Ann. Zool. Fennici 43: 86–95 ISSN 0003-455X
Helsinki 28 April 2006

Woodpeckers: distribution, conservation, and research in a global perspective

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Received 7 Oct. 2005, revised version received 6 Mar. 2006, accepted 6 Feb. 2006

Mikusiński, G. 2006: Woodpeckers: distribution, conservation, and research in a global perspective. — *Ann. Zool. Fennici* 43: 86–95.

The main aim of this paper is to examine and discuss the global pattern of woodpecker diversity from a conservation perspective. In addition, I review ecological traits and the conservation status of the entire family Picidae, and relate these factors to the human driven change in their habitats. Finally, I present a global overview of the research on woodpeckers in order to identify the major gaps in our knowledge which render the management of populations of these species difficult. The hotspots of woodpecker species richness identified by GIS were found in tropical and subtropical forests of South-East Asia, South and Central America, and equatorial Africa. Most of these hotspots were located in developing countries. However, almost 90% of articles published in 1985–2004 encompassed studies performed in North America and Europe, that is, in geographic areas harbouring only 17% of the global number of Picidae species.

Introduction

The family Picidae, which encompasses woodpeckers, wrynecks, and piculets contains ca. 216 closely related species, all with strong ties to forest environments. Trees, snags and logs are primary substrates providing nesting sites, shelter, and food for the majority of woodpeckers (Winkler *et al*. 1995). One striking feature of woodpeckers is their ability to excavate cavities in living and dead trees (Winkler & Christie 2002). Due to this "engineering activity", woodpeckers have been proposed as key-stone species in several communities with large numbers of secondary cavity nesters (Daily *et al*. 1993, Jones *et al*. 1995, Conner *et al*. 2004, Martin *et al*. 2004, Ojeda 2004). Moreover, facultative sap-consuming species are also benefited by their drilling for phloem sap and thus their activities can influence entire community structures (Blendinger 1999, Schlatter & Vergara 2005). Through wood excavation activities, including nest construction and foraging, woodpeckers play a role in wood decomposition processes (Farris *et al*. 2004). It has also been suggested that woodpeckers function as dispersal vectors for wood-living fungi (Jackson & Jackson 2004). It is quite apparent from these relationships that this avian family plays a significant ecological role in forest environments and communities.

Woodpeckers occur in all types of forest and woodland and are found on all continents except of Australia and Antarctica (Winkler *et al*. 2005). Woodpeckers are virtually absent from treeless landscapes such as desert, tundra and alpine areas. In addition, most isolated islands

lack woodpeckers. Most woodpeckers are sedentary birds and are generally considered to be relatively poor dispersers (e.g. Higuchi & Koike 1978). Blackburn *et al.* (1998) conducted a global analysis and found that body mass of woodpeckers was rather weakly correlated with the size of their geographic ranges. Blackburn *et al.* (1998) found that woodpecker geographic range sizes decreased with increased woodpecker species richness and that species living in high latitudes tended to be more widely distributed. Interestingly, the best predictor of species richness for woodpeckers was the area of a given geographic region; smaller regions had more woodpecker species and more endemics.

Several species of woodpeckers have experienced dramatic population declines and range contractions due to habitat loss and degradation through various human activities (Winkler & Christie 2002). This applies to large, area-sensitive species such as the ivory-billed woodpecker (*Campephilus principalis*) or imperial woodpecker (*C. imperialis*) that depend upon vast areas of unmanaged forest as well as small but highly specialised species such as the red-cockaded woodpecker (*Picoides borealis*) or South American piculets with small geographic ranges. The effects of human activities on woodpecker assemblages have been observed at different scales. In a country-by-country analysis, Mikusiński and Angelstam (1997, 1998), reported negative population trends for most European woodpeckers and related species richness to the degree of anthropogenic change for this group of species. In a study from north-eastern Poland, species richness for woodpeckers was positively correlated with the availability of dead wood and large deciduous trees (Angelstam *et al.* 2002) — factors which are closely associated with the level of naturalness of forest stands. Strong negative correlation between woodpecker biomass and density with logging intensity has been found on Borneo (Lammertink 2004) and the Malaysian peninsula (Styring & Ickes 2001). Conner *et al.* (1975) reported higher diversity of woodpecker species in uncut versus cut woodlands in Virginia.

