. However, we cannot discard the hypothesis that Goshawks may have the opportunity to learn which stands in their territory are best for nesting and successively move on it later.

The results for nest tree and nest stand characteristics pose an important question: are specific nest stand structures important, or do they choose a taller tree within a surrounding open architecture (open enough to fly through), which just happens to be most common among mature stands? Are the stand structures mainly a consequence of the tall nest tree choice? Selås (1997) noted that in Norway the settlement of Goshawks in a stand might be influenced by characteristics directly connected with the nest tree. Moreover, denser vegetation around the nest may provide cover and physical protection from predators.

3.2.2. Landscape

To assess preference for or avoidance of human and natural components of the landscape, some researchers calculated the distance of nests to elements such as road, built-up areas, and water (Table 1). These distances varied widely among the different study areas; only nest distance to paths generally had low and relatively similar values, which were significantly shorter for the nest plots than for controls (Speiser & Bosakowski 1987, Penteriani *et al.* 2001).

Landscapes surrounding nest sites, although measured over a large range of distances from the nest, consist mainly of woodland ($\bar{x}$ = 67.1 ± 16.1%, range = 46.1–84.8%, n = 4; Zanghellini & Fasola 1991, Iverson *et al.* 1996, Penteriani & Faivre 1997, Penteriani 1999a). The extremely variable number of all the ecotone kinds ($\bar{x}$ = 29.2 ± 26.8, range 1–93, n = 2), number of different habitats ($\bar{x}$ = 9.2 ± 1.6, range 3–23, n = 2), and Baxter-Wolfe Interdispersion Index values (Hall 1984, ranging from 2 to 108, n = 3) underline the relative structural diversity of the landscape (Hall 1984, Penteriani & Faivre 1997, Penteriani 1999a). Moreover, in a cross-scale analysis between different spatial levels, landscape level only showed minor differences between the nesting and the control plots: the comparison did not yield any significant difference for the landscape structure and composition at this spatial level (Penteriani 1999a, Penteriani *et al.* 2001).

We have to be very cautious when using these types of data, because they may only mirror the local characteristics of landscape and topography, which are used (and not selected) in a solely opportunistic way. For example, Penteriani and Faivre (1997) noted very long nest distances from paved roads, built-up areas, waters, and forest edges. This finding does not mean that Goshawks avoid these elements, but rather in their specific study area all the mature forests are far from villages and roads, the soil is karstic and most of the waters flow underground, and forest edges frequently border unsuitable forest structures due to timber harvesting (lower edges) and climatic conditions (upper edges). Likewise, short distances of nests from water may relate to impermeable soil and to topography characterized by the presence of stream valleys, rather than the species' dependence on water. Given the high variability in the range of values, the distances from the landscape elements reflect local situations and the flexibility of Goshawks, rather than preference or avoidance. Although studies with a landscape-level approach are scarce (Siders 1995, Bosakowski & Speiser 1994, Iverson *et al.* 1996, Penteriani 1999a, Penteriani *et al.* 2001), the findings of the reviewed studies are very different from each other.

If it is possible to describe a "typical" Goshawk nest tree and nest stand, it is more difficult to do so at the landscape level, except for the high forest cover around the nests. Moreover, all the studies analysing nesting habitat preference at the landscape level were carried out within an arbitrary plot surrounding the nests, and not necessarily including all the foraging territory of the species. Reynolds (1983), Hall (1984), and Penteriani *et al.* (2001) suggested that Goshawks could select a nest site based on structural elements at the nest stand level, and not according to landscape level features. Goshawks are opportunistic foragers, quite adaptable to different hunting situations and changes in abundance of prey species (Dietrich & Ellenberg 1982, Widén 1987, Kenward & Widén 1989, Tornberg & Sulkava 1991, Olech 1996, Schaffer & Holroyd 1996), although radio-tracking studies found strong selection for hunting in stands of larger trees (e.g., Widén 1989, Bright-Smith & Mannan 1994, Hargis *et al.* 1994, Beier & Drennan 1997). The time that a pair spends near the nest, during the year, is very long and numerous activities require movements in the vicinity of the nest tree. This could explain the importance of the nest stand structure as the Goshawk's search image, although this does not mean that the degradation of foraging habitat should not affect the species (e.g., Crocker-Bedford 1990, Patla 1991, Widén 1997).

