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The effect of floodplain forest fragmentation on the bird community

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ABSTRACT: The paper reports the results of a study focused on ornithocoenoses of floodplain forests in Litovelské Pomoraví locality (Czech Republic). The edge effect on diversity of the bird community is discussed and some implications for floodplain forest management are presented based on the results of investigations into changes in the bird community due to fragmentation of an originally continuous forest stand by regeneration felling, and the results of research into ornithocoenoses of the age-diversified mosaic of forest stands. Perforation of the continuous old floodplain forest by clear felling, which was investigated within this study, slightly increased the diversity of nesting birds. However, bird species typical of open cultural landscape benefitted, whose nesting was not recorded before the perforation of the originally continuous forest ecosystem.

Keywords: bird communities; floodplain forest; forest management

Knowledge of the effects of different forest management forms on bird communities is important in conservation biology for the formulation of principles of protective management of forest ecosystems in protected areas (Fuller 1990; Thompson 1993; Krementz, Christie 2000), for the use of birds as bioindicators (Zasadil 2001; Šťastný et al. 2004) and also for the protection of some bird species in Natura 2000 sites (Hora 1998). Bird communities are suitable for ecological studies of the forest environment (Wiens 1989). Monographs and literature reviews dealing with the effects of forest management on bird communities include the studies of e.g. Petty and Avery (1990), Sallabanks et al. (2000), Korňan (2006), Hinsley et al. (2006).

Fragmentation is considered to be one of the principal issues of landscape ecology (Farina 2007), which links landscape ecology with conservation biology (Collinge 1996; Pechanec 2010). The process of fragmentation usually has several successive phases (Hunter, Gibbs 2007): *dissection*, *perforation*, *fragmentation* and *attrition* (see also Collinge, Forman 1998). The study deals with some effects of forest management on the diversity and structure of floodplain forest ornithocoenoses based on the observation of bird community changes connected with the forest perforation caused by regeneration felling in hardwood floodplain forests of lowland river habitat type (Chytrý et al. 2001).

MATERIAL AND METHODS

Study sites

A field study of the species composition and quantitative characteristics of floodplain forest nesting ornithocoenoses was conducted in the Litovelské Pomoraví Protected Landscape Area (Machar 2008a) (Fig. 1).

The effect of perforation of a continuous complex of floodplain forests on the structure and diversity of the nesting bird community was studied in Panenský les locality. The site is situated about 7 km northwest of Olomouc, 223 m a.s.l., mapping quadrat no. 6369, 17°10'E, 49°40'N. It is a continuous near-natural floodplain forest habitat of an area of 39 ha that belongs, according to Machar (2001), to the geobiocene group of hornbeam-elm-ash forests (*Ulmi-fraxineta carpini*); in terms of the Czech Natura 2000 habitat typology (Chytrý et al. 2001) it belongs to the habitat type of hard-