Human impact on woodpecker populations encompasses several factors. The most obvious factor for woodpeckers — as well as many other threatened organisms — is habitat loss. Logging of vast areas of woodland as well as their conversion to farmland has been the major cause of range contractions, regional extinctions, and population declines both now and historically (Winkler & Christie 2002). Dependence of woodpeckers on certain forest characteristics typical for unmanaged forest (i.e. presence of large and old trees, high structural diversity, and presence of large quantities of dead wood) makes them particularly susceptible to forestry practices. Short-rotation schemes, selection of few most productive tree species, even-age structure, removal of dead wood, active fire suppression, and replacement of native tree species with fast-growing exotics apparently degrade habitat for woodpeckers (Angelstam & Mikusiński 1994). Alternatively, in areas with traditional, low-intensity agricultural practices as is the case in several regions of Europe, woodpeckers may be relatively abundant in sparsely forested landscapes that contain elements of forest structure such as large, older trees (Mikusiński & Angelstam 1997, 1998). In these areas, the clearance and intensified use of such semi-open landscapes poses the main threat for woodpecker species (Tucker & Evans 1997).

The strong association that woodpeckers display with forest environments and their sensitivity to structural and compositional changes in their habitats caused by human action has been a reason for utilizing woodpeckers in forest and landscape management (e.g. Angelstam & Mikusiński 1994, Diaz 1997, Hutto 1988, Jansson 1998, Nilsson *et al.* 2001, Hess & King 2002, Lammertink 2004, Uliczka *et al.* 2004). Woodpeckers may fit different concepts that recommend use of surrogate species in practical conservation. Woodpeckers have been suggested as indicators for forest biodiversity (Mikusiński & Angelstam 1998, Nilsson *et al.* 2001). It has been argued that since several woodpecker species display a highly specialised selection of resources that are typical of naturally dynamic forests (e.g. dead wood, big and old trees) that their presence may indicate high overall biodiversity. The empirical evidence supporting this hypothesis is growing. Mikusiński *et al.* (2001) demonstrated a strong positive relationship between the number of woodpecker species and overall forest bird

species richness at the landscape scale in Poland. The lesser spotted woodpecker (*Dendrocopos minor*) has been found to be a reliable indicator of the occurrence of avian deciduous forest specialists in northern Europe (Jansson 1998, Roberge & Angelstam 2006). Also tree species diversity was found to be positively correlated with the number of woodpecker species observed in one study performed in south-central Sweden (Angelstam 1990). Martikainen *et al*. (1998) found high numbers of threatened wood-species beetles in areas with white-backed woodpeckers (*Dendrocopos leucotos*) in Finland and Russian Karelia.

Woodpeckers have also been proposed as indicators of structural diversity and ecological quality of forest habitats and as umbrella/focal species for forest and landscape management (McClelland & McClelland 1999, Derleth *et al*. 2000, Angelstam *et al*. 2002, Pakkala *et al*. 2002, Lammertink 2004). Hess and King (2002) used the pileated woodpecker (*Dryocopus pileatus*) as focal species of mature forest for conservation planning in North Carolina. Two species of woodpeckers have been employed as focal species in designing a forest habitat network in northern Italy (Bani *et al*. 2002). The habitat requirements of the three-toed woodpecker (*Picoides tridactylus*) have been used to propose the quantitative snag targets for the coniferous forest management in Europe (Bütler *et al*. 2004). In the state of Mississippi, the successful restoration of pine-grassland habitat for red-cockaded woodpeckers resulted in increased diversity of bird community (Wood *et al*. 2004). Moreover, woodpeckers have been used to predict the impact of forest management on wildlife habitats (Cox & Engstrom 2001, Marzluff 2002). Angelstam *et al*. (2004) proposed several woodpeckers as focal species for the assessment of forest habitat networks in Europe applying habitat suitability modelling. In summary, woodpeckers are an important systematic group from forest and landscape management perspectives because of their sensitivity to forestry and other anthropogenic impacts on the forest environment. It remains to be seen whether they will be used to their full capacity as tools in forest biodiversity management in a global perspective.

In this paper I examine and discuss the global pattern of woodpecker diversity from a conservation perspective. I also review some ecological traits and the conservation status of the entire family Picidae and relate them to the human driven change in their habitats. Finally, I present a global overview of the research on woodpeckers in order to identify the major gaps in our knowledge.