3.3. Holarctic and Nearctic vs. Palearctic comparisons

The comparison between North American and European nest sites, showed a significant difference only in exposures (Table 3), probably due to the high percentage of Alaskan nest sites with southerly exposures (McGowan 1975, Titus *et al.* 1994). The comparison of Holarctic nest tree and nest stand characteristics showed a significant difference in dbh between nest trees and nest stand trees only, and showed no significant differences between nest stand plots and control plots (Table 3). The latter comparison reveals that all the parameters, whilst significantly different between these two types of plots in the individual studies, are not significant when analysed globally. This result may be further corroboration of the adaptability of Goshawks to different stand structures. If Goshawks can accommodate its nesting habitat preferences to the structure of local and available stands, we must be very careful when we try to generally define the "suitable" and "unsuitable" stand structure for nesting. Probably, a structure that is "avoided" in a local situation (e.g., because of the presence of a more mature portion of forest in the neighbourhood) may be used in another situation characterized by a younger forest structure. This result takes us back to the question whether Goshawks are really dependent on a specific stand structure for their nest, or whether the choice of the nest site is mostly determined by the presence of a particular nest tree features and location. Besides, the dbh of the nest tree is the only parameter that proves to be significantly different in the global comparison between the nest tree and the nest stand trees. Nearctic and Palearctic studies on nesting habitat reach similar general conclusions, i.e., the same parameters appeared to be significant and the structure of the nest sites is similar (tall trees, high canopy cover, low tree density).

3.4. Suggestions for future research

Today, we have a lot of data on the characteristics of Goshawk nest trees and stands, and less landscape data. The various determinants of avian habitat selection processes can be distinguished between proximate and ultimate factors. Proximate factors serve to quickly identify important habitat features (they act as immediate stimuli), and ultimate factors determine the success or failure of the individual choice and provide the evolutionary explanation (Hildén 1965). Further studies on habitat use and preference may be helpful, provided that they are justified by local needs (see also DeStefano 1998, Daw & DeStefano 2001), they cover a wide range of levels (cross-scale analysis), to better understand the factors guiding the nesting habitat selection of the species, and at what spatial level they generally act. If a model is based on a narrow spatial range, then the predictions from the model will be limited; the finer the scale of a study, the more accurately it will address the ultimate ecological reasons "why" a species is doing what it does (Keane & Morrison 1994). For this scope, simple and general habitat parameters (e.g., tree dbh, tree height, tree distances) need to be used to describe nesting habitat. The division of the variables used to describe trees in complex and subjective classes can introduce a bias in the habitat analyses, also representing a main difficult in the comparisons between studies. Finally, future studies on nesting habitat use and preferences must strictly consider the concerns recently pointed out in the extremely valuable review of Jones (2001) on habitat selection studies, as: (1) habitat selection refers to a process and not a pattern, (2) many extrinsic factors affect habitat selection and, consequently, the patterns of habitat preferences we observe, and

(3) it is fundamental to account for the hierarchical nature of the habitat selection and generate accurate representations of habitat availability, more than comparisons of used and unused habitat.

Nests need to be searched by methods that enable to cover rapidly and efficiently large areas (e.g., Kennedy & Stahlecker 1993, Penteriani 1999b) to avoid restricting the researches in preselected wood patches that could allow to detect only the most classical models of habitat use and preference.

Descriptive data and correlative information on Goshawk nesting habitat use and preference have been collected for more than 20 years, nearly as a "Herculean" effort. Actually, only direct studies on the species behaviour (e.g., by radio-tracking) can give important information on how a species selects habitats and what factors affect the selection processes at different scales. Data of nesting habitat use and preference, as the ones I presented in my review, only represent the starting point to approach the behavioural processes determining habitat selection (Jones 2001). Now we need specific data to understand how habitat characteristics directly determine survival and reproduction, as stated by Crocker-Bedford (1998), DeStefano (1998), Kennedy (1998) and Smallwood (1998). Studies of individual choice processes, such as the ones allowed by radio-telemetry, may provide several direct data on habitat selection that would not be obtained from correlative studies (Keane & Morrison 1994, Penteriani & Faivre 2001, Penteriani *et al.* 2002).