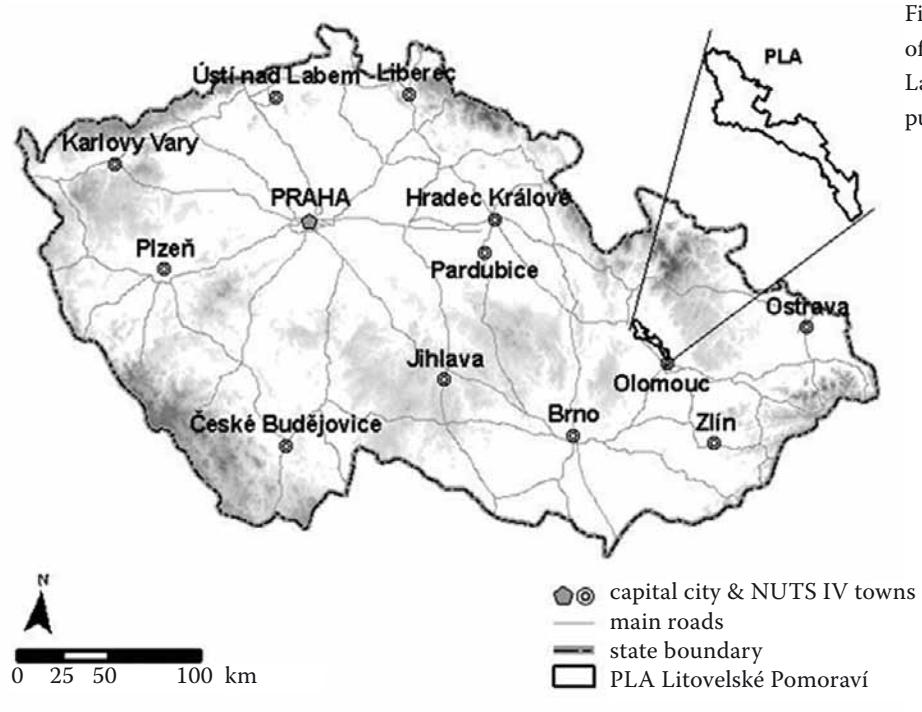

Fig. 1. Location of the study area of Litovelské Pomoraví Protected Landscape Area in the Czech Republic

wood floodplain forests along lowland rivers. The stand was intended to be integrated into the adjacent Nature Reserve and therefore an inventory of the nesting bird community was made in 1995 and 1996 within a study plot of 8.96 ha. In order to exclude the edge effect, the study plot was delimited in the middle of a continuous forest stand so that the boundaries of the plot were at a distance of 80 m at least from the boundaries of the homogeneous forest unit. However, the protection of the forest stand by the Nature Reserve was not declared and from 2002 to 2005 the continuous forest complex was gradually divided by clear felling within the scope of current forest management into several rather large blocks of the old forest of an average area of 12 ha. The average size of the clear-felled areas is 1.5 ha, several randomly situated reserved trees from the original stand have been preserved in the regeneration areas, usually 3–4 old oaks (*Quercus robur*) or ashes (*Fraxinus excelsior*). In the landscape-ecological conception of the fragmentation process, the perforation of the originally homogeneous forest habitat occurred. Clear felling not only disturbed the integrity of the old forest stand but also "opened" the forest interior within the study area in the south-west direction towards the surrounding forest-free agricultural landscape. One of the clear-cut areas directly disturbed 15% of the study plot that was investigated in 1995 and 1996. An ornithological study of the nesting bird community, which was performed in the same area in 2006 and 2007 using the same methods, brought some interesting findings that are presented below.

Methods of field data collection

The study of ornithocoenoses was conducted using the territory mapping method (Svënsson, Williamson 1969) in a combined version according to Tomialojć (1980). Seven mapping visits in morning hours and two additional visits in evening hours for the detection of species with evening activity (thrushes, owls) were made to both sites during the breeding season from the second April ten-day period to the third June ten-day period. One visit usually lasted 3 hours. A direct nest search was focused on the hole-nesting bird species. Birds that were detected visually and acoustically were registered in the visit maps at each visit. Field records were done according to the recommendations of Kropil (1992a). Species maps were drawn in the office using visit maps. Presumed nesting territories were created on the basis of an analysis and evaluation of the species maps with the maximum possible use of simultaneous registrations (Bejček et al. 2001). An individual approach was adopted for the creation of single species territories, characteristics of the sites were taken into account (Janda, Řepa 1986).

Analysis of quantitative and qualitative characteristics of ornithocoenoses

The following quantitative characteristics of the ornithocoenoses were used according to Rajchard et al. (2002): abundance (the number of nesting pairs within the study area), density (the num-

