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Woodpeckers as Indicators for Sustainable Forestry?

First Results of a study in the EU/LIFE – demonstration areas Lüneburger Heide und Solling

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About the project:

The project is designed to review, demonstrate and develop methods to monitor sustainable forestry as defined by the pan-European process. It is supported by the EU-LIFE fund. Totally 7 organisations from Denmark, Finland, France, Germany and Sweden are participating. Lead agency is the National Board of Forestry in Sweden.

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WOODPECKERS AS INDICATORS FOR SUSTAINABLE FORESTRY?
FIRST RESULTS OF A STUDY FROM LOWER SAXONY

Running head:
Woodpeckers as indicators for sustainable forestry?

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Abstract

In the process of developing a monitoring system for sustainable forestry in Europe, we assess the suitability of woodpeckers as indicator species. In this context, we raise questions concerning requirements for a sustainable forestry from a conservation point of view. We suggest that maintaining biodiversity in forests is crucial for sustainability, and that it requires that viable populations be maintained for all naturally occurring species.

Within the framework of the EU-LIFE-Project "Demonstration of Methods to Monitor Sustainable Forestry" a census of six woodpecker species was carried out in the “Lüneburger Heide” and in the “Solling”, two forest regions in Lower Saxony different in structure and history, on each approximately 1800 hectares of woodland. The results emphasize the significance of old forest stands, and especially old deciduous trees, for the abundance and diversity of woodpeckers.

We conclude that woodpeckers as a group are good indicator species, although further research is needed to specify what habitat characteristics the different woodpecker species can indicate, and how closely the occurrence of other taxa of forest organisms is related to the presence of woodpeckers. Woodpeckers can be part of a monitoring system of sustainability in forests, but other indicator species are also required (e.g. mosses, lichens, and fungi).

Zusammenfassung

Im Rahmen des sogenannten „Rio-Prozesses“ wird in Europa zur Zeit an einem Monitoring-System für nachhaltige Forstwirtschaft gearbeitet. In der vorliegenden Arbeit wird die Eignung der Spechte als mögliche Indikatoren in einem solchen Monitoring-System bewertet. Dazu muss zunächst definiert werden, was eine ökologisch nachhaltige Forstwirtschaft im einzelnen bedeutet, welche Anforderungen also die Forstwirtschaft erfüllen muss, um den Erhalt der Biodiversität in Wäldern garantieren zu können. Es wird auf einige in diesem Zusammenhang wichtige, noch offene Fragen hingewiesen.

Im Rahmen des EU-LIFE-Projektes „Demonstration of Methods to Monitor Sustainable Forestry” wurde in der Lüneburger Heide und im Solling eine Spechterfassung auf jeweils etwa 1800 ha Wald durchgeführt. Die Ergebnisse wurden mit den vorliegenden Daten der Forsteinrichtung in Beziehung gesetzt. Die Bedeutung hohen Bestandesalters und besonders alter Laubbäume für die Siedlungsdichte und Artenvielfalt der Spechte wurden bestätigt.

Spechte sind sicherlich als Indikatoren für eine nachhaltige Forstwirtschaft geeignet, wenngleich die Indikationsleistung der verschiedenen Arten noch genauerer Untersuchungen bedarf. Für ein sinnvolles Monitoringsystem nachhaltiger Forstwirtschaft werden jedoch unbedingt weitere Indikatoren aus anderen Organismengruppen benötigt.

Introduction

During the conferences in Helsinki 1993 and Lisbon 1998, the European Ministers of Forestry agreed on common European criteria for sustainable forest-management. These include the preservation of biological diversity of forests (Barthod 1998, Merker & Spellmann 2000). In order to be able to check whether the forests in Europe are actually under sustainable use, and to assess the future development of forest management, a monitoring system is required (Hughes 1996, Angelstam 1998, McLaren et al. 1998, Seymour & Hunter 1999, Mrosek & Balsillie 2001).

In the process of developing a monitoring system, the EU-LIFE-Project "Demonstration of Methods to Monitor Sustainable Forestry." is situated. Countries involved in this project are France, Denmark, Sweden, Finland, and Germany. The Lower Saxony forest administration participates as German partner. One small part of the German investigation was to consider whether or not woodpeckers can serve as an indicator group for "ecological" sustainability of forest management, and how a monitoring system for this purpose could be designed. This was carried out by the "Alfred Toepfer Akademie für Naturschutz", Schneverdingen, in cooperation with the "Staatliche Vogelschutzwarte" at the Lower Saxony "Landesamt für Ökologie" (NLÖ) as technical supervisor.

To check what recommendations could be made for a reliable and large-scale monitoring system for woodpeckers that is supposed to be carried out over large areas, we censused six woodpecker species in two study areas in Lower Saxony. To assess if an ongoing evaluation of an indicator system could be based on the forest data provided by the forestry commission, the woodpecker data were related to forest data drawn from the current forest inventory.

In this paper, first we will discuss what is necessary for a sustainable management of European forests while maintaining biodiversity in forest ecosystems, and if woodpeckers are suitable indicators to monitor such a sustainable management. We will address these questions by reviewing the relevant literature. Next we will suggest a census method for woodpeckers that could be used for a reliable and large-scale monitoring system, and we will present some results of the woodpecker census and some conclusions concerning habitat use of woodpeckers in the two study areas as they relate to the forest inventory data.

Maintaining biodiversity in European forests - requirements for a sustainable forest management from a conservation point of view

It is widely accepted that a sustainable use of the environment has to include not only resource sustainability, but also social and socio-economic aspects and the maintenance of biodiversity (Ammer et al. 1995, Barthod 1998, Mrosek & Balsillie 2001). The conference of European Ministers of Forestry in Lisbon (in June 1998) created a system of criteria and indicators for a sustainable management of European Forests (Table 1). The Center for International Forest Research (CIFOR) has developed a similar system for temperate forests in general (Mrosek & Balsillie 2001).

Every subcriterion in Table 1 is specified by qualitative and quantitative indicators. For example, for subcriterion 4.2 (representative, rare and vulnerable forest ecosystems), the quantitative indicators are: area of natural forest types (virgin forests), area of old semi-natural forest types, strongly protected areas, and areas with a specific conservation management. For subcriterion 4.4 (biodiversity in managed forests), the quantitative indicators are: areas for seed production, areas for gene-resources, proportion of mixed stands with at least 2 or 3 tree species, and annual natural regeneration in relation to total regeneration. For these quantitative indicators, standards and threshold values have to be established. The process of defining requirements for sustainable forest management is still in progress, and there has been much discussion about this over the last years.

Indicator species are sensible only for the ecological aspect of sustainability, so in the following we concentrate exclusively on the maintenance of biodiversity as one important aim for sustainable forestry (criterion 4 in Table 1).

If indicator species for a sustainable forest management are to be selected, we must first clearly define the detailed characteristics of such management. The existing systems of criteria and indicators are too general for this purpose. Forest certifications as the FSC (Forest Stewardship Council) and the PEFC (Pan-European Forest Certification) have developed more detailed guidelines, but these show clear differences in some crucial aspects (FSC Arbeitsgruppe Deutschland 1999, 2001, DFZR 2000, Möller 2000a).

