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Claudia LATUS[1], Krzysztof KUJAWA[2]

[1] Leibniz-Centre for Agricultural Landscape and Land Use Research (ZALF e.V.),
Institute of Land Use Systems and Landscape Ecology,
Eberswalder Str. 84, 15374 Müncheberg, Germany
e-mail: clatus@zalf.de
[2] Polish Academy of Sciences, Research Center for Agricultural and Forest Environment,
Field Station, Turew, Szkolna 4, 64-000 Kościan, Poland,
e-mail: ortolan@poczta.onet.pl

THE EFFECT OF LAND COVER AND FRAGMENTATION OF AGRICULTURAL LANDSCAPE ON THE DENSITY OF WHITE STORK (*CICONIA CICONIA* L.) IN BRANDENBURG, GERMANY

ABSTRACT: The aim of the study was to identify landscape properties which are responsible for the large differences in White Stork population densities occurring in an agricultural landscape. The study area covered six plots (308–1218 km^2) in Brandenburg (Germany). They differed in respect to proportions of main landscape components (grasslands, crop fields, woodlands, parks and gardens, built-up areas), to degree of fragmentation of grasslands and crop fields and to proportions of different grassland types (moist meadows, slightly moist pasturelands, dry grasslands, persistent nitrophilous ruderal communities, herbaceous perennials and intensively used sown grassland). The correlation coefficients between the Stork density and proportions of main landscape components were small ($|r_s|<0.7$) and insignificant ($P>0.15$) but the Stork density was positively related to proportion of intensively used sown grasslands. However, the greatest part of variation in Stork density could be explained by the fragmentation of grasslands and crop fields. Stork density was positively correlated with density of crop field patches as well as with grassland edge density. The spatial distribution of these patches was not important. Our results suggest that at a moderate proportion (ca. 10%) of grasslands, composition and high fragmentation of these habitats are vital for white storks.

KEY WORDS: White Stork population density, landscape structure, grassland, fragmentation.

1. INTRODUCTION

White Stork is a regional species characteristic for Europe, which was subjected to a long-term study (e.g. Lack 1966). Baierlein (1991) described population trends of the species in Europe. The bird is a sensitive indicator for land-use and environmental protection (Rat von Sachverständigen für Umweltfragen 2002). White storks have been censused in Brandenburg since 1934 (Ludwig 1994), where in 1990s 1200 breeding pairs were recorded. It is now the ”stork - richest” region of Germany. The population density varied in space between 0.5 and 11 pairs per 100 km^{-2}.

The food availability is often considered as the reason for the large differences in bird density. Food uptake of white stork, that prefers the animal food, is not very selective. The habitats preferred by storks during their stay from March to August, are the valleys with grasslands and river valleys with floodplain (Jonkers 1989, AG Berlin/Brandenburger Ornithologen 2001). In general, the occurrence of birds depends not only on the presence of their preferred habitats but also on landscape structure as Mazerolle and Villard (1999) and others have shown. The knowledge on the importance of landscape structure as the value of habitat quality for birds is still rather low. The landscape structure is also vital for the nest distribution of White Stork as it has been shown by Latus *et al.* (2000). In this paper we consider the role of landscape features as the factors responsible for differences in stork densities in an agricultural landscape.

2. STUDY AREA, MATERIAL AND METHODS

The study area consisted of six administrative, typical rural districts of Brandenburg, Germany (Fig. 1), where agriculture dominated. Mean annual precipitation in the area was between 500 and 600 mm; yearly average temperature was 8.1°C for all areas. The averaged yields of the main crops showed no differences. The yield of hay which indicates productivity of grasslands was similar in four areas. Only Seelow and Forst showed a smaller value. So, these data indicate rather similar farming input in all the study areas.

The landscape structure was quantified with the aid of biotope-type CIR database at a 1:10000 scale (Landesumweltamt Brandenburg 1995). Spatial pattern of landscape was quantitatively described with the use of variables related to habitat patches. A habitat patch was defined as a homogenous area of the same habitat with no respect to their shape. Following habitat types were distinguished and used for analyses: water flows and bodies, fens, grasslands, bushes, hedges and tree-lines, woods, crop fields, parks together with gardens, mines, built-up areas. The grassland areas consisted of moist meadows, slightly moist pasturelands, dry grasslands, persistent nitrophilous ruderal communities, herbaceous perennials and intensively used sown grassland. For quantifying landscape diversity, Shannon's diversity