Material and methods

Analyses in this study were performed at the global scale. I created a spatially-explicit Geographic Information System (GIS) database on the distribution of the breeding ranges of 216 *Picidae* species, including woodpeckers, wrynecks and piculets. The source of information on geographic ranges of species was taken from distribution maps published in Winkler and Christie (2002). Spatial analyses were performed using ArcView 3.2 (ESRI 2000). A set of global maps provided with this software was used as background information during the process of digitalisation. In addition, information on the global distribution of major vegetation zones was provided with this software. The spatial resolution of the created database corresponded to a grid with cell dimensions 1° latitude × 1° longitude. Breeding ranges of all species were manually digitised into this grid and then summarised spatially using the overlay function in vector format. Borders between adjacent cells with the same number of woodpecker species were then dissolved. This resulted in a vector-based map with polygons with values corresponding to 1–25 species present.

Information on woodpeckers listed into different threat categories according to IUCN classification as well as on the numbers of woodpecker species present in different countries was extracted from BirdLife International homepage in the Search for Species mode (www.birdlife.org/datazone/species/index.html). The data on woodpecker's body size and their diet was assembled from Winkler and Christie (2002).

The literature survey for articles on woodpeckers has been performed using Wildlife and Ecology Studies Worldwide database (NISC 2005). I searched for articles that contained at least one of following words in the title

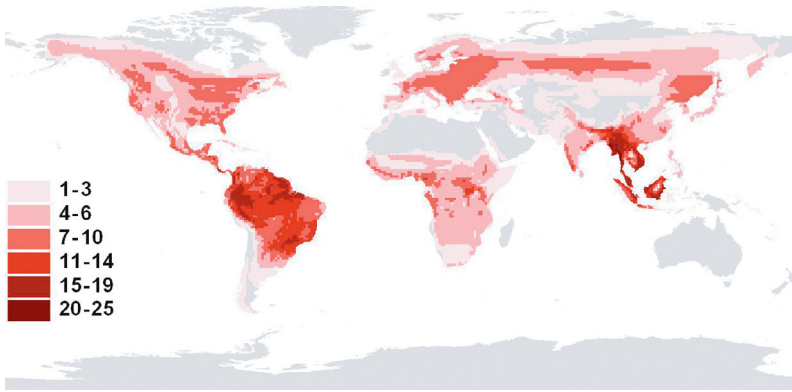

Fig. 1. Global pattern of species richness in family Picidae.

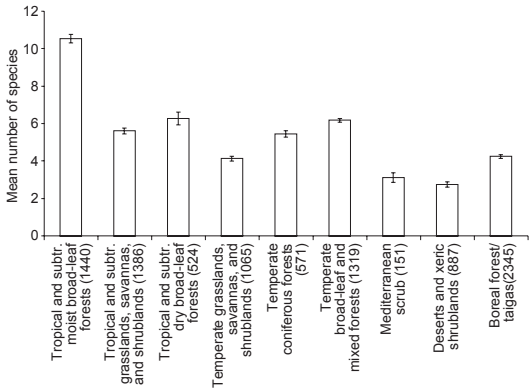

Fig. 2. Mean number of woodpecker species in major woody vegetation types. Number of 1 × 1 geographic degree plots representing each type in parentheses. Bars denote 95% confidence intervals of the mean.

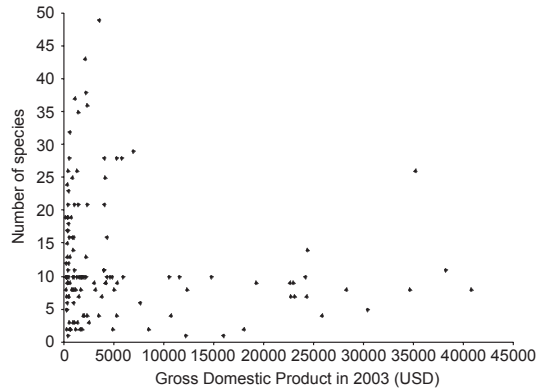

Fig. 3. Number of woodpecker species in countries with different Gross National Product per capita according to UNEP (2005). Only countries with area > 5000 km^2 were included (n = 135).