We need also to consider that, although Goshawk is a protected species, the direct influence of human disturbance is poorly known. For example, human pressure by shooting could destroy nests illegally and determine different patterns of the observed nesting habitat use.

Kenward (1996) takes a wider view of nesting habitat, by developing different hypotheses on adaptation to deforestation (competition, predation, and shortage of winter food) in Europe and North America, and gives interesting clues for future studies, such as interspecific aggression or competition, as well as winter requirements (for both migratory and resident populations). Actually, it would be useful to have more data on the scarcely investigated winter food (a possible limiting factor of nesting populations, Wikman & Lindén 1981) and on its links with winter habitat preferences and selection. Moreover, breeding *vs.* wintertime habitat needs might differ in areas where Goshawk is a sedentary species.

No marked differences in nesting habitat preference appear to exist between North American and European Goshawks, while adaptation to man-made changes in nest sites seems to be different (Kenward 1996, Penteriani 1999a, Penteriani & Faivre 2001). In addition to possible subspecific variation in behaviour (Bosakowski 1999), European Goshawks may also have evolved more by artificial selection through human-modified landscapes. North American Goshawks have only had to deal with deforestation for a couple of hundred years, whereas in Europe logging is a more ancient practice (Bosakowski 1999, Penteriani 1999a, Penteriani & Faivre 2001). As a result, it would be interesting to identify differences in the process of adaptation during the Pleistocene glaciations and determine the timescales and extent of anthropogenic pressure on forested habitats (Mönkkönen & Welsh 1994), as well as conduct on-site experiments to measure responses to silvicultural treatments, as underlined by DeStefano (1998). Determining how nesting habitat characteristics can affect viability is especially important to population conservation and management. Moreover, prey abundance as a result of landscape characteristics might affect habitat use and preferences of Goshawks. As pointed out by Squires and Reynolds (1997), we need today more data on how population demographics, competitive or predatory inter-specific interactions and main preys are impacted by habitat fragmentation and changes in structure at various ecological scales (Crocker-Bedford 1990, DeStefano & McCloskey 1997, Widén 1997, Penteriani & Faivre 2001).

3.5. Management implications

Studies on nesting habitat use and preference can represent the first step for biologists and foresters to manage woodland areas to preserve the most mature stands in which Goshawks generally reproduce. For example, pre-commercial thinning might be used to create forest stands similar to

Table 3. Characteristics of Goshawk nest sites (medians). The features of North American *vs.* European nest sites, as well as the general characteristics of nest tree *vs.* nests stand trees and nest stand plots *vs.* control plots are analysed by the Mann-Whitney U-test.

	North America *vs.* Europe		North American and European Data Pooled			Sources[a]
			nest tree	nest stand	control plots	
Nest tree dbh (cm)	48.0	50.0				3, 6, 7, 8, 10, 14, 15, 17, 18, 19, 20, 23, 25, 28, 30, 32, 33, 34, 39, 41, 42
	(U = –0.27,	P = 0.79)				
Nest stand dbh (cm)	27.4	39.8	50.0	29.4	21.0	6, 7, 8, 10, 13, 17, 18, 22, 23, 27, 29, 30, 32, 34, 39, 42
	(U = –1.28,	P = 0.2)	(U = –3.74,	P < 0.001)[b]	(U = –1.29, P = 0.19)[c]	
Nest stand basal area (m^2/ha)				35.6	26.0	3, 8, 10, 15, 16, 19, 23, 29, 30, 32, 33, 34, 39
					(U = –1.62, P = 0.53)	
Nest tree height (m)	25.9	24.4				1, 4, 6, 7, 10, 13, 14, 15, 17, 18, 19, 20, 23, 25, 30, 32, 33, 34, 39, 42
	(U = 1.55,	P = 0.12)				
Nest stand tree height (m)	20.6	24.8	25.9	22.6	18.9	6, 16, 22, 29, 30, 33, 34, 42
	(U = –1.07,	P = 0.28)	(U = –1.11,	P = 0.27)	(U = –1.59, P = 0.11)	
% coniferous nest trees	10.0	26.1				2, 5, 8, 6, 10, 11, 12, 14, 15, 16, 18, 22, 25, 28, 29, 33, 34, 39, 42
	(U = –0.98,	P = 0.33)				
% broadleaved nest trees	11.8	6.4				2, 5, 8, 6, 10, 11, 12, 14, 15, 16, 18, 22, 25, 28, 29, 33, 34, 39, 42
	(U = 0.08,	P = 0.93)				
Stand canopy cover (%)	69.1	88.0		71.1	58.0	6, 7, 8, 10, 13, 14, 16, 31, 32, 33, 34, 38, 39
	(U = –1.11,	P = 0.27)			(U = –1.21, P = 0.22)	

Continues

Table 3. Continued.