Many authors agree that maintaining biodiversity requires that viable populations should be maintained of all naturally occurring species (Angelstam 1999, Seymour & Hunter 1999, Reif 1999/2000). Although this might be regarded as completely self-evident, it is a very ambitious goal and a difficult forestry management task (Angelstam 1999). If the goal is accepted, some important questions arise concerning ecological aspects of forest management:

- To what extent are unmanaged reference areas important to maintain biodiversity, and what proportion of unmanaged forests is necessary (Ammer et al. 1995, Scherzinger 1996, Norton 1999, Seymour & Hunter 1999, Sachverständigenrat für Umweltfragen 2000)? The importance of unmanaged forests as reference areas has to be considered, as natural successional cycles of European forest ecosystems are insufficiently known (Leibundgut 1993, Rauh 1993, Korpel 1997, Angelstam 1999, Ohlson & Tryterud 1999, Zukrigl 1999). Additionally, unmanaged control areas may be important as benchmarks in order to separate forestry effects on population trends of animal and plant species from the effects of factors unrelated to management measures such as long-term climate changes (McLaren et al. 1998, Norton 1999, Schulze 1999).
- Should forest management in general be closely orientated towards natural forest dynamics (Scherzinger 1996, Angelstam 1998, Ohlson & Tryterud 1999, Seymour & Hunter 1999)? To what extent is it necessary (and possible) to allow and include successional processes in managed forests (Sturm 1993, Scherzinger 1997, Möller 2000b)?
- In what way and to what extent does tree species composition (and the use of exotic tree species) affect biodiversity in forests (Scherzinger 1996, Palik & Engstrom 1999, Reif 1999/2000, Bürger-Arndt 2000)?
- What amount of dead wood and “biotope trees” is required in managed forests to offer enough habitat for dead-wood specialists (Angelstam 1990, Rauh & Schmitt

1991, Kleinevoss et al. 1996, Haase et al. 1998, McComb & Lindenmayer 1999, Köhler 2000)?

- Do we have enough old forests stands to keep all the species that are dependent on old and very old trees (many mosses, lichens, fungi, xylobiontic invertebrates, but also several vertebrate species; Scherzinger 1996, Kost 1989, Uliczka & Angelstam 1999, Hanstein 2000, Möller 2000)?

Woodpeckers as indicators for a sustainable forestry

The suitability of woodpeckers as indicators for biodiversity in forests (and in the following for a sustainable forestry) has been discussed intensively in recent years (Scherzinger 1982, Angelstam 1990, Short & Horne 1990, Rauh 1993, Angelstam & Mikusiński 1994, Fernandez & Azkona 1996, Jedicke 1997, Mikusiński 1997, Scherzinger 1998). Of course, woodpeckers or other indicator species cannot indicate a certain type of management, but only habitat characteristics that derive from management measures. To assess the suitability of different woodpecker species as indicators and to specify what habitat characteristics they can indicate, the "fundamental niches" of each species must be sufficiently known. Although the ecology of European woodpeckers is relatively well understood compared to the situation for other vertebrate or even invertebrate species, in some aspects there is still a lack of information even for the very well-known and widespread Great Spotted Woodpecker *Picoides major* (e.g. the importance of migration patterns and seasonal differences in feeding ecology in different forest types).

Generally, woodpeckers appear to be a good choice indicator species for biodiversity in forests (Scherzinger 1982, Mikusiński & Angelstam 1997, McLaren et al. 1998). Following the criteria for indicator species for sustainable forestry used by McLaren et al. (1998), woodpeckers as a group meet the most important criteria:

- Many woodpeckers are "keystone species": the cavities excavated by woodpeckers are an important, sometimes indispensable habitat resource for many other species of birds, mammals, and invertebrates.
- Most woodpeckers are resident species, and as such they are more reliable indicators than migrants, whose populations are affected not only by conditions on their breeding grounds, but also by habitat changes in their migration and wintering areas.
- Woodpeckers are directly affected by forest management measures.
- The different woodpecker species are dependent on properties of naturally dynamic forests as well as properties of naturally dynamic forest landscapes, so they can indicate habitat changes at different scales.
- They use different strata of vegetation from the ground and lying dead wood to the trunk region and the canopy of forests.
- They show a great variety of feeding strategies from the omnivorous Great Spotted Woodpecker to the very specialized, ant-eating Green Woodpecker *Picus viridis*.

- Census techniques for woodpeckers are available, even though more evidence from field research is necessary to assess the reliability and effectiveness of these methods.

Of course there is one more crucial requirement for indicator species: patterns of distribution and abundance of indicator species must reflect those of other taxa (Mikusiński 1997). So far, this has been proven for woodpeckers only in a relatively limited context. For example, species richness of saproxylic beetles (Coleoptera) in Karelia (north-east Europe) was considerably higher in habitats occupied by the White-backed Woodpecker (*Picoides leucotos*; Martikainen et al. 1998). Jansson (1998) found that when the Lesser Spotted Woodpecker *Picoides minor* was present in a patch of deciduous forest, the probability of the presence of Long-tailed Tit *Aegithalos caudatus*, Marsh Tit *Parus palustris* and Blue Tit *Parus caeruleus* was very high.

However, we have good indications that similar relationships exist between woodpeckers and the occurrence of many other species. Generally, European woodpecker species are adapted to habitat structures of old forests: a patchy stand structure with gaps, dead wood (especially standing dead wood of bigger dimensions), and old trees with broken boughs and treetops (Scherzinger 1996). The same habitat structures are very important for a lot of other species, for example cavity-breeding birds, some raptors, owls, bats, xylobiontic insects, fungi, mosses and lichens (Wesolowski 1989, Angelstam 1990, Rauh & Schmitt 1991, Kleinevoss et al. 1996, Hohlfeldt 1997, Borrmann 1996, Scherzinger 1996, Haase et al. 1998, McComb & Lindenmayer 1999, Hanstein 2000, Köhler 2000). Mikusiński & Angelstam (1998) used the completeness of the woodpecker guild as an indicator for forest biodiversity in Central Europe. On the other hand, they suggest that the relative abundance of the omnivorous Great Spotted Woodpecker might be a good predictor of the level of anthropogenic change in forest ecosystems.

Materials and methods

In 2000, a census of six woodpecker species was carried out in two study areas in Lower Saxony: the “Lüneburger Heide” (53°11’N, 09°53’E), a region in the lowland strongly affected by deforestation and characterized by large areas of heath vegetation in the past, then reforestated since the 1850s; and the “Solling” (51°45’N, 09°31’E), a low mountain range in the south of Lower Saxony with a longer history of forestry. In each study area, 12 census plots (each between 50 and 230 hectares) were selected, thus including a total of about 1800 ha in each region.

In the “Lüneburger Heide”, the census plots are dominated by Pine *Pinus sylvestris* forest (32 %) and mixed Pine and Spruce *Picea abies* forest (25 %). Stands of Beech *Fagus sylvaticus* and Oak *Quercus robur/petraea* add to almost 12 %. Other important tree species are Birch *Betula pendula* and *B. pubescens*, Larch *Larix decidua* and *L. kaempferi* and Douglas Fir *Pseudotsuga menziesii*. About 30 % of the stands are more than 100 years old.

The “Solling” is dominated by Beech (25 %), Spruce (25 %), or mixed Beech and Spruce stands (22 %). Stands of Oak and Oak mixed with Beech or Hornbeam *Carpinus betulus* take about 15 %. Other important tree species are Birch and Larch. The stands are on average older than in the “Lüneburger Heide”, 52 % are older than 100 years.

The census method used was a modified type of territory mapping (cf. Bibby et al. 1995), specially adapted for censusing woodpeckers. We propose this method for use in monitoring woodpeckers in European forests.

Important requirements for the method were a clear standardization, compatibility for different forest types in Europe, and efficiency, including cost effectiveness. The census should be carried out on a yearly basis, until natural population dynamics (depending on severe winters, for example, or supply of pine and spruce cones in the case of the Great Spotted Woodpecker) are sufficiently understood. After that a census every three or five years should be enough.

We recommend the following protocols.

- The census should take place in spring, when calling and drumming activity of woodpeckers is highest (in north Germany in March and April).
- Each census plot should be visited 3 times at intervals of 10 to 14 days.
- Single census plots should have a size of about 150 ha.
- The route through a census plot (or, if possible, linear transects) should not be more than 150 meters away from any point of the area; so the distance between two linear transects should be 300 m at maximum.
- We recommend use of existing pathways where available, because this is easier and produces less noise; furthermore, one can concentrate on the birds instead of the thorny undergrowth.
- The fieldworker should move at a rate of 1.5 to 2 km per hour, so that a census plot can be mapped in about 4 to 5 hours during one morning.
- A scale of 1:10.000 is sufficient for the map.
- No mapping should take place in bad weather conditions (wind of more than 4 Beaufort or heavy rain).
- Every woodpecker sighting should be noted on the map and additionally on a prepared data paper, where the sighting number, time, species, and record type (optical or acoustical record, type of vocalisation, drumming or other instrumental sounds) and, if possible, sex, behaviour, tree species and stratum (ground, trunk, lower canopy, upper canopy) should be recorded.
- For the Grey-headed and the Middle Spotted woodpecker, the use of playback (tape recorder) is recommended, especially in areas with low densities of these species.