(translated title): woodpecker(s), wryneck(s), piculet(s), flicker(s), sapsucker(s), flameback(s), goldenback(s), yellownape(s). I covered a 20-year period (1985–2004). All titles and abstracts (when available) were reviewed and the following parameters were recorded in spread sheet format: species, year of publication, country, continent, first author and type of study (ecological, behavioural, faunistic and biogeographic, other). Publications concerning two or more species of woodpeckers were recorded as "several species" instead of species names. All references that appeared two or more times in the database were manually removed.

Results

The map illustrating the global pattern in species richness within family Picidae pointed to the regions of southeast Asia and northern and central parts of South America as species richness hotspots with at least 15 species present at the regional level (Fig. 1). In particular, hotspots were found in Myanmar, Thailand, Vietnam, Cambodia, Malaysia and Indonesia in Asia, as well as in Brazil, Colombia, Peru, Ecuador and Suriname in South America. Equatorial Africa and Central America also had relatively high global levels of woodpecker species richness. Among different major vegetation zones with woody vegetation, moist broadleaved tropical and subtropical forests had, on average, the highest number of woodpecker species (Fig. 2). Most occurrences of high woodpecker species richness were found to be in economically developing countries (Fig. 3).

Ants, other arthropods, fruits and berries were among the most commonly observed food items taken by woodpeckers (Winkler & Chris-

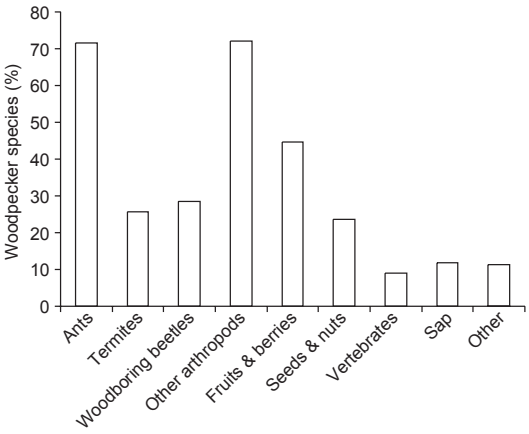

Fig. 4. Diet of Picidae according to species accounts in Winkler and Christie (2002).

tie 2002; Fig. 4). Clearly, well-described and known species had much higher numbers of foods listed. Interestingly, this source indicates that the diets of 37 species (17%) are virtually unknown to science.

In total, 25 species of Picidae are listed by IUCN as threatened or near threatened in the following categories: CR = 3 species, VU = 7 species, NT = 15 species (Table 1). Almost half of them (12 species) are considered as restricted-range species (i.e. with geographic range < 50 000 km^2). Most of the endangered species occur in areas with generally high woodpecker species richness. The percentage of species in different size classes in threatened (near threatened) species and non-threatened categories is illustrated in Fig. 5. The proportions of threatened (near threatened) species in different size classes were dissimilar from those of the remaining woodpecker species (χ^2 = 11.4, df = 5, p = 0.044). In particular size class 10–15 cm (containing mostly piculets) and the largest woodpeckers were relatively more abundant among threatened (near threatened) species in comparison with the remaining species. Habitat loss and degradation due to forest logging and removal of wood are the major threats indicated for all listed species. In some cases, hunting and collecting (e.g. imperial woodpecker), forest

Table 1. Species listed by IUNC as threatened or near threatened. Categories: Critically Endangered (CR), Vulnerable (V), Near Threatened (NT). Regions: Africa (AF), Asia (AS), Latin America (LA), North America (NA).