Table 1. The bird community structure in the Panenský les study site

Species	1995–1996		2006–2007	
	density (pairs per 10 ha)	dominance (%)	density (pairs per 10 ha)	dominance (%)
Parus major	14.0	11.4	10.6	8.0
Sturnus vulgaris	13.4	9.5	10.1	8.6
Sylvia atricapilla	12.8	9.1	5.6	4.7
Ficedula albicollis	12.8	9.1	5.6	4.7
Fringilla coelebs	9.5	6.4	6.1	5.1
Parus caeruleus	7.3	5.1	5.0	4.2
Turdus merula	6.7	4.7	4.5	3.8
Erithacus rubecula	6.1	4.4	3.9	3.3
Prunella modularis	5.6	3.9	4.5	3.8
Phylloscopus collybita	5.6	3.9	6.7	5.7
Sitta europaea	5.6	3.9	3.3	2.9
Turdus pilaris	5.0	3.5	3.3	2.9
Coccothraustes coccothraustes	5.0	3.5	3.9	3.3
Emberiza citronella	–	–	3.9	3.3
Passer montanus	3.4	2.9	8.9	7.5
Dendrocopos major	2.8	2.1	2.8	2.4
Sylvia curruca	–	–	2.8	2.4
Troglodytes troglodyte	2.8	2.1	3.9	4.2
Parus palustris	2.8	2.1	1.7	1.4
Dendrocopos medius	1.7	1.2	–	–
Hippolais icterina	1.7	1.2	1.7	1.4
Sylvia borin	–	–	1.7	1.4
Phylloscopus sibilatrix	1.7	1.2	0.6	0.5
Muscicapa striata	1.7	1.2	0.6	0.5
Aegithalos caudatus	1.7	1.2	2.8	2.4
Certhia brachydactyla	1.7	1.2	2.2	1.9
Acrocephalus palustris	–	–	1.7	1.4
Columba palumbus	1.1	0.8	1.1	0.9
Steptopelia decaocto	1.1	0.8	1.1	0.9
Luscinia megarhynch	–	–	1.1	0.9
Locustella fluviatilis	–	–	1.1	0.9
Anthus trivialis	1.1	0.8	2.2	1.9
Oriolus oriolus	1.1	0.8	1.1	0.9
Strix aluco	1.1	0.8	1.1	0.9
Dryocopus martius	1.1	0.8	–	–
Picus canus	0.6	0.4	–	–
Lanius collurio	–	–	0.6	0.5
Carduelis cannabina	–	–	0.6	0.5
Total	138.6	100	118.4	100

Table 2. The main characteristics of the bird community of the Panenský les study site

Characteristic	1995–1996	2006–2007
Density of nesting species	138.60	118.40
Diversity index H'	4.32	4.66
Equitability index J'	0.87	0.90

ber of pairs per 10 ha) and dominance (%) classified according to Tischler (1949). Dominance distribution graphs were processed according to Bejček and Šťastný (1984). Diversity index H' (Shannon, Weaver 1949) and equitability index J' (Sheldon 1969) were computed for each ornithocoenosis using the field data. The classification of the species into four nesting ecological synusiae (hole-nesting birds, ground-nesting birds, shrub-nesting birds, canopy-nesting birds) was performed *a priori* (Wiens 1989) on the basis of field data and literature information (Hudec, Šťastný 2005).

Sörensen similarity index QS (Sörensen 1948) and Renkonen similarity index Re (Janda, Řepa 1986) were used for the analysis of faunistic similarity of the compared ornithocoenoses. Critical values of QS and Re indices were considered according to Jablonski (1972). The similarity of the ornithocoenoses was also evaluated using dissimilarity index CD according to Rejmánek (1978) with the index critical values according to Järvinen and Vätisänen (1976). The commonly applied Jaccard index *Ja* (%) (Kovář 2005) was used for the analysis of percentage correspondence of the species composition of the ornithocoenoses. Comparison of bird densities was performed using an independent two-sample *t*-test; Minitab program, version 15.1.1, was used for the statistical analysis. Normal distribution of data was assessed visually using data distribution diagrams (Zvára 2006).

RESULTS

Thirthy one nesting bird species were recorded in the study area during the breeding season in 1995–1996 (Table 1). These were species typical of the floodplain forest interior. The total density of the community was 138.6 pairs per 10 ha, the value of diversity index was H' = 4.32 and the value of equitability index J' = 0.87 (Table 2), which corresponded with the values ascertained for nesting bird communities of well-preserved old floodplain forest stands in central Moravia (e.g. Bureš, Maton 1984). Dominant species of the floodplain forest bird community were *Parus major*, *Sturnus vulgaris*, *Sylvia atricapilla*, *Ficedula albicollis*, *Fringilla coelebs*, *Parus caeruleus*, *Turdus merula*, *Erithacus rubecula*, *Prunella modullaris*, *Phylloscopus collybita* and *Sitta europaea*. The dominance of these species was caused by the highly heterogeneous character of the forest stand with many suitable nesting cavities and richly structured undergrowth. The curve of dominance distribution without any sharp breaks (Fig. 2) indicates the favourable distribution of dominance in the community and relatively considerable stability of the bird component of the biogeocoenosis. Such distribution of dominance is in agreement with a general trend; the dominance of the most numerous species is usually relatively low in species-rich zoocoenoses (Losos et al. 1984).

