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Bird Diversity as a Support Decision Tool for Sustainable Management in Temperate Forested Floodplain Landscapes

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Abstract: Sustainably managed forests provide multiple ecosystem services in cultural landscapes, including maintaining biodiversity. Better understanding of the benefits regarding the biodiversity of different silvicultural practices is important for sustainable landscape management. Conservation targets in forested landscapes should be determined by land managers and policy-makers, based on serious ecological research. This study deals with response of bird diversity to three different habitat types of temperate hardwood floodplain forests, which reflect specific forms of forest management. Research was based on long-term field bird census in the years 1998 to 2002 applying the point count method. Data was analysed using regression analysis with dummy variables. The results of the study indicate that hardwood floodplain forest heterogeneity, supported by different types of forest management (old-growth forest protection, group-selection harvesting and forest edge protection), provides large-scale habitat mosaic conditions suitable for many breeding bird species with different ecological niches. This result suggests that comparison of bird diversity response to different forest management types can be used as a decision support tool for sustainable landscape management strategy and local management practices in forested cultural lowland landscapes. Improvements in both regional and local ecological knowledge are generally needed in order to control floodplain land use decisions, which are typically made on the scale of landscape management.

Keywords: group-selection harvesting; hardwood floodplain forest; forest edge; old-growth forest; regression analysis with dummy variables

1. Introduction

Landscape structure and dynamics affect the abundance and distribution of organisms in forested landscapes [1]. Changes in land use are one of the major forces altering forest ecosystems and their functions in cultural landscapes all over the world [2]. Improved knowledge of the relationships between the drivers behind forest ecosystem change and the provisioning of ecosystem services is of vital importance in order to manage forest ecosystems sustainably in cultural landscapes and safeguard them for future generations [3]. However, little is known about the extent to which these drivers impact forests [4]. Globally, most forests are managed for commodity extraction (such as timber), and understanding the costs and benefits to biodiversity management of different silvicultural practices is important for sustainable forest management in the landscape [5]. Villard and Jonsson 2009 [6] suggest that conservation targets in forested landscapes should be determined by land managers and policy-makers, based on serious ecological research that deals with the maintenance of forest habitats above transition zones, below which, species loss is likely to occur. Forest ecosystems are crucial in maintaining climate, biodiversity and human well-being [7]. At the landscape scale, the benefits produced by forests are strongly influenced by forest management [8]. This is especially important in cultural lowland landscapes along large rivers, areas which have suffered from a significant decline in riparian floodplain forests [9].

In the European temperate zone, hardwood floodplain forests (HFF) are endangered habitats. HFF provide various important ecosystem services in the lowland landscapes [10]. Land use changes and land use intensification induced by human activities are closely connected to the current ecological status of HFF in many European regions [11]. Despite centuries of intense human pressure, HFF are forest ecosystems with very rich alpha-biodiversity on the scale of individual trees and on the scale of forest stands [12,13]. A mosaic of floodplain forest habitats (including rivers and wetlands) creates a unique ecological gradient of beta-biodiversity [14]. Thus, HFF are key ecosystems in the maintenance of biodiversity on the scale of lowland riparian landscapes [15]. Because of their high biodiversity value, the natural and semi-natural remnants of HFF are usually included in ecological networks in a landscape [16]. They are also protected within the framework of international (such as the Natura 2000 European Network) or national systems for protected areas [17]. Most HFF habitats, not including protected areas, are managed under off-reserve conservation measures [18], which use sustainable forest management principles [19].