Species	Category	Region	Comments
Rusty-necked piculet (*Picumnus fuscus*)	NT	LA	restricted-range species
Speckle-chested piculet (*Picumnus steindachneri*)	VU	LA	restricted-range species
Tawny piculet (*Picumnus fulvescens*)	NT	LA	restricted-range species
Ochraceous piculet (*Picumnus limae*)	VU	LA	restricted-range species
Mottled piculet (*Picumnus nebulosus*)	NT	LA	
Guadeloupe woodpecker (*Melanerpes herminieri*)	NT	LA	restricted-range species
Red-headed woodpecker (*Melanerpes erythrocephalus*)	NT	NA	
Knysna woodpecker (*Campethera notata*)	NT	AF	restricted-range species
Stierling's woodpecker (*Dendropicos stierlingi*)	NT	AF	
Sulu woodpecker (*Dendrocopos ramsayi*)	VU	AS	restricted-range species
Arabian woodpecker (*Dendrocopos dorae*)	VU	AS	
Red-cockaded woodpecker (*Picoides borealis*)	VU	NA	
Chocó woodpecker (*Veniliornis chocoensis*)	NT	LA	restricted-range species
Yellow-browed woodpecker (*Piculus aurulentus*)	NT	LA	
Fernandina's flicker (*Colaptes fernandinae*)	VU	LA	restricted-range species
Helmeted woodpecker (*Dryocopus galeatus*)	VU	LA	restricted-range species
Black-bodied woodpecker (*Dryocopus schulzi*)	NT	LA	
Andaman woodpecker (*Dryocopus hodgei*)	NT	AS	restricted-range species
Guayaquil woodpecker (*Campephilus gayaquilensis*)	NT	LA	
Imperial woodpecker (*Campephilus imperialis*)	CR	LA	probably extinct
Ivory-billed woodpecker (*Campephilus principalis*)	CR	NA	< 50 individuals
Red-collared woodpecker (*Picus rabieri*)	NT	AS	
Olive-backed woodpecker (*Dinopium rafflesii*)	NT	AS	
Okinawa woodpecker (*Sapheopipo noguchii*)	CR	AS	restricted-range species
Buff-necked woodpecker (*Meiglyptes tukki*)	NT	AS	

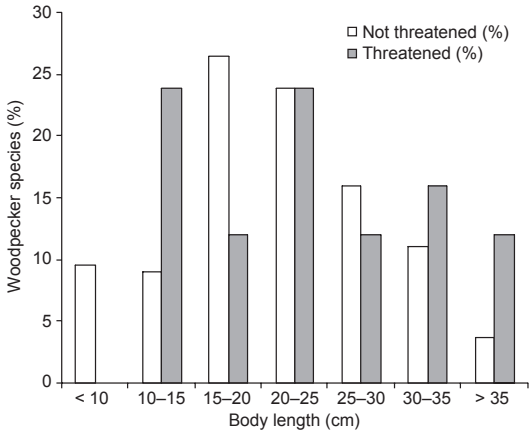

Fig. 5. Body length in globally threatened (near threatened) *vs.* unthreatened species of woodpeckers.

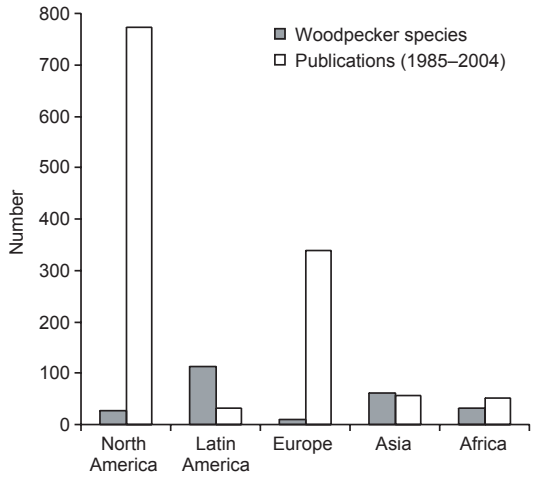

Fig. 6. Number of articles found in Wildlife & Ecology Studies Worldwide database (NISC 2005) and number of woodpeckers in different regions of the world.

fires and hurricanes (e.g. red-cockaded woodpecker) were considered to be additional causes of population declines.

In total, 1252 articles on woodpeckers published between 1985 and 2004 were found in Wildlife and Ecology Studies Worldwide database. These included 1050 single-species articles that encompassed 65 species. Table 2 provides the list of the 15 species with highest numbers of articles published. I found a great disproportion in the number of woodpecker species occurring in Europe and North America and the number of articles published about these species (Fig. 6).

Discussion

The global pattern of species diversity in Picidae generally follows the well-known latitudinal gradient of decreasing species richness from lower to higher latitudes (Rosenzweig 1995, Gaston 2000). This trend confirms an earlier finding at a much more coarse resolution by Blackburn *et al*. (1998). Identified hotspots of woodpecker diversity largely overlapped with distribution of hotspots of avian species richness (Orme *et al*. 2005). In the case of woodpeckers, the prerequisite for high species richness appears to be presence of vast areas of woodland with high structural and compositional diversity. These environments are found mostly in tropical and subtropical moist broadleaved forests of

Table 2. Species with highest number of articles published between 1985 and 2004 according to Wildlife & Ecology Studies Worldwide database.