In 2006–2007, after the perforation of the biogeocoenosis by a forestry intervention, the total number of 36 nesting bird species was recorded (Table 1). It means that the species diversity of the nesting bird community within the study area increased by seven species after the perforation. Nesting of new bird species was initiated. *Luscinia megarhynchos*, *Locustella fluviatilis*, *Acrocephalus palustris*, *Sylvia curruca*, *Sylvia borin*, *Lanius collurio*, *Carduelis cannabina* and *Emberiza citrinella* were re-

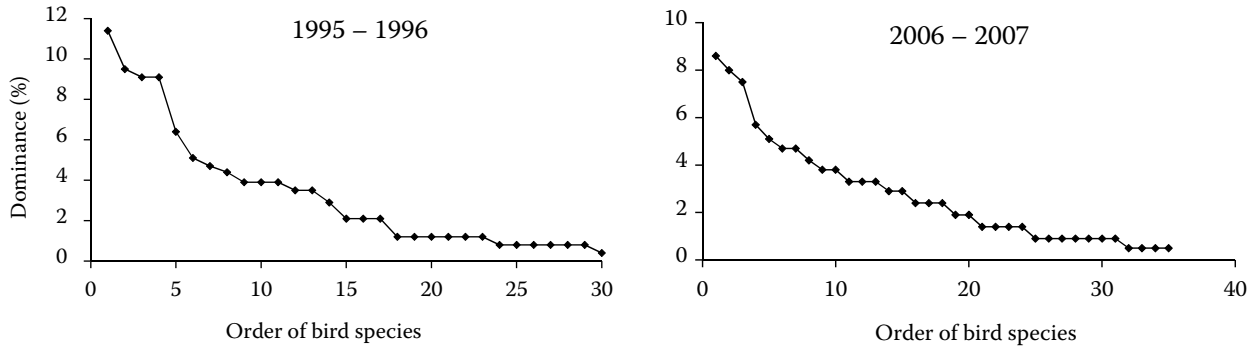

Fig. 2. Distribution of dominance in the bird community in the Panenský les study site in 1995–1996 (left) and in 2006–2007 (right)

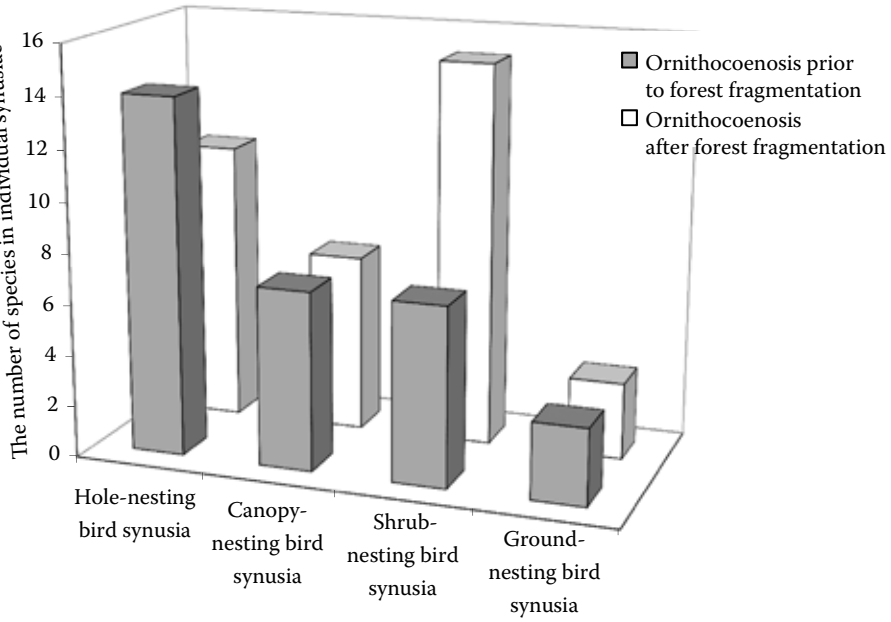

Fig. 3. Effects of forest fragmentation on the structure of the nesting bird community in the Panenský les study site

corded in newly created clear-cut areas and at their margins. These species, which are typical of open forest-free landscape, were not recorded in the original continuous complex of old floodplain forest in 1995 and 1996. Two nesting birds (*Dryocopus martius*, *Dendrocopos medius*) that are typical of the mature floodplain forest interior disappeared (Table 1). Outside the study plot, new nesting birds (*Carduelis chloris* and *Carduelis carduelis*) appeared in the clear-cut areas within the complex of the old floodplain forest. The main features of the dominance distribution in the community remained unchanged (Fig. 2). Changes in particular nesting synusiae are documented in Fig. 3. The increase in the number of species after the fragmentation was caused mainly by accessory species (Table 1), which is also reflected in a slightly higher value of diversity index $H' = 4.66$ at a high level of equitability $J' = 0.90$ (Table 2).