Sustainable forest management is inevitably based on ecological research into forest ecosystems. In accordance with recently defined key ecological research questions for Central European forests [20], we have focused our study on the impact of forest management on bird diversity in temperate European HFF. Although serious research efforts in the assessment of avian responses to temperate forest management systems (especially for high forest systems) have been made [21], it is still largely unknown how the bird assemblages are affected by clear-cutting, group-cutting, individual selection cutting and their variants [22]. Hardwood floodplain forests are similar to most other temperate forest habitats in bird density and diversity [23–25]. European temperate HFF are considered to be hot spots for forest bird diversity in cultural lowland landscapes along large rivers [26]. Although the ecological importance of HFF for birds is obvious, there is a serious lack of studies that have examined, from a long-term perspective, how the diversity of breeding birds changes in relation to different types of forest management systems in HFF [27,28].

We have focused on how bird diversity in HFF corresponds to three different habitat types, each of which reflects a specific form of forest management. These are (1) nonmanaged old-growth forest stands in strictly protected areas, (2) old-growth forest stands with small open patches which are a consequence of group-selection harvesting and (3) edges of old-growth forest blocks bordered by clear-cutting areas. According to current knowledge concerning avian responses to temperate forest management [29,30], our hypothesis was created as the expectation that the highest bird species diversity would be on the edges of forests, which fulfils, from the perspective of the landscape, the ecological function of ecotones [31]. Our study, based on long-term (years 1998 to 2012) field research into breeding birds, used the point count method to compare bird diversity in these three habitat types. The results of this comparison can be used as a decision support tool for sustainable landscape management practices in protected areas, where the aim is to conserve hardwood floodplain forest habitats.

2. Materials and Methods

2.1. Study Area

The study was carried out in the core zone of Litovelske Pomoravi Protected Landscape Area (LPPLA) [32] along the meandering River Morava in the Czech Republic [33]. The study area is located between towns Litovel and Olomouc. The core zone of LPPLA (total area 307 ha) is covered by old-growth forest stands of hardwood floodplain forests that are considered to be an endangered form of forest vegetation in the Czech Republic [34]. Forest stands are composed predominantly of Pedunculate Oak (*Quercus robur* L.) and European Ash (*Fraxinus excelsior* L.), with an admixture of tree species Small-leaved Lime (*Tilia cordata* Mill.), Field Maple (*Acer campestre* L.), Sycamore Maple (*Acer pseudoplatanus* L.), Norway Maple (*Acer platanoides* L.), Hornbeam (*Carpinus betulus* L.), European White Elm (*Ulmus laevis* Pallas) and Bird Charry (*Prunus padus* L.) [35]. These forest stands are classified as riparian mixed forests along the great rivers (international habitat code 91F0) according to the Natura 2000 habitats classification [36].

Three conservation management practices are in progress in the study area: (1) Strict protection of old-growth (without any forest management activities) is the prevailing type of conservation (in 80% of LPPLA core zone), (2) group-selection harvesting (GSH) in old-growth forests (in 20% of LPPLA core zone) make up the remainder and (3) creating of edges of old-growth forest blocks bordered by clear-cutting areas. The conservation target of GSH in the study area is to support more heterogeneity of forest stands. The old-growth forests in the LPPLA core zone are bordered by clear-cutting hardwood floodplain forests, which act as a buffer zone for LPPLA.

2.2. Bird Field Census

We studied the birds in the area using the point count method [37] during the breeding seasons from 1998 to 2012. Eleven sampling points were within old-growth unmanaged forest stands, 13 were in forest stands managed by group-selection harvesting and 16 were in edges of old-growth unmanaged stands (Table 1). The minimal distance between sampling points was 300 m, which was chosen in order to facilitate the representative sampling of each management category while ensuring the independence of data related to each sampling point as recommended by Bibby and Buckland [38]. In order to avoid mistakes based on the different detectability of birds in hardwood floodplain forests [39], only birds detected within 50 m of each researcher were counted. Timed counts (10 min) were used to detect bird species diversity and abundance at each sampling point in early mornings (between 5:00 and 9:30). Birds were detected both visually and acoustically. Bird counting at sampling points was carried out three times each breeding season (mid-April, mid-May and mid-June).

Table 1. Sampling points in the study area.