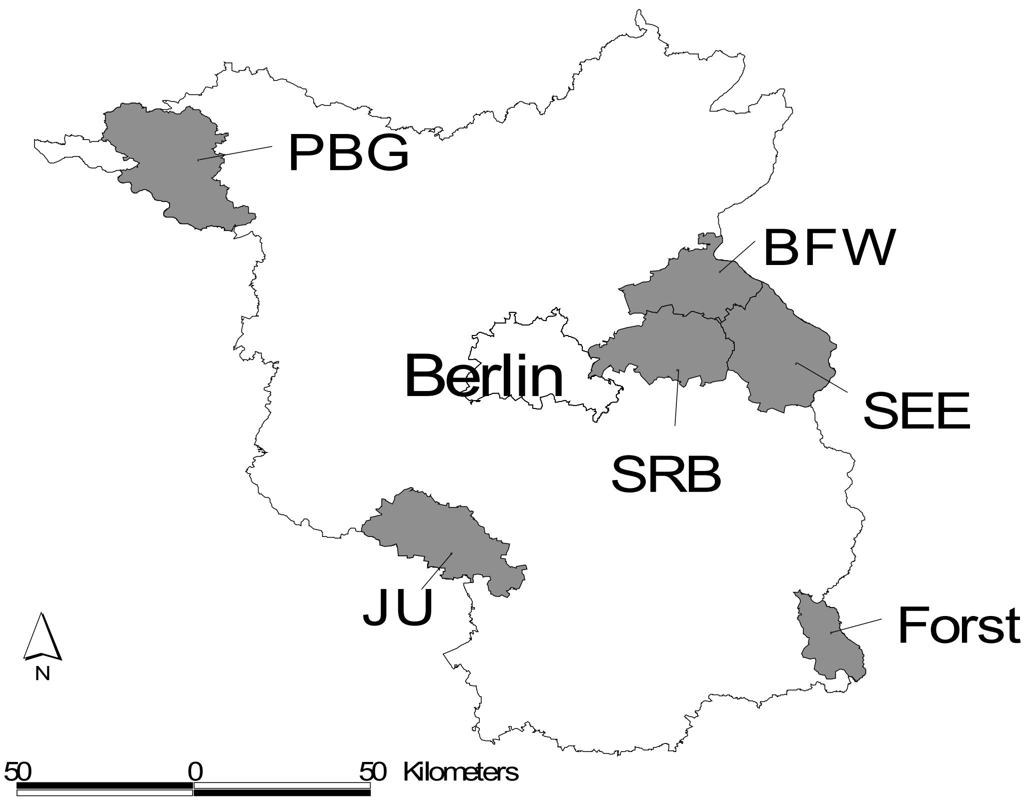

Fig. 1. Location of the six study areas within Brandenburg (Germany). PBG – Perleberg, BFW – Bad Freienwalde, JU – Jüterborg, SRB – Strausberg, SEE – Seelow, Forst.

index H' (Krebs 1989) was used, calculated according to the formula:

$$H' = \sum_{i=1}^{n} p_i \cdot \log p_i \quad (1)$$

where *pi* is the proportion of the total area of habitat *i* for total study area.

Besides the area-based variables listed above, also line-based variables indicating the landscape fragmentation were used like the edge density of grasslands, of crop fields and of woods. Edge is here regarded as a borderline of individual patch. The edge density, i.e., sum of perimeters of all patches per area for each of these habitats mentioned above was calculated. The index „*d*" of spatial distribution of grassland and crop field patches was calculated according to Trojan (1975). The index is defined as the variance divided by average area of grassland (or crop field patches) in each study area. The interpretation of the value estimated is as follows: if $d < 1$, then distribution of patches tends to be uniform; if $d = 1$, then distribution of patches is random; if $d > 1$, then distribution of patches tends to be aggregated.

For all other features (land use and human impacts etc.) main data were taken from the statistical annuals (LDS Brandenburg 1994) like: number of villages and towns, number of inhabitants and road density.

The data on White Stork density collected in 1994 (Ludwig 1994) were used. The White Stork densities (StD) as well as the share of unsuccessful pairs (% HPo) differed between the study areas while mean numbers of fledglings per nest (JZm and JZa) were similar (Table 1).

Significancy of the differences in proportion of habitats between the regions was determined with the aid of Chi-square test. The relationships between stork density (StD) and independent variables (landscape factors) were tested with the aid of Spearman rank correlation coefficient analysis. To reduce the number of variables related to grassland types, of which some were inter-correlated, principal component analysis (PCA) has been performed. Statistical analysis has been performed with the aid of Statistica 5.5 software.