Analyses of the woodpecker data were carried out on two spatial levels: On the stand level, the “density” of woodpecker sightings (sightings/ha) was determined, while on the census plot level the abundance (territories/ha) of woodpecker species was compared. Data analyses were carried out using the Geographical Information System program ArcView 3.2.

The forest parameters, mainly the age and species composition of the stands, were taken from the current forest inventory. In this paper, we concentrate on the importance of stand age and elevation of the census plot above sea level. In the forest inventory in Lower Saxony, stands are divided into 9 age classes based on the age of the main tree species in the stand or the one the management measures are aligned with. Each age class covers 20 years, so age class 1 includes trees of 1 to 20 years, age class 2 21 to 40 years, and so on. Age class 9 consists of all stands older than 160 years. Stands with "legacy trees" ("Überhälter"; trees of the previous tree generation that were not cut when the stand was harvested), occurring in age classes 1 to 3, were excluded from the analysis, because a few old trees on a stand can be of much more ecological importance than all the young trees that define the age class.

Results

In the "Lüneburger Heide", 4 woodpecker species were found: Great Spotted Woodpecker, Lesser Spotted Woodpecker, Green Woodpecker and Black Woodpecker *Dryocopus martius*. The wryneck *Jynx torquilla* is quite frequent in the region, but this species was not included in the study because it is rather a bird of the open and half-open landscape. In the "Solling" 6 woodpecker species were recorded: Great Spotted Woodpecker, Middle Spotted woodpecker *Picoides medius*, Lesser Spotted Woodpecker, Grey-headed woodpecker *Picus canus* and Black woodpecker.

In both regions, the Lesser Spotted Woodpecker was so rare that a quantitative analysis of the data was not possible. Table 2 shows the abundance of woodpeckers in the 24 study plots.

On the stand level, the "sighting density" for all woodpecker species increases with the stand age (Fig. 1, Fig. 2) in both study areas. Especially in the "Lüneburger Heide", the Great Spotted Woodpecker was regularly recorded in stands of age class 2, 3, and 4 (though much more frequent on older stands), while all other species seemed to avoid stands younger than 100 years. Of all recorded species, the Middle Spotted Woodpecker seemed to have the strongest affinity to old trees (Fig. 2). Fig. 3 shows the "sighting density" of all woodpeckers on stands of the different age classes compared to the average.

On the census plot level, the results are similar. A comparison of the 12 census plots in each area ("Lüneburger Heide" and "Solling") suggests that the total woodpecker abundance is positively correlated with the proportion of trees older than 80 years in a census plot (Rs = 0,804 resp. Rs = 0,692; Table 3; Fig. 4). The same is true for the Great Spotted Woodpecker as the most numerous species (Table 3). The other species occurred only in a few census plots or their abundance was generally too low for a single species analysis.

In Solling, where diversity of woodpecker species was a little higher than in the Lüneburger Heide, the number of species in a census plot was also positively correlated with the proportion of trees older 80 years (Rs = 0,769; Fig. 5). Higher elevations of more than 400 m above sea level had a negative effect on both woodpecker abundance and diversity (Fig. 6).

Table 3 shows the correlation coefficients (Spearman Rank Correlation) for all tested age and elevation parameters in both study areas.

Discussion

The results emphasize the significance of old forest stands, and especially old deciduous trees, for the abundance and diversity of woodpeckers. The very old stands in this study (age class 9, more than 160 years old) are by far the most attractive areas for woodpeckers. Although data on the amount of dead wood in the different stands were not available, it can be assumed that in most cases the stands of age class 9 are the ones richest in dead wood and snags. The amount of dead wood, lying and standing, increases considerably when a stand turns from the "optimum phase" (where harvesting normally takes place) to the early "climax phase" (in Germany sometimes called "plenter phase") in the forest development (Leibundgut 1993, Scherzinger 1996). The importance of dead wood, especially standing dead wood of large dimensions, for woodpeckers (for excavating cavities as well as for foraging) has been shown by many authors (e.g. Scherzinger 1982, Noeke 1989, Angelstam 1990, Short & Horne 1990, Utschick 1991, Rauh 1993, Pechacek 1995, Wesolowski & Tomialojc 1995, Smith 1997, McComb & Lindenmayer 1999).

Woodpecker abundance was considerably higher in the "Lüneburger Heide" than in the "Solling". Only two census plots in the "Solling", both with a high proportion of oaks, show total woodpecker abundances that reach the average of the "Lüneburger Heide" region. This might be due to the relatively high elevation of many census plots in the "Solling", together with the fact that the forest is often dominated by spruce stands, especially on higher elevations. These are unsuitable for most of the woodpeckers, and only marginal habitat for the Great Spotted and Black Woodpecker (Glutz von Blotzheim & Bauer 1980, Scherzinger 1982, Wagner 2000). Compared to other forest regions in Germany, the abundance of Great Spotted and Black Woodpeckers in the "Lüneburger Heide" is relatively high (Glutz von Blotzheim & Bauer 1980, Zang 1986, Flade 1994, Blume & Tiefenbach 1997).

On the other hand, diversity of woodpeckers is higher in the "Solling" region. With Middle Spotted and Grey-headed Woodpecker as "additional" species compared to the "Lüneburger Heide", those census plots in the "Solling" rich in old deciduous trees are inhabited by 3 to 5 woodpecker species.

There are only a few records of Middle Spotted and Grey-headed Woodpeckers from the "Lüneburger Heide", mainly from the first half of the 20th century (Lütkepohl & Prüter 2000, Schmidt 2001). Nevertheless, we suggest that before the almost complete deforestation of the north German lowlands, both species could have occurred in the formerly typical lowland deciduous forests (Mikusiński & Angelstam 1997, 1998). The same might be true for the White-backed Woodpecker (Glutz von Blotzheim & Bauer 1980). So the present absence of these species is possibly not due to natural geographic restrictions, but only to the complete change of the landscape by human activities (Mikusiński & Angelstam 1998).

Conclusion

The six woodpecker species differ in their suitability as indicator species. Further research for the "fundamental niche" of the species is needed to specify what habitat characteristics (on different spatial scales) the different species can indicate.

Furthermore, there is a lack of studies that clearly relate occurrence of woodpeckers to other taxa (Mikusiński 1997).

Despite these deficiencies, we conclude that woodpeckers in general seem to be good indicators for sustainable forestry. Of course, they can only be one part of a serious monitoring system of sustainability. Grouse (Scherzinger 1997, Angelstam 1998), some species of owls and raptors (Scherzinger 1997, Thompson & Angelstam 1999), flycatchers (Paleit et al. 1998) and other birds also might be good indicators. Other groups of organisms must be considered, too. For example, xylobiontic insects are good indicators for the quality of dead wood habitats (Rauh & Schmitt 1991, Möller 1993). While the diversity of vascular plants doesn't seem to be a suitable indicator at least for European forests (Westphal in press), fungi (Kost 1989, Schmidt 1998, Ohlson & Tryterud 1999), lichens (Litterski 1998, Ohlson & Tryterud 1999, Okolów 1999, Uliczka & Angelstam 2000), and mosses (Ohlson et al. 1997, Berg 1998), due to specific requirements towards the quality of forest ecosystems, are good indicator species.

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References

Ammer, U., R. Detsch & U. Schulz, 1995: Konzepte der Landnutzung - Concepts of Land Use. Forstwissenschaftliches Centralblatt 114: 107-125.