The total density of the bird community after the forest perforation decreased to 118.4 pairs per 10 ha. Nevertheless, the statistical analysis of the change in density after the perforation did not show any significant difference (calculated value $T = 1.20$, critical table value $P = 2.009$, significance level $\alpha = 0.05$). The results of the statistical analysis are in agreement with the results of the comparison of bird communities by means of ornithological indices of similarity of species composition, similarity of dominance and similarity of diversity: the values of all three calculated indices range between strong similarity and similarity (Table 3). It shows a relatively high level of stability of the quantitative composition of the nesting bird community in floodplain forest, regardless of the effects of forest perforation.

DISCUSSION

The landscape structure of central European floodplain forests is significantly affected by forest management practices including regeneration methods, silvicultural operations and felling (Oszlányi 1999). Therefore, forest management fundamental-

Table 3. Similarity of bird communities of the Panenský les study site: a comparison between the breeding seasons 1995–1996 and 2006–2007

Characteristic of analysed bird community	Similarity index	Index value for communities recorded in 1995–1996 and 2006–2007	Critical value of index
Similarity of species spectrum	index *QS*	43.3	similarity
Similarity of dominance	index *Re*	77.1	strong similarity
Similarity of diversity	index *CD*	11.5	strong similarity
Correspondence of species composition	Jaccard index	63.4 %	–

ly affects the biodiversity of floodplain forest biogeocoenoses that are classified in Central Europe as habitat types of Community interest in the Natura 2000 network. Mature species and age-diversified floodplain forest stands that were investigated in this study are, in terms of a model of succession changes in forest ornithocoenoses (Glowaczinski 1975; Glowaczinski, Weiner 1983), close to the idealized notion of forest climax. Although the conception of climax as the only objective of priority nature protection is logically doubted in conservation biology with respect to species linked to the early or perpetually disturbed succession stages of habitats (e.g. Fiedler, Jain 1992), it is obvious that, in the case of central European floodplain forest biogeocoenosis, the highest density of the forest interior bird community can be found in stands of climax character (i.e. in heterogeneous richly structured stands). It must be stressed that this is true only of bird species of the specific forest interior, and cannot be applied to the biodiversity of floodplain forest bird communities in a larger area, i.e. in an area of tens of hectares or larger. In larger areas, biodiversity increases due to the contribution of species typical of forest margins and open forest-free landscape, which successfully penetrate into floodplain forest habitats because of their fragmentation by regeneration operations and because of the construction of forest road networks and emergence of forest-free areas of different purposes on forest land.

It also needs to be taken into account that all central European floodplain forests are biogeocoenoses distinctly formed by anthropogenic factors (Řehořek 2001, 2008). The results of this study show that high diversity can be reached even in strongly impacted biogeocoenoses, which is just typical of floodplain forest biogeocoenoses (Maděra 2003). The study by Schlaghamerský and Hudec (2008) contains an overview of the fauna of European temperate floodplain forests including avifauna. Studies dealing with the effects of forest management on bird communities of central European floodplain (or oak) forests are relatively numerous. The effects of forest operations on bird communities of lowland (floodplain) forests with oak, manifested vicariously in different developmental stages of the forest, were studied in Poland by Tomialojć (1974), Glowaczinski (1975) and Glowaczinski and Weiner (1983), in Germany e.g. by Koop (1968) and Stein (1968) and in Hungary by Waliczky (1991). A relation between the structure and tree species composition of coppice woodlots and forest bird species in the Sarmassa River valley in the northwest of Italy was demonstrated in the study of Lailo (2002). Based on the investigation of nest site selection in spotted woodpeckers *Dendrocopos medius* and *D. major* in lowland oak forests in Switzerland, Pasinelli (2007) presented some recommendations for the protection of old dying and dead trees within forest management of central European oak forests. Fuller (1990) conducted a long-time search of compromise forms of management of lowland forests in Britain while using a coppice management system with regard to maintaining the diversity of bird communities. Bureš (1988) demonstrated the effect of tending forest operations on the floodplain forest bird community in Litovelské Pomoraví. The density of nesting birds was significantly lower in a mature floodplain forest with reduced coverage of shrub and subdominant tree layers if compared to a richly structured multi-storeyed stand with dense coverage of the shrub layer. A positive effect of reserved trees on the bird community diversity was demonstrated by Lešo (2003) in young oak stands in central Slovakia. The bird community structure in Slovak lowland forests was studied e.g. by Turček (1961), Kropil (1993) and Korňan (1996). Ornithocoenoses of the Hron River floodplain were studied by Krištín and Sárossy (2001) and those of the Danube floodplain e.g. by Ferianc (1955), Randík (1987), Kropil (1992b), Bohuš (1993) and Kalivodová and Darolová (1998). Slovak ornithologists have shown a considerable interest in the ecological function of rivers as bird migration corridors (e.g. Palášthy, Voskár 1966). Darolová (1993) studied the winter floodplain forest bird community of the Danube and the Slovak bank of the Morava River.