Species	Number of articles
Red-cockaded woodpecker (*Picoides borealis*)	301
Great spotted woodpecker (*Dendrocopos major*)	62
Northern flicker (*Colaptes auratus*)	61
Pileated woodpecker (*Dryocopus pileatus*)	58
Black woodpecker (*Dryocopus martius*)	55
Acorn woodpecker (*Melanerpes formicivorus*)	54
Middle spotted woodpecker (*Dendrocopos medius*)	40
White-backed woodpecker (*Dendrocopos leucotos*)	36
Red-bellied woodpecker (*Melanerpes carolinus*)	27
Three-toed woodpecker (*Picoides tridactylus*)	24
Red-headed woodpecker (*Melanerpes erythrocephalus*)	23
Yellow-bellied Sapsucker (*Sphyrapicus varius*)	22
Wryneck (*Jynx torquilla*)	21
Downy woodpecker (*Picoides pubescens*)	20
Lewis's woodpecker (*Melanerpes lewis*)	16

south-east Asia and South America (Figs. 1 and 2). Temperate and boreal forest vegetation zones have a moderate number of species present at regional level.

In a global perspective, arthropods clearly dominate diets in Picidae (Fig. 4). However, woodpecker diets also include vegetable items such as fruit, nuts, berries and sap. I found a relatively low proportion of species that specialised in wood-boring beetles and their larvae (< 30% of species), the food often perceived as most typical for woodpeckers. Interestingly, ants seem to be an important ingredient of woodpecker diets world-wide. An obvious weakness of this analysis is that the data used are not quantitative and thus it is difficult to know the importance of different food items for lesser-known species. Detailed studies on food of European woodpecker species indicate significant regional and seasonal variations in diets (Cramp 1985). Information on the diet of the great majority of woodpecker species comes not from comprehensive foraging studies or stomach contents analyses but from more or less incidental observations. Askins (1983) compared foraging behaviour of 11 species of woodpeckers in Guatemala, Maryland, and Minnesota and found a similar degree of specialisation in both tropical and temperate species. I argue that with more knowledge on foraging habits of woodpeckers we are going to see, not only a broader spectrum of different food items utilised by particular species, but also a clearer pattern of seasonal and regional specialisation and the importance of animal versus vegetarian ingredients in diets.

Judging from the proportion of woodpecker species listed by IUCN (11.5%), the global conservation status of this group of birds is not extreme. Some other broadly distributed groups of forest birds like parrots (Psittacidae), hornbills (Bucerotidae), or nuthatches (Sittidae) have higher proportions of threatened species (40%, 39% and 27%, respectively), while others like tits (Paridae) or wrens (Troglodytidae) have lower proportions of threatened species (5.5% and 9.2%, respectively). High proportions of threatened species among parrots and hornbills may be partly explained by the fact that these families are nearly exclusive to the tropics where the fastest habitat destruction is occurring. In addition, many parrot species are small island endemics.

Does the relatively low proportion of officially listed species mean that woodpeckers as a group of forest specialists are not particularly threatened by recent global intensification of logging and other human-related changes affecting forest environments? A closer look at the geographic locations of the hotspots of woodpecker species richness may suggest the opposite. Most hotspots are located in areas with tropical and subtropical moist forests as the major vegetation types. Since the majority of these areas have been recently subjected to intensive clearing operations the amount and quality of available woodpecker habitat has declined drastically. Estimated cumulative forest loss in Malaysia, Myanmar, Thailand and Vietnam, countries that harbour the majority of Asian woodpecker diversity hotspots, amount to 39%, 55%, 71% and 68%, respectively (FAO 2000, Pahari & Murai 1999). These figures illustrate loss of original forest cover but are silent on the structural and compositional changes in managed forests that negatively affect the quality of woodpecker habitats (e.g. Lammertink 2004).

Similarly, forest loss in the South American hotspots is drastic. In the case of Brasilian Amazonia, the tropical forest area remained a largely intact area until the inauguration of the Transamazon Highway in 1970, but the pace of forest clearing has been rapid since then (Fearnside 2005). Also, in Colombia, Peru, and Ecuador the deforestation has been a major land-use change affecting entire regions (Pahari & Murai 1999). In an area of over 3000 km^2 located at the border between Colombia and Ecuador — within one of the woodpecker diversity hotspots — Viña *et al.* (2004) estimated with the use of satellite images the deforestation rate during a 23-yr period at 43% and 22% on the Colombian and Ecuadorian sides of the border, respectively. The establishment of protected areas (PA) in woodpecker diversity hotspots is not necessarily securing the maintenance of their natural habitats. In protected areas in south-western Borneo (Kalimantan) for example, the lowland forest cover declined by 56% (29 000 km^2) from 1985 to 2001 (Curran *et al.* 2004).