Angelstam, P., 1990: Factors Determining the Composition and Persistance of Local Woodpecker Assemblages in Taiga Forest in Sweden - a Case for Landscape Ecological Studies. Conservation and management of woodpecker populations. A. Carlson and G. Aulén. Uppsala, Swedish University of Agricultural Sciences, Department of Wildlife Ecology. Report 17**:** 147-166.

Angelstam, P., 1998: Maintaining and restoring biodiversity in European boreal forests by developing natural disturbance regimes. Journal of Vegetation Science 9: 593-602.

Angelstam, P., 1999: Reference areas as a tool for sustaining forest biodiversity in managed landscapes. Naturschutzreport 16: 96-121.

Angelstam, P. & G. Mikusiński, 1994: Woodpecker assemblages in natural and managed boreal and hemiboreal forest - a review. Annales Zoologici Fennici 31: 157-172.

Barthod, C., 1998: Criteria and indicators for sustainable temperate forest management - 1992 to 1996. Unasylva 49: 53-56.

Berg, C., 1998: Die Moosflora des Darßwaldes. Natur und Naturschutz in Mecklenburg-Vorpommern 34: 69-77.

Bibby, C. J., N. D. Burgess & D.A. Hill, 1995: Methoden der Feldornithologie: Bestandserfassung in der Praxis. Radebeul.

Blume, D. & J. Tiefenbach, 1997: Die Buntspechte. Magdeburg, Germany.

Borrmann, K., 1996: Vierzig Jahre Naturwaldforschung im Heilige Hallen-Bestand. AFZ/Der Wald 51(23): 1292-1296.

Bürger-Arndt, R., 2000: Kenntnisse zur Synökologie der Douglasie als Grundlage für eine naturschutzfachliche Einschätzung. Forst und Holz 55(22): 707-712.

Deutscher Forst-Zertifizierungsrat, 2000: PEFC Deutschland. Leitlinien für nachhaltige Waldbewirtschaftung zur Einbindung der Waldbesitzer in den regionalen Rahmen - Anahng IV der Systembeschreibung. Deutscher Forst-Zertifizierungsrat. Stuttgart: 6 pages.

Fernandez, C. & P. Azkona, 1996: Influence of forest structure on the density and distribution of the White-backed Woodpecker *Dendrocopos leucotos* and Black Woodpecker *Dryocopus martius* in Quinto Real (Spanish western Pyrenees). Bird Study 43: 305-313.

Flade, M., 1994: Die Brutvogelgemeinschaften Mittel und Norddeutschlands: Grundlagen für den Gebrauch vogelkundlicher Daten in der Landschaftsplanung. Eching, Germany.

Forest Stewardship Council (FSC) Arbeitsgruppe Deutschland, 1999: Richtlinien nachhaltiger Forstwirtschaft - Deutsche FSC-Standards. FSC Arbeitsgruppe Deutschland e. V. Freiburg**:** 31 pages.

Forest Stewardship Council (FSC) Arbeitsgruppe Deutschland, 2001: FSC setzt Maßstäbe: Vergleich der Zertifizierungssysteme von FSC und PEFC - Zusammenfassung der gemeinsamen Synopse. FSC Arbeitsgruppe Deutschland e. V. Freiburg**:** 4 pages.

Glutz von Blotzheim, U. & K. M. Bauer, 1980: Handbuch der Vögel Mitteleuropas, Band 9, Columbiformes - Piciformes. Wiesbaden, Akademische Verlagsgesellschaft.

Haase, V., W. Topp & P. Zach, 1998: Eichen-Totholz im Wirtschaftswald als Lebensraum für xylobionte Insekten. Zeitschrift für Ökologie und Naturschutz 7: 137-153.

Hanstein, U., 2000: Vom Geheimnis des Alterns - am Beispiel nordwestdeutscher Tiefland-Buchenwälder. Forst und Holz 55(15): 477-480.

Hohlfeldt, F., 1997: Vergleichende ornithologische Untersuchungen in je sechs Bann- und Wirtschaftswäldern im Hinblick auf die Bedeutung des Totholzes für Vögel. Ornithologische Jahreshefte für Baden-Württemberg 13(1): 1-127.

Hughes, R., 1996: Certification of sustainable forest management systems: The importance of field verification. The Forestry Chronicle 72(6): 595-597.

Jansson, G., 1998: Guild indicator species on a landscape scale - an example with four avian habitat specialists. Ornis Fennica 75: 119-127.

Jedicke, E., 1997: Spechte als Zielarten des Naturschutzes. Vogelkundliche Hefte Edertal 23: 5-43.

Kleinevoss, K., W. Topp & J. Bohac, 1996: Buchen-Totholz im Wirtschaftswald als Lebensraum für xylobionte Insekten. Zeitschrift für Ökologie und Naturschutz 5: 85-95.

Köhler, F., 2000: Totholzkäfer in Naturwaldzellen des nördlichen Rheinlands - Vergleichende Studien zur Totholzkäferfauna Deutschlands und deutschen Naturwaldforschung. Recklinghausen, LÖBF.

Korpel, S., 1997: Totholz in Naturwäldern und Konsequenzen für Naturschutz und Forstwirtschaft. Forst und Holz 52(21): 619-624.

Kost, G., 1989: Bannwälder als Refugien für gefährdete Pilze. Natur und Landschaft 64(12): 578-582.

Leibundgut, H., 1993: Europäische Urwälder - Wegweiser zur naturnahen Waldwirtschaft. Bern und Stuttgart.

Litterski, B., 1998. Flechtenflora auf ausgewählten Monitoringflächen im Nationalpark Vorpommersche Boddenlandschaft. Natur und Naturschutz in Mecklenburg-Vorpommern 34: 78-97.

Lütkepohl, M. & J. Prüter, 2000: Die Vögel im Naturschutzgebiet Lüneburger Heide. Bremen.

Martikainen, P., L. Kaila & Y. Haila, 1998: Threatened beetles in White-backed Woodpecker habitats. Conservation biology 12: 293-301.

McComb, W. & D. Lindenmayer, 1999: Dying, dead, and down trees. Pages 335-372 in M. L. Hunter, editor. Maintaining Biodiversity in Forest Ecosystems. Cambridge, New York, Melbourne.

McLaren, M. A., I. D. Thompson & J. A. Baker, 1998: Selection of vertebrate wildlife indicators for monitoring sustainable forest management in Ontario. The Forestry Chronicle 74(2): 241-248.

Merker, K. & H. Spellmann, 2000: Nachweis forstlicher Nachhaltigkeit - Das EU-LIFE-Projekt der LFV Niedersachsen. Forst und Holz 55(2): 51-55.

Mikusiński, G., 1997: Woodpeckers in Time and Space - The role of natural and anthropogenic factors. Department of Conservation Biology. Uppsala, Swedish University of Agricultural Sciences: 23.

Mikusiński, G. & P. Angelstam, 1997: Economic Geography, Forest Distribution and Woodpecker Diversity in Central Europe. Woodpeckers in Time and Space - The role of natural and anthropogenic factors. G. Mikusiński. Uppsala, Swedish University of Agricultural Sciences.

Mikusiński, G. & P. Angelstam, 1997: European Woodpeckers and anthropogenic habitat change: a review. Vogelwelt 118: 277-283.

Mikusiński, G. & P. Angelstam, 1998: Economic Geography, Forest Distribution, and Woodpecker Diversity in Central Europe. Conservation Biology 12(1): 200-208.

Möller, G., 1993: Alt- und Totholz in Land- und Forstwirtschaft - Ökologie, Gefährdungssituation, Schutzmaßnahmen. Mitteilungen aus der NNA 4(5): 30-47.

Mrosek, T. & D. Balsillie, 2001: Kriterien und Indikatoren einer nachhaltigen Waldbewirtschaftung auf Forstbetriebsebene. AFZ/Der Wald 56(4): 193-195.

Noeke, G., 1989: Baumhöhlen in Buchenbeständen - Welche Rolle spielt das Bestandesalter? LÖLF-Mitteilungen 14(3): 20-22.

Norton, D. A., 1999: Forest reserves. Pages 525-555 in M. L. Hunter, editor. Maintaining Biodiversity in Forest Ecosystems. Cambridge, New York, Melbourne.