Most studies of floodplain forest bird communities from the geographical area of Bohemia and Moravia were usually focused on mature (rather old) and richly structured floodplain forest stands where high diversity of bird communities can be expected: Ginter (1964), Kux (1978), Chytil (1981), Bureš and Maton (1984), Toman (1984), Pavelka (1987), Bauer (1991), Storch (1998), Lemberk (2001). On the other hand, few authors studied the relations between the man-made mosaic structure of alluvial habitats with floodplain forests and bird communities (Hubálek 1999). Detailed information is available about ornithocoenoses of pond dikes in the Třeboň area, which are similar in some aspects to line floodplain forest communities (Zasadil 1994). Well analyzed was the avifauna of floodplain forests in the area of the confluence of the Morava and Dyje Rivers (Zuna-Kratky et

Table 4. Comparison of results of this study with other investigations of floodplain forest ornithocoenoses in the Czech Republic

Author/locality	Prevailing group of biogeocoenoses	Size of study area (ha)	Edge effect excluded	Number of nesting pairs	Density (pairs per 10 ha)	H'	J'
Bureš, Maton (1984)	poplar-elm-ash forests	15		39	161	3.08	0.84
Bureš (1986)	hornbeam-elm-ash forests, poplar-elm-ash forests	5		48	79	3.01	0.81
Horák (1998)	hornbeam-elm-ash forests			44	39	4.72	0.86
Chytil (1981)	hornbeam-elm-ash forests, poplar-elm-ash forests, willow-alder forests	10		37	177	4.54	0.89
Kubečka (2003)	hornbeam-elm-ash forests	12	+	28	93		
Lemberk (2001)/Bošín	hornbeam-elm-ash forests	32		44	103	4.65	0.85
Lemberk (2001)/Dubno	hornbeam-elm-ash forests	51		40	101	4.20	0.79
Lemberk (2001)/Choltice	hornbeam-elm-ash forests	52		42	109	4.39	0.81
Lemberk (2001)/Zbytka	poplar-elm-ash forests	43		41	80.5	4.39	0.82
Machar (2008b)/Panenský les prior to fragmentation	hornbeam-elm-ash forests	9	+	31	139	4.32	0.87
Machar (2008b)/Panenský les after fragmentation	hornbeam-elm-ash forests	9		36	118	4.66	0.90
Machar (2008b)/Šargoun	hornbeam-elm-ash forests	12	+	33	135	4.46	0.89
Machar (2008b)/Vrapač	hornbeam-elm-ash forests	13	+	31	126	4.35	0.88
Pavelka (1987)	hornbeam-elm-ash forests	10	+	25	113	4.02	0.87
Polášek (1991)	hornbeam-elm-ash forests	10	+	23	92	3.76	0.85
Pykal (1991)	hornbeam-elm-ash forests	22		36	112	4.30	0.83
Růžička (1985)	poplar-elm-ash forests	10	+	23	102	3.87	0.88
Storch (1998)	willow-alder forests	12		30	270	3.86	0.79
Toman (1984)	hornbeam-elm-ash forests, poplar-elm-ash forests, willow-alder forests	5		30	174	4.19	0.85

al. 2000; Chytil, Macháček 2002; Horal et al. 2004). The study of Čmelík et al. (1999) was focused on the reaction of birds to the disastrous floods in the Morava River floodplain in 1997. Long-term development trends of floodplain forest bird communities in the Morava River basin in the context of anthropogenic changes in the alluvial landscape were investigated in the studies of e.g. Balát (1977), Pellantová and Martiško (1993), Hubálek (1997), Hudec (2001). Results of the project Important Bird Areas in the Czech Republic (Málková, Lacina 2001) are a valuable source of data on the avifauna of some localities that are interesting from the ornithological viewpoint. Today, an increasing amount of faunistic and ecological data on birds of floodplain forest habitats in the Czech Republic can be obtained from the internet (www.biomonitoring.cz; see Hora et al. 2010).