Sampling Point Number	Forest Management Type [1]	Geographical Coordinates of Sampling Point (X; Y)	
1	GSH	17,023588	49,711416
2	GSH	17,028122	49,710015
3	GSH	17,032610	49,709873
4	OG	17,036488	49,709060
5	OG	17,039696	49,706825
6	OG	17,043901	49,705563
7	FE	17,046132	49,703869
8	FE	17,046822	49,707414
9	FE	17,047211	49,710218
10	FE	17,042236	49,712155
11	FE	17,039660	49,713576
12	OG	17,035687	49,711928
13	GSH	17,030570	49,712499
14	GSH	17,026340	49,714876
15	FE	17,023697	49,716371
16	FE	17,019245	49,717060
17	FE	17,015360	49,718724
18	FE	17,011551	49,720036

Table 1. *Cont.*

Sampling Point Number	Forest Management Type [1]	Geographical Coordinates of Sampling Point (X; Y)	
19	GSH	17,009531	49,717354
20	GSH	17,013130	49,715835
21	GSH	17,142123	49,694951
22	GSH	17,137688	49,696125
23	FE	17,134834	49,698084
24	FE	17,131537	49,699445
25	OG	17,128188	49,701191
26	OG	17,125478	49,702966
27	FE	17,100230	49,702422
28	FE	17,101913	49,705381
29	GSH	17,106941	49,704883
30	OG	17,111523	49,703406
31	OG	17,117065	49,698567
32	OG	17,117208	49,695150
33	OG	17,120693	49,693302
34	FE	17,121567	49,689126
35	FE	17,126060	49,689830
36	GSH	17,129847	49,691070
37	OG	17,132785	49,692822
38	GSH	17,136087	49,691396
39	GSH	17,122792	49,686054
40	FE	17,130718	49,684676

[1] OG = interior of old-growth unmanaged forest stand, FE = edge of old-growth unmanaged forest stand, GSH = forest stand managed by group-selection harvesting.

2.3. Statistical Analyses

The aim of the statistical analyses was to find whether there was a statistically significant difference in the number of bird species observed in areas under different types of forest management. Observational data from 40 sampling points were grouped into three categories according to the form of forest management in which sampling points were located: (i) group-selection timber harvested forest, (ii) old-growth forest and (iii) forest edge. We hypothesised that the highest number of observed bird species should be found at the forest edge, because of knowledge of edge effect consequences for bird diversity in HFF [40]. The structure of all statistical analyses is presented in Table 2.

Table 2. Structure of the statistical analyses.

Analyses Structure	1st Regression	2nd Regression	3rd Regression
Data structure	Time dimension ignored	Time dimension aggregated into years	Time dimension included
Dependent variable [1] construction	Number of bird species observed at each counting point averaged over the entire period	Number of bird species observed at each counting point averaged over individual years	Total number of bird species observed each time at each counting point
Methods	Cross-sectional OLS regression with dummy variables indicating the type of forest management	RE panel regression with dummy variables indicating the type of forest management	RE panel regression with dummy variables indicating the type of forest management

[1] Dependent variable = number of bird species.

To verify this research hypothesis, we used regression analysis with dummy variables. The dependent variable worked with the number of observed birds at individual counting points, while the independent variable was a categorical one that indicated the form of forest management. To avoid the trap of perfect collinearity, the independent variable was represented in the regression analysis by a set of two dummy variables: one for the group-selection timber harvested forest and the other for the old-growth forest. Since the forest edge was regarded as the reference category, the regression coefficients indicated the differences in the number of birds observed in the two former categories when compared to the reference category.

We performed the regression analysis three times (Table 2). In the first regression analysis we ignored the time dimension of the bird counting; for each counting point we averaged the number of observed bird species over the entire time period. Thus we obtained (cross-sectional) data for the 40 sampling points that were grouped into the three categories as defined above. To estimate the regression coefficients we used the ordinary least squares (OLS) method with robust standard errors [41].