	North America *vs.* Europe		North American and European Data Pooled			Sources[a]
			nest tree	nest stand	control plots	
Canopy height (m)			13.5	14.0		10, 25, 30, 32, 34
			(U = –0.65,	P = 0.51)		
Distance between trees (m)			7.6	5.7		10, 18, 22, 30, 32, 34, 42
			(U = –1.17,	P = 0.24)		
Tree density (stems/ha)	482.0	300.0		454.5	336.0	6, 7, 8, 10, 13, 17, 19, 23, 30,
	(U = 0,	P = 1)			(U = 0.43, P = 0.66)	32, 34, 38, 39
Elevation (m a.s.l.)	1881.5	915.5				5, 6, 10, 11, 12, 15, 21, 24, 26,
	(U = 1.18,	P = 0.24)				28, 29, 32, 33, 34, 37, 42
% N-exposure	18.6	10.1				8, 15, 16, 21, 23, 24, 34, 42
	(U = 1.26,	P = 0.21)				
% S-exposure	7.0	0.0				8, 15, 16, 21, 23, 24, 34, 42
	(U = 3.02,	P < 0.001)				
Slope gradient (degrees)				12.4	12.7	15, 21, 28, 24, 34, 39, 42
					(U = 0.32, P = 0.75)	
Distance to path (m)	118.8	44.4		51.2	80.8	14, 22, 31, 34, 42
	(U = 1.9,	P = 0.06)			(U = 0.43, P = 0.66)	
Distance to paved road (m)	1477.4	828.2				14, 22, 24, 31, 34, 42
	(U = 1.16,	P = 0.25)				
Distance to water (m)	172.1	213.5		172.1	201.1	6, 10, 14, 15, 21, 22, 24, 25,
	(U = –0.92,	P = 0.35)			(U = 0.43, P = 0.66)	26, 31, 34
Distance to built-up area (m)	1052.2	1556.5		1334.6	1728.5	9, 15, 22, 24, 34, 42
	(U = –0.39,	P = 0.7)			(U = 0, P = 1)	

[a] Sources: see Fig. 1.
[b] = Mann-Whitney U-test for the comparison nest tree *vs.* nest stand
[c] = Mann-Whitney U-test for the comparison nest stand *vs.* control plots

those needed by goshawks, as also noted by Squires and Ruggiero (1996), by both a selective cutting of trees and forest portions, as well as by the assessment of the size of the patches concerned by harvesting. A crucial element for the conservation of the species may be the conservation or creation of mature stands (with the local characteristics pointed out in my review) on the goshawk's preferred slope orientation and spaced on the basis of the local minimum average distance between breeding pairs. The best solution to manage nesting pairs seems to be the creation of a mosaic of neighbouring tall-tree stands inside a forested landscape, although each local situation should be evaluated before planning forest management.

The importance of large patches of mature forests for goshawks does not only concern its nesting habitat. Although few works examined how goshawks select hunting habitat, this species showed a strong preference for moderately dense, mature forests characterised by tall trees and high flight space increasing the availability of preys (Widén 1989, Beier & Drennan 1997). For this reason, forest management recommendations should also improve conditions for goshawks foraging habitats, during both the winter and the breeding seasons. In fact, because during winter goshawks are under greater thermal stress, several avian prey have migrated and some mammalian preys are hibernating, they may select winter hunting habitats that differ markedly from the foraging habitats they use during the reproduction (Beyer & Drennan 1997).

The experimental results of Petty (1996) and Penteriani and Faivre (2001) seems to recognize the need of a buffer area of unlogged trees of 1 to > 5 ha around the nest tree. Actually, in several cases, it was noted that Goshawk nests are always placed inside the older portion of a tall tree forest, which lies inside a less mature portion. Moreover, few information is available on whether Goshawks can cope with a small amount of logging within their nesting stands, as long as not too much habitat in their home ranges is degraded in terms of prey abundance and available hunting territory.