Table 4 shows a comparison of the author's own results of field investigations of ornithocoenoses in floodplain forests in Litovelské Pomoraví locality with the results of other authors who studied ornithocoenoses of mature (i.e. old and multistoreyed) hardwood floodplain forest habitats using the same method (territory mapping method in the combined version according to Tomiałojć (1980). In this comparison, the edge effect on the species diversity of the ornithocoenosis is appar-

ent: the maximum of 33 nesting species was recorded in study plots that were delimited within a homogeneous forest complex, far from its margins for reasons of the author's effort to reduce any impacts of the edge effect. In localities where the edge effect was not eliminated, as many as 48 nesting species were found within a study plot. The edge effect is also important in a softwood floodplain forest habitat. Bališ (in Ferianc 1955) reported the density of 14.8 individuals·ha^{-1} in the interior of a willow-poplar floodplain forest in Žitný ostrov locality and 46.8 individuals·ha^{-1} in the peripheral band of the same habitat. Considerable differences appear between results of studies performed at the same habitats using different methods, which indicates methodological problems. For instance Kaňuch (1990) studied the bird community of hornbeam-elm-ash forest (*Ulmi-fraxineta carpini*) using line transects (Janda, Řepa 1986) and found 25 nesting species in a 15 ha plot with the density of 55 to 80 pairs per 10 ha. A very low value of diversity index in this study (H' = 2.27; equitability J' = 0.84) can be explained by the use of natural logarithm in the calculations.

The area of a study plot is crucial for the evaluation of biodiversity of a floodplain forest community (Reichholf 1985). For example Koutný (2004) studied 70 ha of the Zástudánčí National Nature Reserve using point transects and recorded 54 nesting bird species, which is 55% more when compared to the results of Toman (1984), who studied a 5 ha plot in this area using the mapping method. Outstanding species richness of bird communities was recorded in studies aimed at the investigation of large units of the landscape consisting predominantly of floodplain forest habitats. Ferianc (1955) recorded 75 nesting species in floodplain forests of the Žitný ostrov inland, Kux (1978) recorded 65 nesting species in floodplain forests of South Moravia in 1957–1977. Hubálek (1999) found out 164 bird species in the alluvial landscape of the Dyje River between Stará Břeclav and Ladná with prevailing floodplain forest habitats. In floodplain forests of Soutok and Tvrdonicko, Horal et al. (2004) recorded 142 nesting species since 1990.

Density, which can express the conservation value of nature reserves for birds quite satisfactorily (Virkkala et al. 1994), was used as one of the indicators in the evaluation of the relationship between forest habitat and ornithocoenoses. However, density as an indicator of environment quality should not be used alone without correlations with other demographic and ecological characteristics of the bird community (Vanhorne 1983; Mancke, Gavin 2000; Adamík 2005).

CONCLUSIONS

It is obvious that in the central European floodplain forest geobiocoenosis the highest density of the forest interior bird community can be found in stands of climax character (i.e. in heterogeneous richly structured stands). It must be stressed that this is true only of bird species of the specific forest interior, and cannot be applied to the biodiversity of floodplain forest bird communities in a larger area, i.e. in an area of tens of hectares or larger. In larger areas, biodiversity increases due to the contribution of bird species typical of forest margins and open forest-free landscape, which successfully penetrate into floodplain forest habitats because of their fragmentation by regeneration operations and because of the construction of forest road networks and emergence of forest-free areas of different purposes on forest land. Perforation of the continuous old floodplain forest by clear felling, which was investigated within this study, slightly increased the diversity of nesting birds. However, bird species typical of open cultural landscape benefitted, whose nesting was not recorded before the perforation of the originally continuous forest ecosystem. The perforation of forest habitat by clear felling launched changes in diversity and density of a relatively stable nesting bird community, and further development can be expected depending on the applied forms of forest management. Changes in the species and quantitative composition of a bird community that depend on the forest stand development conditioned by forest management can be regarded as a model of man-controlled succession of the community (Lešo 2003).

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