In the second regression, we included the time dimension of the bird counting, aggregated into years of observation. This means that for each sampling point we averaged the number of observed species over each year. Thus we created a panel of data with the time dimension of 15 years and with the cross-sectional dimension of 40 sampling points. The counting points were once again divided by a set of two dummy variables into the three types of environment. The coefficients were now estimated using the random effects (RE) method with the robust standard errors [42].

The third regression included all the birds counted at each sampling point. This means that, once again, we generated a panel of data, but in this case the time dimension consisted of a maximum of 45 moments, while the cross-sectional dimension remained as above. However, observations were missing from some counting points and moments. To estimate the regression coefficients, we used the RE method with robust standard errors. All calculations were performed using the statistical software Stata 15 [43].

3. Results

We found a total of 59 breeding bird species in the study area, with a total abundance of 13,249 individuals (Table 3). We identified nine dominant species in the study area (dominance > 5%): Great Spotted Woodpecker (*Dendrocopos major*), Eurasian Blackbird (*Turdus merula*), Blackcap (*Sylvia atricapilla*), Common Chiffchaff (*Phylloscopus collybita*), Collared Flycatcher (*Ficedula albicollis*), Great tit (*Parus major*), Wood Nuthatch (*Sitta europaea*), Common Starling (*Sturnus vulgaris*) and Chaffinch (*Fringilla coelebs*). All are typical bird species for European hardwood floodplain forest habitats.

Table 3. Bird species diversity, total abundance and dominance at all sampling points.

Bird Species	Nesting Habitat Preference	Abundance [n]	Dominance [%]
Black Stork (*Ciconia nigra*)	INT [1]	5	0.04
Honey-Buzzard (*Pernis apivorus*)	INT	2	0.01
Common Buzzard (*Buteo buteo*)	INT	153	1.15
Common Pheasant (*Phasianus colchicus*)	OCB [2]	41	0.31
Wood Pigeon (*Columba palumbus*)	OCB	240	1.81
Collared Dove (*Streptopelia decaocto*)	OCB	8	0.06
Turtle Dove (*Streptopelia turtur*)	INT	65	0.49
Common Cuckoo (*Cuculus canorus*)	OCB	82	0.62
Tawny Owl (*Strix aluco*)	INT	2	0.01
Eurasian Wryneck (*Jynx torquilla*)	INT	4	0.03
Grey-faced Woodpecker (*Picus canus*)	OCB	36	0.27
Eurasian Green Woodpecker (*Picus viridis*)	INT	47	0.35
Black Woodpecker (*Dryocopus martius*)	INT	26	0.19
Great Spotted Woodpecker (*Dendrocopos major*)	OCB	718	5.42