Ohlson, M., L. Söderström, G. Hörnberg, O. Zackrisson & J. Hermansoon, 1997: Habitat Qualities versus Long-Term Continuity as Determinants od Biodiversity in Boreal Old-Growth Swamp Forests. Biological Conservation 81: 221-231.

Ohlson, M. & E. Tryterud, 1999: Long-term spruce-forest continuity - a challenge for a sustainable Scandinavian forestry. Forest Ecology and Management 124: 27-34.

Okolów, C., 1999: Schutz der Biodiversität und der natürlichen Prozesse sowie Probleme der Wiederherstellung von geschützten Ökosystemen im Nationalpark von Bialowieza. Naturschutzreport 16: 61-71.

Paleit, J., K. Richarz & A. Schulte, 1998: Vogelkundliche Gesichtspunkte zum Management des geplanten Nationalparks Kellerwald. Vogel und Umwelt 9: 247-277.

Palik, B. & R. T. Engstrom, 1999: Species composition. Pages 65-94 in M. L. Hunter, editor. Maintaining Biodiversity in Forest Ecosystems. Cambridge, New York, Melbourne.

Pechacek, P., 1995: Spechte (Picidae) im Nationalpark Berchtesgaden - Habitatwahl, Nahrungsökologie, Populationsdichte. Forschungsberichte Nationalpark Berchtesgaden 31: 183.

Rauh, J., 1993: Faunistisch-ökologische Bewertung von Naturwaldreservaten anhand repräsentativer Tiergruppen. Naturwaldreservate in Bayern, Schriftenreihe des bayerischen Staatsministeriums für Ernährung, Landwirtschaft und Forsten 2: 3-199.

Rauh, J. & M. Schmitt, 1991: Methodik und Ergebnisse der Totholzforschung in Naturwaldreservaten. Forstwissenschaftliches Centralblatt 110: 114-127.

Reif, A., 1999/2000: Das naturschutzfachliche Kriterium der Naturnähe und seine Bedeutung für die Waldwirtschaft. Zeitschrift für Ökologie und Naturschutz 8: 239-250.

Scherzinger, W., 1982: Die Spechte im Nationalpark Bayerischer Wald. Schriftenreihe des Bayerischen Staatsministeriums für Ernährung, Landwirtschaft und Forsten 9: 1-119.

Scherzinger, W., 1996: Naturschutz im Wald - Qualitätsziele einer dynamischen Waldentwicklung. Stuttgart.

Scherzinger, W., 1997: Naturwald und Kulturwald aus der Vogelperspektive. Ber. z. Vogelschutz 35: 49-60.

Scherzinger, W., 1998: Sind Spechte "gute" Indikatoren der ökologischen Situation von Wäldern? Vogelwelt 119(1): 1-6.

Schmidt, F.-U., 2001: Die Vogelwelt im Landkreis Soltau-Fallingbostel. Naturkundliche Beiträge Soltau-Fallingbostel 7/8: 1-358.

Schmidt, I., 1998: Erfassung und Bewertung der Pilzflora ausgewählter Flächen des Darß im Jahr 1994. Natur und Naturschutz in Mecklenburg-Vorpommern 34: 43-68.

Schulze, E. D., 1999: Biodiversität und Ökosystemfunktionen in den laubabwerfenden Wäldern der gemäßigte Zone. Naturschutzreport 16: 18-45.

Seymour, R. S. & M. L. Hunter, 1999: Principles of ecological forestry. Pages 22-64 in M. L: Hunter, editor. Maintaining Biodiversity in Forest Ecosystems. Cambridge, New York, Melbourne.

Short, L. L. & J. F. M. Horne, 1990: Woodpeckers - a World Perspective and Conservation Concerns. Conservation and management of woodpecker populations. A. Carlson and G. Aulén. Uppsala, Swedish University of Agricultural Sciences, Department of Wildlife Ecology. Report 17: 5-12.

Smith, K. W., 1997: Nest site selection of the Great Spotted Woodpecker *Dendrocopos major* in two oak woods in southern England and its implications for woodland management. Biological Conservation 80: 283-288.

Sturm, K., 1993: Methoden und Ziele der Waldbiotopkartierung. Mitteilungen aus der NNA 4 (5): 7-20.

Sturm, K., 1993: Prozeßschutz - ein Konzept für naturschutzgerechte Waldwirtschaft. Zeitschrift für Ökologie und Naturschutz 2: 181-192.

Thompson, I. D. & P. Angelstam, 1999: Special Species. Pages 434-459 in M.J. Hunter, editor. Maintaining Biodiversity in Forest Ecosystems. Cambridge, New York, Melbourne.

Uliczka, H. & P. Angelstam, 1999: Occurence of epiphytic macrolichens in relation to tree species and age in managed boreal forest. Ecography 22: 396-405.

Uliczka, H. & P. Angelstam, 2000: Assessing conservation values of forest stands based on specialised lichens and birds. Biological Conservation 95: 343-351.

Utschick, H., 1991: Beziehungen zwischen Totholzreichtum und Vogelwelt in Wirtschaftswäldern. Forstwissenschaftliches Centralblatt 110: 135-148.

Wagner, M., 2000: Zum Vorkommen des Sperlingskauzes (*Glaucidium passerinum*) im Südharz. Landschaftspflege und Naturschutz in Thüringen 37(1): 24-28.

Wesolowski, T., 1989: Nest-sites of hole-nesters in a primaeval temperate forest (Bialowieza National Park, Poland). Acta ornithologica 25(3): 321-351.

Wesolowski, T. & L. Tomialojc, 1995: Ornithologische Untersuchungen im Urwald von Bialowieza - eine Übersicht. Ornithologischer Beobachter 92: 111-146.

Zang, H., 1986: Schwarzspecht - *Dryocopus martius*. Pages 131-137 in H. Zang & H. Heckenroth, editors. Die Vögel Niedersachsens. Naturschutz und Landschaftspflege in Niedersachsen B, H. 2.7.

Zukrigl, K., 1999: Die Bedeutung unbewirtschafteter Wälder für die Forstwissenschaft. Naturschutzreport 16: 13-17.

Internet references

Möller, G., 2000a: Waldzertifizierung - Quo vadis? Büro für Dendroentomologie - Baumschutzgemeinschaft. Berlin: 6 pages. http://tintling.gewerbenet.de/moeller.htm

Möller, G., 2000b: Schutz und Entwicklung von Alt- und Totholzlebensräumen im Saarland - didaktische Grundlagen unter besonderer Berücksichtigung des Saarkohlenwaldes. Berlin. http://www.expo2000.saarland.de/forstsb/materialien/moellertext/lebenimtotholz.htm

Sachverständigenrat für Umweltfragen (2000): Umweltgutachten 2000 des Rates von Sachverständigen für Umweltfragen. http://www.umweltrat.de/gut00kf2.htm