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Selostus: **Kanahaukan pesimähabitaatti Euroopassa ja Pohjois-Amerikassa: kirjallisuuskatsaus**

Katsaus käsittelee monenlaisissa metsäympäristöissä pesivän kanahaukan pesimähabitaatteja Euroopassa ja Pohjois-Amerikassa. Katsauksen tarkoituksena on (1) koota yhteen kanahaukan pesimäympäristöstä saatavilla oleva tutkimustieto, (2) identifioida ne pesimähabitaatin piirteet, jotka ovat yhteisiä uudelle ja vanhalle mantereelle sekä (3) arvioida kanahaukan habitaattitutkimuksen tutkimustarpeita ja tutkimuksen suuntaviivoja. Kirjoittaja kävi läpi kaikkiaan 43 manuaalisessa tai online-tiedonhaussa esille tullutta tutkimusta, jotka käsittelivät kanahaukan pesintää. Tutkimuksista 15 oli tehty Euroopassa ja 28 Pohjois-Amerikassa. Kahden viime vuosikymmenen aikana tutkijat ovat kuvailleet yli 300 muuttujaa kanahaukan pesimäympäristön käyttöön tai valintaan liittyen. Yksittäisissä tutkimuksissa kanahaukan pesien määrä vaihteli 10–74 ollen keskimäärin 29. Vain yhdeksässä tutkimuksessa kanahaukan pesimähabitaattia vertailtiin alueella tarjolla oleviin habitaatteihin. Vertailu olisi kuitenkin välttämätön, jotta voidaan todeta millaista pesimähabitaattia kanahaukka suosii. Kirjoittajan mukaan yleisesti käytetyt 0,04 ja 0,08 hehtaarin tutkimusruudut eivät ole riittävän suuria kuvaamaan kanahaukan pesimämetsikön laatua. Monissa tutkimuksissa kanahaukan pesiä on etsitty vain parhailta habitaateilta. Lähestymistapa voi vääristää kuvaa kanahaukan pesimäpaikan valinnasta. Pesäpaikkojen etsinnän tulisi kattaa kaikki potentiaaliset pesimähabitaatit. Käsillä olleiden tutkimusten mukaan kanahaukka pesii metsikön varttuneimmassa osassa, valitsee pesäpuukseen pesimämetsän suurimman puun ja rakentaa pesänsä korkealle (2/3 latvuskorkeudesta) puun runkoa vasten. Pesimämetsikön ikä on yleensä yli 80 vuotta. Usein pesäpuun ympärillä on jonkin verran avointa lentoalaa. Pesimäpuun rinnankorkeusläpimitta oli ainoa muuttuja, jossa havaittiin ero vertailussa pesimämetsikön muihin puihin. Pesintään käytetty puu oli vankempi kuin pesimämetsän muut puut. Kanahaukan pesimämaisema on rakenteeltaan monimuotoinen, yleensä metsävaltainen. Maisematason tutkimuksia on kuitenkin toistaiseksi tehty liian vähän verrattuna pesäpuu- ja pesimämetsikkötason tutkimuksiin. Kanahaukka suosii Euroopassa samanlaisia pesimäympäristöjä kuin Pohjois-Amerikassakin. Kirjoittaja suosittelee, että tulevaisuudessa aihetta tutkittaisiin monimittakaavaista lähestymistapaa käyttäen. Radiotelemetriset tutkimukset antaisivat tarkempaa tietoa kanahaukan pesimäympäristön valinnasta ja käytöstä kuin pelkät pesimäpaikkakuvaukset. Niin ikään tulisi huomioida, että kanahaukan pesimäaikainen ja talviaikainen habitaatinvalinta voivat erota toisistaan. Kirjoittajan mukaan lisätietoa tarvitaan erityisesti siitä, kuinka habitaatin ja maiseman laatu vaikuttavat kanahaukan pesimämenestykseen ja elossasäilymiseen. Artikkelin lopussa kirjoittaja antaa ohjeita kanahaukan elinolosuhteiden parantamiseen.

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