Table 3. *Cont.*

Bird Species	Nesting Habitat Preference	Abundance [n]	Dominance [%]
Middle Spotted Woodpecker (*Leiopicus medius*)	INT	94	0.71
Lesser Spotted Woodpecker (*Dendrocopos minor*)	OCB	44	0.33
Tree Pipit (*Anthus trivialis*)	INT	10	0.07
White Wagtail (*Motacilla alba*)	OCB	4	0.03
Winter Wren (*Troglodytes troglodytes*)	INT	370	2.79
Hedge Accentor (*Prunella modularis*)	INT	99	0.75
European Robin (*Erithacus rubecula*)	INT	447	3.37
Common Nightingale (*Luscinia megarhynchos*)	OCB	3	0.02
Eurasian Blackbird (*Turdus merula*)	INT	667	5.03
Fieldfare (*Turdus pilaris*)	INT	40	0.30
Song Thrush (*Turdus philomelos*)	OCB	348	2.62
Mistle Thrush (*Turdus viscivorus*)	INT	16	0.12
River Warbler (*Locustella fluviatilis*	OCB	98	0.74
Icterine Warbler (*Hippolais icterina*)	OCB	8	0.06
Lesser Whitethroat (*Sylvia curruca*)	OCB	1	0.01
Common Whitethroat (*Sylvia communis*)	OCB	27	0.20
Garden Warbler (*Sylvia borin*)	OCB	97	0.73
Blackcap (*Sylvia atricapilla*)	INT	1262	9.52
Wood Warbler (*Phylloscopus sibilatrix*)	INT	41	0.31
Common Chiffchaff (*Phylloscopus collybita*)	INT	832	6.28
Willow Warbler (*Phylloscopus trochilus*)	INT	28	0.21
Goldcrest (*Regulus regulus*)	INT	15	0.11
Spotted Flycatcher (*Muscicapa striata*)	OCB	164	1.23
Collared Flycatcher (*Ficedula albicollis*)	INT	764	5.76
Long-tailed Tit (*Aegithalos caudatus*)	OCB	39	0.29
Marsh Tit (*Poecile palustris*)	INT	84	0.63
Blue Tit (*Cyanistes caeruleus*)	INT	950	7.17
Great Tit (*Parus major*)	INT	1047	7.90
Willow Tit (*Poecile montanus*)	INT	3	0.02
Wood Nuthatch (*Sitta europaea*)	INT	953	7.19
Short-toed Treecreeper (*Certhia brachydactyla*)	INT	88	0.66
Golden Oriole (*Oriolus oriolus*)	INT	226	1.70
Red-backed shrike (*Lanius collurio*)	OCB	1	0.01
Eurasian Jay (*Garrulus glandarius*)	OCB	138	1.04
Hooded Crow (*Corvus cornix*)	OCB	52	0.39
Common Raven (*Corvus corax*)	OCB	6	0.04
Common Starling (*Sturnus vulgaris*)	OCB	860	6.49
Tree Sparrow (*Passer montanus*)	OCB	20	0.15
Chaffinch (*Fringilla coelebs*)	OCB	1245	9.39
European Serin (*Serinus serinus*)	OCB	3	0.02
European Greenfinch (*Carduelis chloris*)	OCB	9	0.06
European Goldfinch (*Carduelis carduelis*)	OCB	22	0.16
Eurasian Linnet (*Carduelis cannabina*)	OCB	1	0.01
Hawfinch (*Coccothraustes coccothraustes*)	INT	386	2.91
Yellowhammer (*Emberiza citrinella*)	OCB	208	1.56
Total		13,249	100

[1] INT = forest interior, [2] OCB = open country bird.

Bird species in old-growth forest stands were predominantly forest dwelling species (*C. nigra*, *F. albicollis* and *S. europaea*). Bird diversity in forests managed by GSTH was enriched by early successional lowland forest species (*L. fluviatilis*). The highest bird diversity was detected at the forest edges of old-growth stands.

The results of the regression analyses (Table 4) are very similar, no matter which approach we adopt. This indicates a certain level of robustness in our outcomes. The results confirm that the highest number of bird species can be observed at the forest edge and this is indicated by the negative coefficients in all regressions. However, while the difference between the number of bird species in old-growth forest and the forest edge is highly significant (at the 1% level), the difference between the number of bird species in the group-selection timber harvested forest and in the forest edge is only marginally significant (at the 10% level). The joint significance tests of the categorical variable indicate that the form of management is significant in all three regressions (as denoted by the F test and the chi^2 tests).

Table 4. Results of the statistical tests of hypotheses.

Results for	1st Regression	2nd Regression	3rd Regression
GSH [1]	−0.618 * (0.351)	−0.599 * (0.359)	−0.623 * (0.346)
OG [2]	−0.835 *** (0.292)	−0.763 *** (0.279)	−0.805 *** (0.286)
_constant	9.130 *** (0.222)	9.146 *** (0.222)	9.123 *** (0.219)
R^2	0.161	0.143 (between groups)	0.161 (between groups)
F test	4.20 **		
Wald chi^2		7.59 **	8.170 **
No. of observations	40	400	1160
No. of groups		40	40

[1] GSH = forest stand managed by group-selection harvesting, [2] OG = interior of old-growth unmanaged forest stands. Robust standard errors are in the parentheses. Regression coefficients are significant at *** 1% significance level, ** 5% significance level and * 10% significance level.