Sheet 1

Criterion 1: Forest Resources	Criterion 2: Health and Vitality	Criterion 3: Production	Criterion 4: Biodiversity	Criterion 5: Conservation functions	Criterion 6: Socio-economic functions
1.1 general legal validity		3.1 wood production	4.1 general conditions	5.1 general conservation	6.1 Importance for national economy
1.2 land use and forest area		3.2 other products	4.2 representative, rare and vulnerable forest ecosystems	5.2 soil erosion	6.2 recreation function
1.3 stock / wood reserves			4.3 endangered species	5.3 water balance in forests	6.3 employment function
1.4 carbon balance			4.4 biodiversity in managed forests		6.4 research and training
					6.5 public relations work
					6.6 participation
					6.7 cultural values

sheet 2

study area / census plot	**elevation** m above s.l.	**area** ha	**GSWO** terr./10 ha	**MSWO** terr./10 ha	**LSWO** terr./10 ha	**GWO** terr./100 ha	**GHWO** terr./100 ha	**BWO** terr./100 ha	**all WO** terr../10 ha
Lüneburger Heide (NW German Lowlands)									
Ki-Wald N Bullenberge	60-65	121,3	0,49	-	-	-	-	0,82	0,58
Bullenberge	65-75	152,1	1,12	-	-	-	-	1,31	1,25
Erhorner Dünen	70-80	84,2	1,19	-	-	1,19	-	1,19	1,43
Karck-Berg und Altes Feld	80-120	134,3	1,19	-	-	-	-	0,74	1,27
An der alten Wümme	70-75	125,3	1,12	-	-	-	-	0,80	1,20
Meninger Holz	80-105	139,9	1,14	-	-	-	-	1,43	1,29
Hainköpen	100-125	54,0	1,85	-	-	1,85	-	1,85	2,22
Oberhaverbecker Holz	95-125	141,1	0,99	-	0,07	0,71	-	2,13	1,35
Wald bei Volkwardingen	80-95	141,1	0,57	-	-	-	-	0,71	0,64
Toppenstedter Wald	80-100	162,1	0,80	-	-	0,62	-	1,23	0,99
Heimbucher Heide	60-100	186,2	0,43	-	-	-	-	0,54	0,48
Döhler Fuhren	65-95	142,9	0,84	-	-	-	-	0,70	0,91
Auf dem Töps	70-110	240,1	0,46	-	-	-	-		0,46
sum/average		1824,6	0,85	-	0,01	0,22	-	0,93	0,97
Solling (mountain area)									
Wolfskopf	380-440	157,7	0,25	-	-	-	0,06	0,06	0,38
Friedrichshäuser Bruch	440-510	136,5	0,07	-	-	-	-	0,07	0,15
Kleines Bruch	350-400	114,5	0,17	-	-	-	-	0,09	0,26
Limker Strang	400-440	168,7	0,18	0,06	-	-	0,06	-	0,30
Am Wildpark	320-450	118,9	0,50	0,34	-	-	0,08	0,08	1,01
Buchenwald bei Boffzen	200-350	101,7	0,29	-	-	-	-	0,10	0,39
Hainbuchensohl	360-420	113,0	0,44	-	-	-	0,09	0,09	0,62
Reiherbachtal	200-280	172,8	0,41	0,35	0,06	-	-	0,06	0,87
Uhlenbruch	460-490	127,9	0,16	-	-	-	-	0,08	0,23
Langer Grund	380-460	142,5	0,28	-	-	-	-	0,07	0,35
Winterlieth	380-490	227,3	0,09	-	-	-	0,04	-	0,13
Gr. Kuhlenberg, Weserst.	120-330	204,0	0,34	0,10	0,10	-	0,05	0,05	0,64
sum/average		1785,5	0,26	0,07	0,02	-	0,03	0,06	0,44

sheet 3

		elevation	>80	>100	>120
Abundance GSWO	**LGH**	0,234	0,631*	0,530*	0,097
	Solling	-0,705**	0,538*	0,643*	0,538*
Abundance all WO	**LGH**	0,474	0,804**	0,748**	0,517*
	Solling	-0,771**	0,692**	0,748**	0,587*
Number of species	**LGH**	0,577*	0,694**	0,670*	0,670*
	Solling	-0,486	0,769**	0,857***	0,829***
		decid. >80	**decid. >120**	**conif. >80**	**conif. >120**
Abundance GSWO	**LGH**	0,456	0,259	0,698**	0,080
	Solling	0,601*	0,476	-0,224	0,250
Abundance all WO	**LGH**	0,706**	0,614*	0,503*	0,448
	Solling	0,699**	0,531*	-0,259	0,142
Number of species	**LGH**	0,806**	0,767**	0,124	0,484
	Solling	0,738**	0,797**	-0,084	0,142

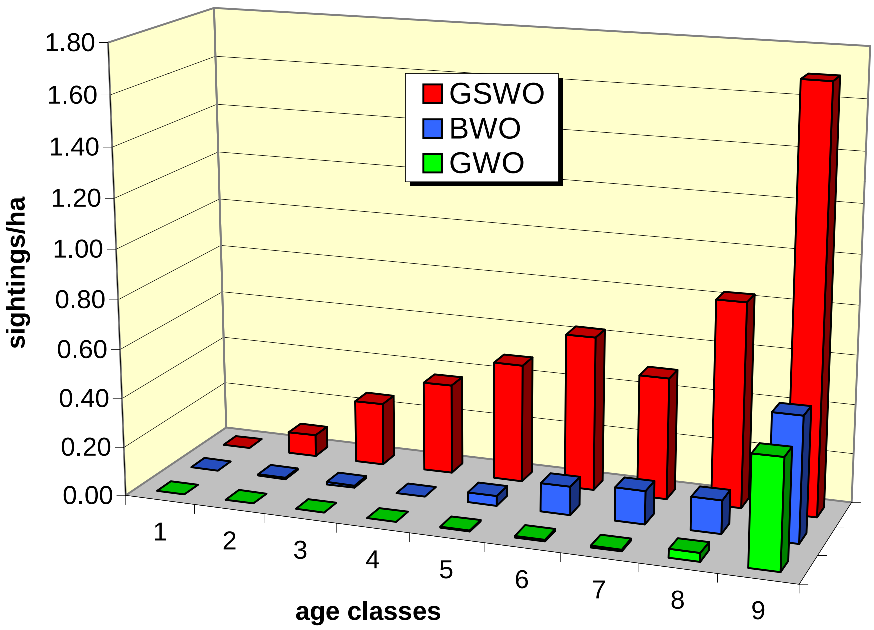

Fig. 1: Distribution of woodpecker sightings of three species (GSWO: Great Spotted Woodpecker; BWO: Black Woodpecker; GWO: Green Woodpecker) on age classes of forest stands (stands with „legacy trees“ excluded) in the Lüneburger Heide (sightings per ha). n=1109.

Verteilung der Spechtbeobachtungen der einzelnen Arten auf die Altersklassen (ohne Überhälter-Flächen) in den Untersuchungsgebieten in der Lüneburger Heide (relative Nutzung in Beob./ha).

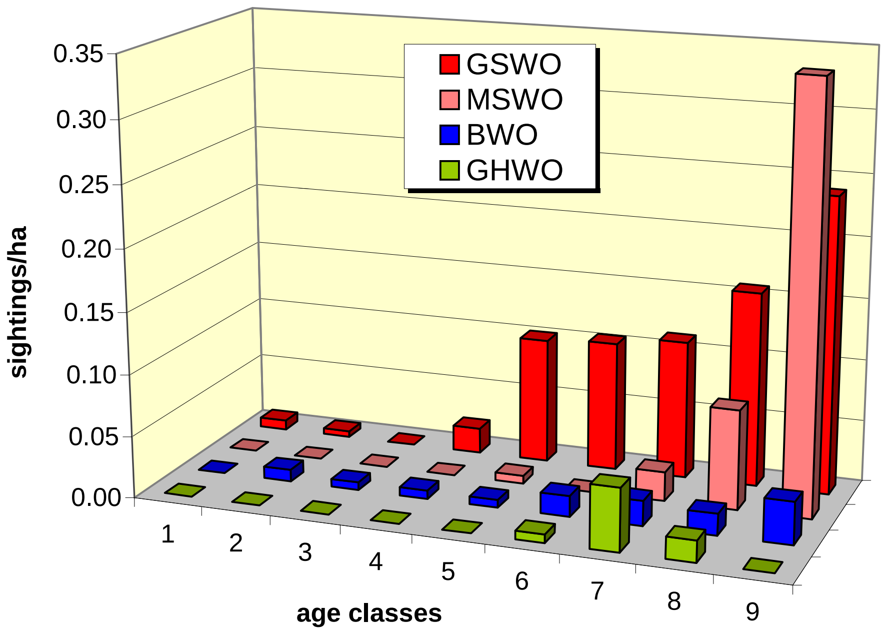

Fig. 2: Distribution of woodpecker sightings of four species (GSWO: Great Spotted Woodpecker; MSWO: Middle Spotted Woodpecker; BWO: Black Woodpecker; GHWO: Grey-headed Woodpecker) on age classes of forest stands (stands with „legacy trees“ excluded) in the Solling low mountain range (sightings per ha). n=260.