I predict that a clear positive relationship between the deforestation rate and human population density (Pahari & Murai 1999), considered together with high annual human population growth (> 1.5%) in the woodpecker-richest countries, may lead to a rapid increase in the number of globally threatened species of Picidae in the near future. Cincotta *et al*. (2000) found that human population growth in global biodiversity hotspots is substantially above that of developing countries in general, and predicted that human-induced changes negatively affecting biodiversity are likely to continue in these areas. Regional extinctions and population contractions of woodpecker species related to socio-economic development resulting in forest loss and degradation have been described from temperate and subtropical zones (e.g. Pettersson 1984, Virkkala *et al*. 1993, Jackson 1994, Mikusiński & Angelstam 1997, 1998). Since the rapid deforestation of areas with highest woodpecker diversity in the tropics is a relatively recent phenomenon, we have to consider a potentially large unrealised "extinction debt" (*sensu* Tilman *et al*. 1994) as an important conservation issue in the near future.

Some features of woodpecker distribution patterns and biology make them especially prone to rapid declines due to increase of human population. First, woodpecker species occurring in low latitudes tend to have relatively small geographic ranges (Blackburn *et al*. 1998) and therefore several range restricted species may be more susceptible to regional forest loss. Second, many woodpecker species are specialised foragers that do not attain high population densities but have relatively large home-ranges, and therefore a viable forest population will need relative large areas with a network of functional habitats. The situation of the largest *Camphepilus* species is a good illustration of this problem. Third, due to their incompatibility with many forestry practices concerning the lack of big and old trees, of dead wood, and the reduction of compositional and structural diversity, woodpeckers may be unable to thrive in managed forests and forest plantations.

The literature survey on woodpeckers provided striking results concerning the disproportionate number of studies performed on species in temperate versus tropical zones. Fifteen North American and European species of woodpeckers (7% of *Picidae*) accounted for 70% of all single-species articles published in the years 1985–2004. I found a total of 33 articles (less than 3% of the total) concerning woodpeckers in Latin America where over half of all woodpecker species occur. Even if we take into account inaccessibility of some local, regional, and national studies in the database used, the geographic distribution of woodpecker studies seems to be far from representative. The lack of knowledge on diets of 37 species in the most recent and in-depth global accounts on woodpecker life-histories provided by Winkler and Christie (2002) is a good illustration of this problem. What kinds of studies on woodpeckers are needed to be performed and reported to the international community? Most importantly, more reports on woodpecker assemblages from the areas identified as continental or regional hotspots are required. These should cover the conservation status and habitat requirements of particular species, their sensitivity to human impact, and their ecological role in the ecosystems. Good examples of such studies are those provided by Styring and Ickes (2001), Lammertink (2004) and Schlatter and Vergara (2005).

Winkler and Christie (2002) identified gaps in our knowledge on life-history traits and the conservation status of particular species. The keystone role of woodpeckers as excavators in communities with secondary cavity users and with species that feed on sap or invertebrates exposed by woodpeckers should be assessed. The knowledge on habitat requirements of such key-stone species are necessary for conservation planning in both primeval and managed forests. It is possible that several woodpecker species in the low latitudes will be useful focal/umbrella species. In terms of woodpecker conservation, it seems that emphasis should be put on larger species. The large species tend to be more often threatened (Fig. 5) due to their large area requirements, their specialisation on foraging substrate, and their need for trees with large dimensions for nesting and roosting.

The woodpeckers are an important part of forest ecosystems on five continents. This group includes highly specialised species that are

threatened by the recent and future deforestation of tropical and subtropical areas. At the same time our knowledge on the majority of species is quite limited. I urge all woodpecker researchers to design and perform studies that can fill the gaps in our knowledge. Such studies will not only illuminate our understanding of woodpecker biology and ecology, but will also contribute to the maintenance of forest biodiversity world-wide.

Acknowledgements

Many thanks to Martjan Lammertink, Jean-Michel Roberge and Scott Brainerd for their comments on earlier drafts of this paper.

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