Although the results indicate a higher number of bird species observed in the group-selection timber harvested forest than in the old-growth forest, the difference is clearly statistically insignificant (the *p*-values for the corresponding coefficients would be 0.515 in the 1st regression, 0.618 in the 2nd regression and 0.575 in the 3rd regression). This suggests that the difference in the number of observed bird species in these two management categories is essentially negligible.

Since count data were used in the 3rd regression, we checked the robustness of the results using the Poisson random effects model with robust standard errors. It did not change the findings by much. The coefficient for the group-selection timber harvested forest stayed negative and significant at the 10% level. Likewise, the coefficient for the old-growth forest remained negative as well but was now significant only at the 5% level.

The distribution and variability of the number of bird species observed in the areas under different types of forest management is illustrated by the boxplot (Figure 1) that corresponds to the results of the third regression analysis described above.

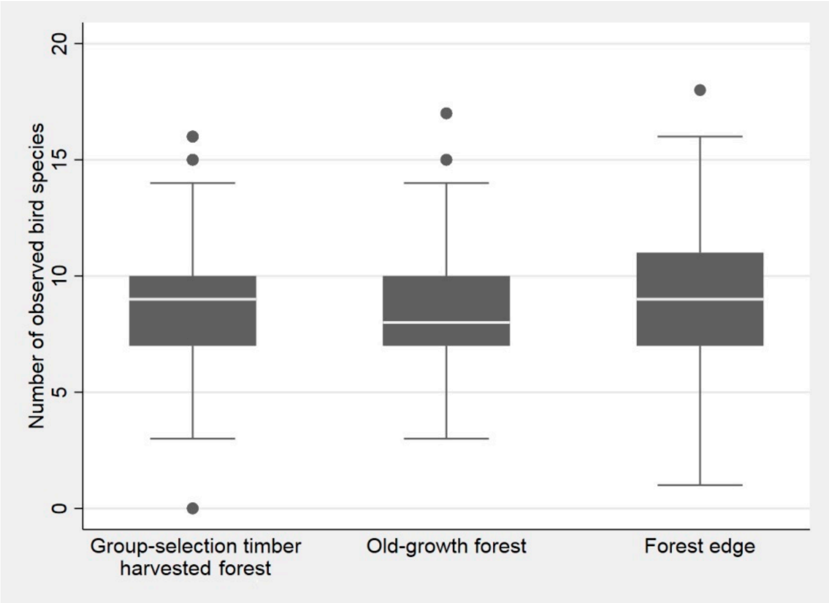

Figure 1. Boxplot for the 3rd regression. Distribution and variability of bird diversity in different types of forest management.

4. Discussion

Bird diversity is a very good indicator when analysing the consequences of forest habitat changes at the landscape level [44,45]. Bird species' responses to landscape structure are taxon-specific and according to their niche attribute [46]. Thus, bird assemblages are composed of species that can be considered as edge-sensitive, fine grain-dependent, interior-sensitive, etc. [47]. This demonstrates that there are various implications that can be drawn from bird studies and used in the development of sustainable forest management concepts [48].