Verteilung der Spechtbeobachtungen der einzelnen Arten auf die Altersklassen (ALTK; ohne Überhälter-Flächen) in den Untersuchungsgebieten im Solling (relative Nutzung in Beob./ha).

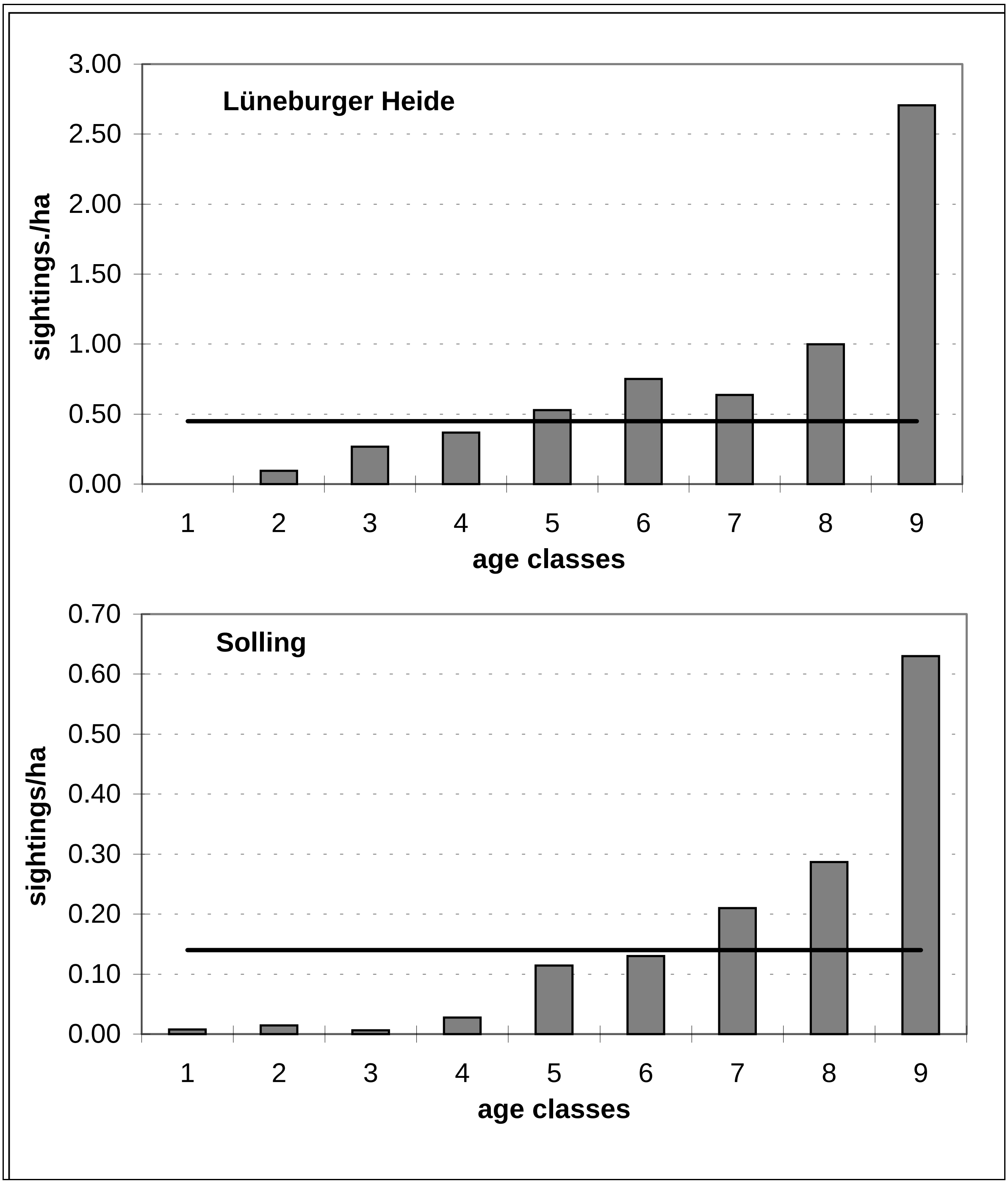

Fig. 3: Distribution of Woodpecker sightings (all species) on age classes of forest stands (stands with „legacy trees" excluded) in the Lüneburger Heide (above) and in the Solling (below; sightings per ha), compared to the average of 0.45 resp. 0.14 sightings per ha (horizontal line).n=1109 resp. n=260.

Verteilung der gesamten Spechtbeobachtungen auf die Altersklassen (ohne Überhälter-Flächen) in den Untersuchungsgebieten in der Lüneburger Heide (oben) und im Solling (unten; relative Nutzung in Beob./ha) im Vergleich zur durchschnittlichen Beobachtungsdichte von 0,45 bzw. 0,14 Beob./ha (horizontale Linie).

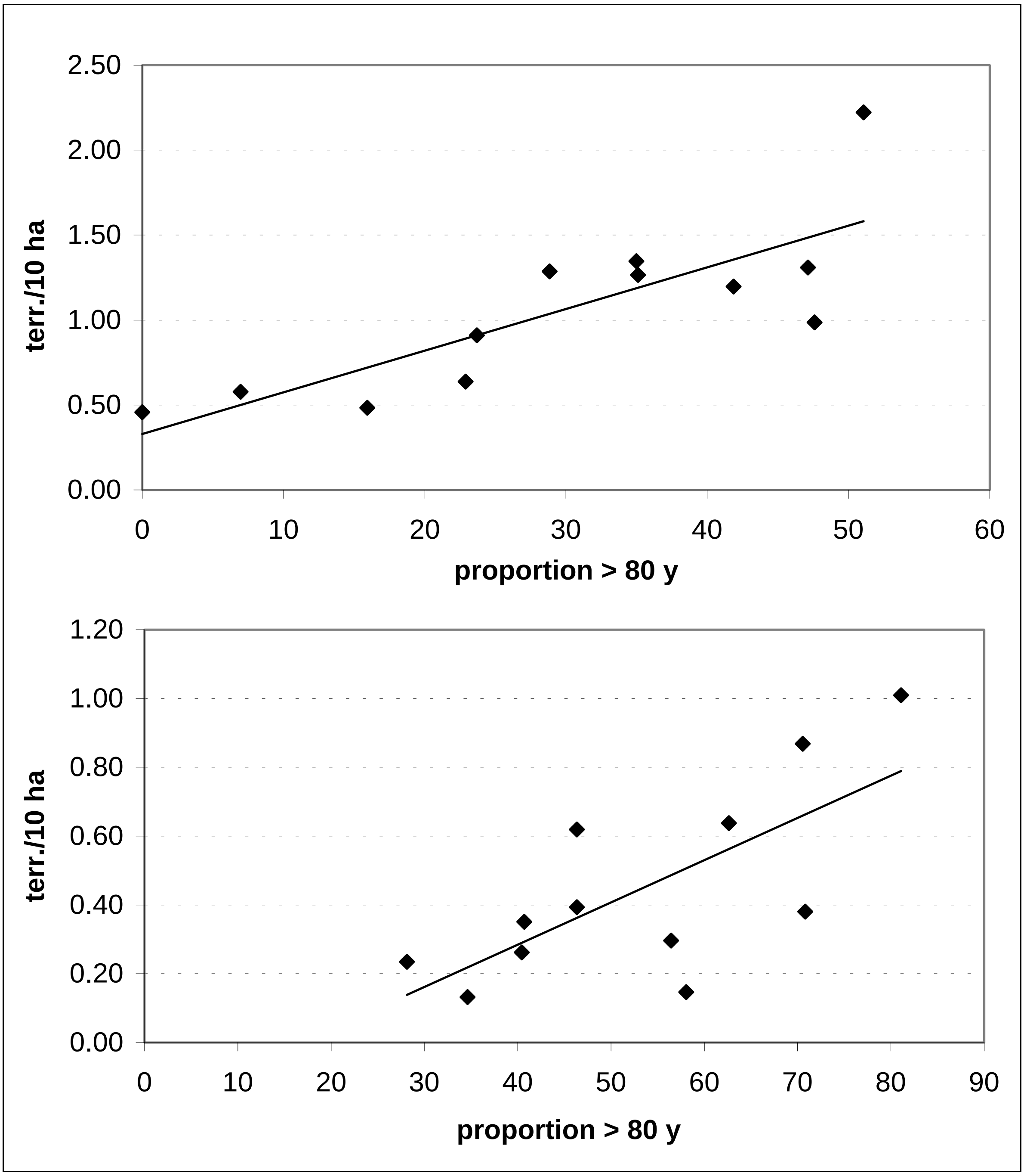

Fig. 4: Relation of total abundance of woodpeckers and the proportion of >80-year-old trees in the 12 census plots in the Lüneburger Heide (above) and in the Solling low mountain range (below).