The number of 59 breeding bird species in the study area of LPPLA reflects the current knowledge related to the high diversity of bird communities in temperate hardwood floodplain forests in North America [49,50] and Europe [51,52]. Our results relating to the dominance of bird species in HFF (Table 3) are in accordance with our studies published earlier [53,54], which indicated that the dominant bird species are common birds in European lowland cultural landscapes, but some species are of conservation concern—e.g., *F. albicollis* is a bird species in the focus of the Bird Directive under Natura 2000 [55]. Generally, the dominant breeding birds in HFF are typical forest dwelling species (e.g., *S. europaea*) and typical "open country birds"—species known to be tolerant to much disturbed landscapes [56]. These are such birds as *D. major*, *S. vulgaris* and *F. coelebs.* This can explain the highest bird diversity in forest edges in our study in the context of the ecotone effect [57,58].

Only a few studies have examined the consequences of group-selection timber harvesting for forest bird diversity in temperate hardwood forests, and most of these studies are short-term [59]. One rare and valuable study by Campbell et al. [60] focused on the long-term effects of GSH on the abundance of forest birds. The study was carried out in mixed oak–pine forests in Maine and used territory mapping. Bird species responses to GSH were found to be idiosyncratic; in general, the mature forest birds remained and bird species connected to early successional habitat temporarily benefited from GSH. Our results from Litovelske Pomoravi are remarkably in accordance with the results of the above-mentioned study [60] in relation to the support of GSH for the occurrence of some early successional birds, which benefit from small open areas in mature forests.

In the literature, there is a significant lack of studies aimed at assessing of GSH in habitats of temperate hardwood floodplain forests. This is probably because this form of forest management is not applied in floodplain forests [61]. Thus, it seems our study is one of the first published studies on the impact of GSH on birds in HFF habitats. The first phase of GSH in Litovelske Pomoravi involves relatively small patches (up to 0.5 ha) in the mature forest stands. These are very similar to the small open areas which can be caused by natural disturbances in old-growth hardwood forests. This management phase creates a valuable ephemeral habitat for early successional bird species (*S. curruca* and *L. fluviatilis*), while habitats for birds connected to mature forests are still maintained. This is important at the landscape level because cultural landscapes in European lowlands are mosaics of different forest successional stages, and old-growth stands are usually very rare [62].

Forest fragmentation and its various effects on the ecological functions and biodiversity of forests have been widely studied, but a common consensus on specific impacts seems elusive, partly due to differences in methodological approaches [63] and to regional idiosyncrasies [64]. Successful management aimed at maintaining bird species in woodlands affected by fragmentation needs to ensure there is protection and/or rehabilitation of ground vegetation and overstorey, as pointed out by Montague-Drake et al. [65] in relation to temperate woodlands of Australia. In temperate hardwood forests ground vegetation can be seriously disturbed by ungulate browsing with consequences for bird diversity [66] due to the absence of large predators [67]. Thus, we should also take into account ungulate management on the landscape scale [68,69].

Old forest stands play an important role in the conservation of bird diversity in managed temperate forests [70]. Lindenmayer et al. [71] identified a significant gradient in bird alpha-diversity in hardwood forests depending on the form of management, with the lowest values found in conventional clear-felled areas and the highest values in unlogged old-growth forest areas. These facts allow us to see the implications for bird-friendly silvicultural practices based on the conservation of large old-growth stands in forested landscapes which are managed for timber production [72]. Our results from the study area LPPLA confirmed this—we detected high bird diversity in old-growth hardwood floodplain forests.

Old-growth forest stands in our study area are bordered by large areas of managed forests on which clear-cutting practices are carried out. Clear-cutting is a traditional forest management practice in commercially managed European temperate hardwood floodplain forests [73]. The main reason for clear-cutting is to maintain the light-demanding Pedunculate oak (*Quercus robur* L.) as the main tree species in hardwood forest stands in the buffer zone of LPPLA [74]. In some temperate European regions with large areas of hardwood floodplain forests (such as in Croatia and Serbia) sustainable forest management is strictly focused on practices which favour the Pedunculate oak as the main tree species of managed floodplain forests. This is for economic reasons [75]. As stated by Dobrovolny et al. [76], the current management system in Czech floodplain forests (outside protected areas) should be gradually converted to the Croatian model of forest management, with a multilayered forest structure [77] that is more focused on individual tree growth and stability for trees with high economic value and high reproductive potential.

One ecologically friendly modification to clear-cutting is green-tree retention [78], which is aimed at maintaining forest biodiversity connected to old-growth forest structures that remain on cut areas [79]. As revealed in a review by Rosenwald and Lõhmus [80], green tree retention almost always improves the habitat of disturbance phase birds on areas where most trees have been cut down and for forest species in regenerated forest stands on a local scale. But landscape perspectives related to green-tree retention are still missing from recent studies. Green-tree retention can be applied as aggregated patches of trees [81] or as retention of large, individual green trees on cuts [82]. In our previous study, we confirmed the importance of retaining very large, individual legacy trees [83] of the Pedunculate oaks on cuts in hardwood floodplain forests for bird diversity, especially for guilds of hole-nesters [84]. However, as highlighted by the study [85], despite the fact that green tree retention provides breeding quality habitats for a large group of forest birds, it is not equivalent to the conservation of intact old-growth forests, and thus this suggests that intact old-growth forest ecosystems should be maintained in landscapes if we want to conserve forest biodiversity. The findings of the study [86] are in close accordance with our results from Litovelske Pomoravi: Here, old-growth hardwood floodplain forest stands are key breeding habitats for forest dwelling bird species, such as *Ciconia nigra*, *Ficedula albicollis* and *Sitta europaea*.

The question as to "how the distribution of bird species responds to different vegetation structures at woodland edges" remains an area where there is a gap in the knowledge related to bird responses to transitional habitats in cultural landscapes [87]. Improvements in regional and local ecological knowledge are needed in order to control floodplain land use decisions which are typically made on the scale of landscape management [88]. Our study, based on long-term (1998–2015) field research on breeding birds used the point count method and compared bird diversity in three types of floodplain forest habitat. It is suggested that the results of this comparison are used as a decision support tool for sustainable landscape management practices in protected areas aimed at the conservation of hardwood floodplain forest habitats. Our results indicate the importance of old-growth stands and GSH as well as showing the key role played by forest edges as habitats for breeding birds. The study indicates that fine-scale floodplain forest heterogeneity produced by different types of forest management in Litovelske Pomoravi provides large-scale habitat mosaic conditions suitable for many bird species with different niches. The diverse mosaic of forest habitats (including mature stands, small open patches and forest edges) benefits species in mature forests as well as early successional species. If clear-cutting is modified by green tree retention aimed at the conservation of biodiversity depending on mature forest structures on cuts, we would achieve very rich bird diversity on the landscape scale. Thus, this seems to be a key answer to the research question of this paper: The combination of different forest management treatments on a local scale can be considered as sustainable forest management with the target of maintaining bird diversity in hardwood floodplain forests [89,90].

5. Conclusions

We need to seriously improve our understanding of how landscape perspective fosters a multiscale approach to landscape management and landscape/conservation planning. This knowledge is extraordinarily important for large floodplain forest areas along lowland rivers; areas which have been impacted on by humans for centuries. If we aim to maintain the vital ecosystem functions of floodplain forests as key ecosystems, we would need to apply sustainability as a key conceptual framework for forest management.

We can use bird diversity as a decision support tool for the application of sustainability principles in landscape management. The results of this paper, based on the responses of birds to different management practices in temperate cultural floodplain landscapes, indicate the importance of mosaics of landscape habitats. If forest management creates a diverse mosaic of forest habitats, including mature stands, small open patches and forest edges, it would benefit forest bird diversity on the landscape scale. Its successful achievement requires a coordinated effort in forest management strategy by landowners and decision makers and it can support a multifunctionality of forests. The results of our study from the Litovelske Pomoravi Protected Landscape Area are portable on an international scale for sustainable management strategies related to lowland cultural landscape areas, including managed and unmanaged temperate hardwood floodplain forests.

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