Beziehung zwischen der Gesamtabundanz aller Spechtarten und dem Anteil >80jähriger Bäume an der Bestockung in den Untersuchungsgebieten in der Lüneburger Heide (oben) und im Solling (unten).

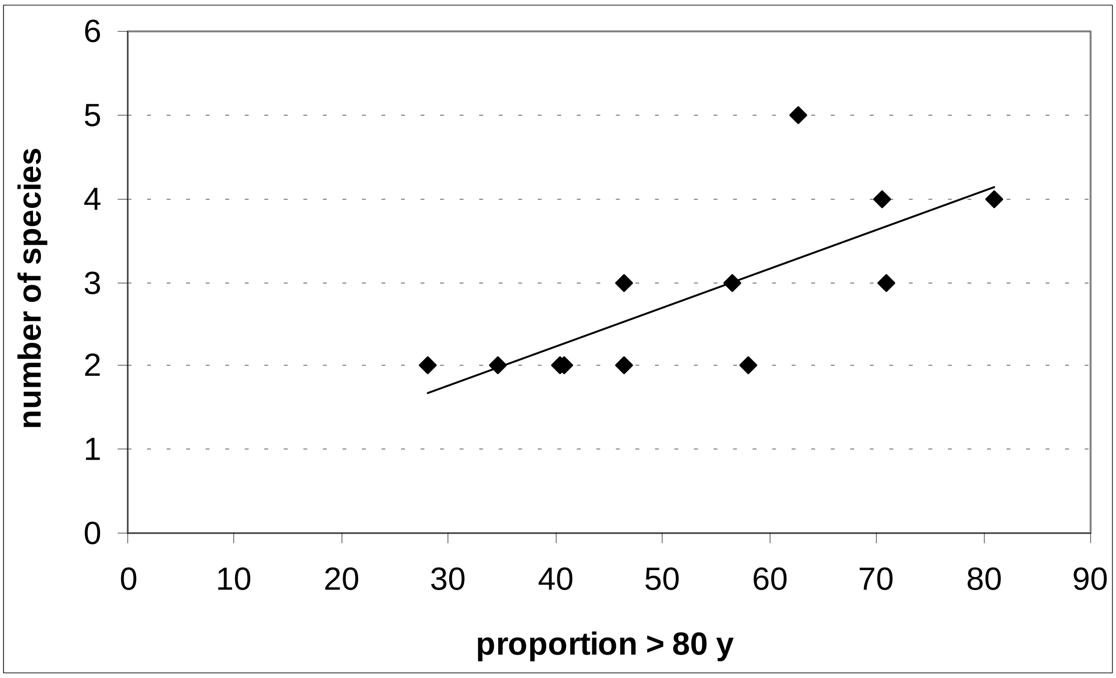

Fig. 5: Relation of woodpecker diversity (number of species) and the proportion of >80-year-old trees in the Solling.

Beziehung zwischen Artenzahl der Spechte und Anteil über 80jähriger Bäume an der Bestockung im Solling.

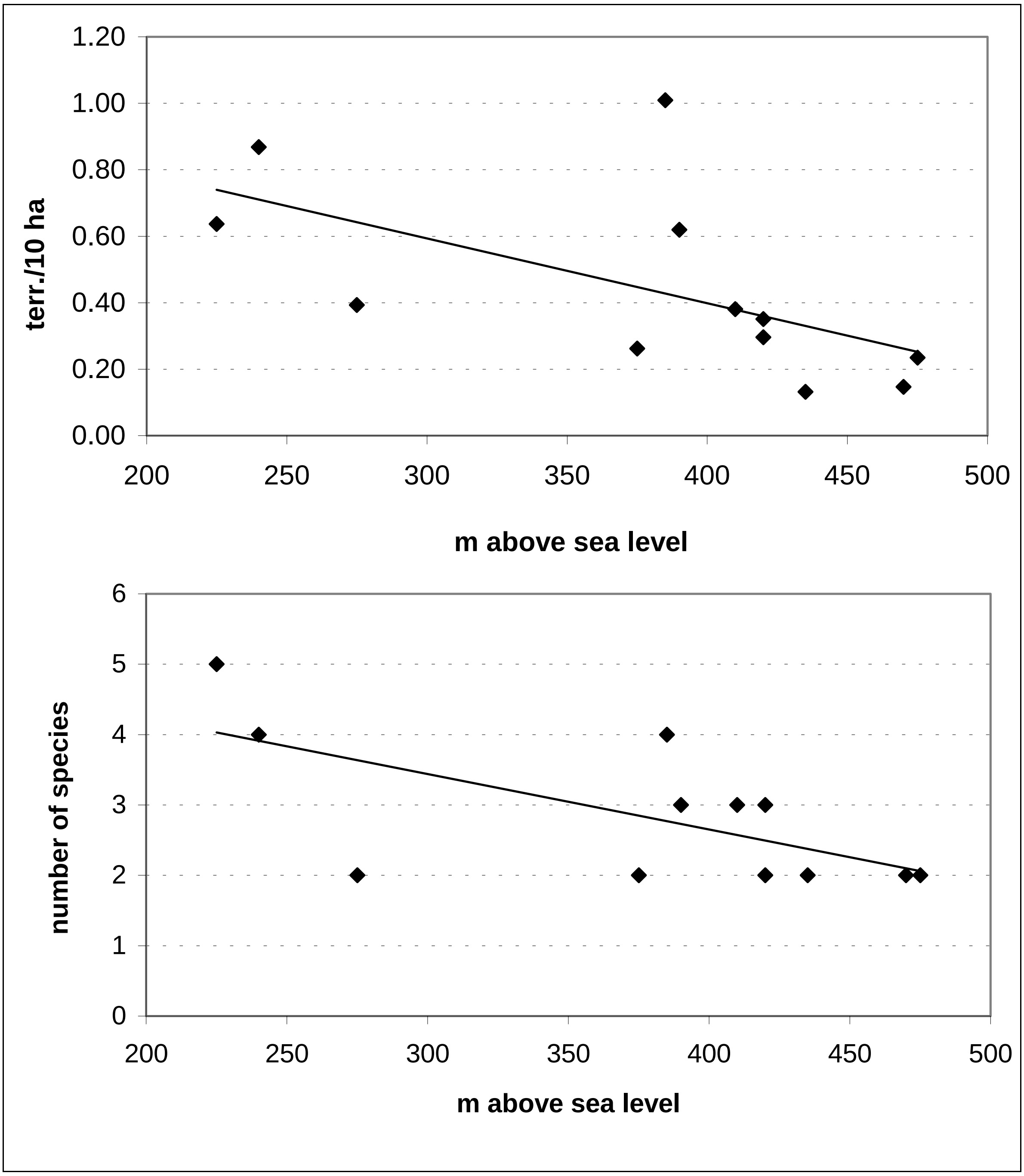

Fig. 6: Relation of total woodpecker abundance (above) resp. diversity (below) and elevation of census plots (below) in the Solling.
Abhängigkeit der Gesamt-Abundanz (oben) bzw. der Artenzahl der Spechte (unten) von der Höhe über NN der Untersuchungsgebiete im Solling