3. RESULTS

3.1. Differences in landscape structure between study areas

Basing on variables listed above, some differences in landscape composition were recognized (Table 2). In Perleberg grasslands covered significantly higher (Chi-square test, $P < 0.001$) proportion of landscape. In Seelow and Forst proportions of woods and crop fields were strongly deviated; in Strausberg and Forst proportion of built-up areas were somewhat higher. Fens and waters differed more strongly, but their proportions were very little. The density of villages and towns as well as the inhabitants density were very similar with exception of Strausberg and Forst where respective values were higher. The differences of densities of roads were not very conspicuous, too.

Table 1. Breeding parameters of White Stork populations in study areas by Ludwig (1994). JZa: average number of fledglings per pair; JZm: average number of fledglings per successful pair; HPo (%): number of pairs without fledglings in %; HPa: number of all pairs; StD (stork density): number of pairs per 100 km^2.

	Study areas[1)]					
	Perleberg	Bad Freien-walde	Jüterborg	Strausberg	Seelow	Forst
Area (km^2)	1218	589	766	689	843	308
JZa	1.2	1.4	1.5	1.1	1.4	1.5
JZm	2.0	2.1	2.0	2.0	1.9	2.0
HPo (%)	41.2	30.4	25.0	46.7	27.5	23.8
Hpa	136	23	4	15	40	21
StD	11.0	3.9	0.5	2.2	4.7	6.9

[1] see Fig. 1.

Table 2. Percentage share of individual habitat types in study areas, Shannon's diversity index H' calculated on the database of CIR-biotope types and indices of urbanization (LDS Brandenburg 1994). Abbreviations of area names – see Fig.1.

Biotope type	PBG	BFW	JU	SRB	SEE	Forst
Water flows	0.8	0.8	0.0	0.0	0.7	0.3
Water bodies	0.5	0.7	0.1	2.4	1.6	1.3
Fens	0.2	0.4	0.1	0.9	0.4	0.2
Grasslands	22.0	8.9	11.4	8.8	8.4	9.7
Heath, bushes	0.1	0.0	1.3	0.0	0.0	0.1
Hedges, tree-lines	0.8	0.6	0.1	1.2	0.6	0.5
Woods	26.1	28.1	31.9	34.9	12.0	45.0
Crop fields	43.3	53.0	48.3	39.4	68.8	26.2
Parks, gardens	1.8	2.2	1.3	1.8	2.9	1.4
Mines	0.2	0.1	1.1	0.4	0.2	5.9
Buil-up areas	4.2	5.1	4.4	10.2	4.1	9.3
Diversity index H'	1.4	1.3	1.3	1.4	1.1	1.5
Localities (per 100 km^2)	9.8	8.6	7.9	5.6	7.3	8.1
Inhabitants (per km^2)	59.0	60.0	46.0	127.0	46.0	118.0
Roads (km per 100 km^2)	34.7	40.9	28.5	45.4	34.6	30.5

Table 3. Percentage share of individual grassland types in relation to total area of the six study areas. Abbreviations of area names – see Fig.1.

Type of grassland	PBG	BFW	JU	SRB	SEE	Forst
Moist meadows	1.8	1.2	1.4	1.7	2.7	0.6
Slightly moist pastureland	0.2	1.1	3.4	2.1	1.7	1.2
Dry grassland	0.2	0.3	0.8	0.1	0.2	0.5
Persistent nitrophilous ruderal communities	1.4	2.1	3.9	1.4	1.3	2.4
Herbaceous perennials	0.7	0.3	0.1	0.1	0.2	0.2
Intensively used sown grassland	17.6	3.9	1.8	3.4	2.3	4.8

Table 4. Variable loadings in principal component analysis (PCA) of composition of grassland types. Dry grasslands and herbaceous perennials were excluded from analysis because of their small share.

Variable	PC1	PC2
Moist meadows	0.093	–0.953
Slightly moist pasturelands	0.956	0.095
Persistent nitrophilous ruderal communities	0.612	0.700
Intensively used sown grasslands	–0.877	0.021
Eigenvalues	2.066	1.407
Share	0.516	0.352

Significant differences between the study areas were found in respect to the composition of grasslands (Table 3). The principal component analysis shows that variability of grassland composition can be described by two factors. Principal component PC1 had high positive loadings for slightly moist pastureland and high negative loadings for intensively used grassland. Principal component PC2 had high negative loadings for moist meadows. PC1 and PC2 together explained 87 % of the variation of grassland type composition (Table 4).

All habitats assumed to be important for White Stork were less fragmented in Jüterborg (JU) excluding settlements (Table 5). The mean patch sizes in JU were on average bigger than in all other regions (excluding parks, which were very similar in size in all study areas, and settlements, which were bigger in Strausberg). In respect to number of patches per area unit JU was again less fragmented. The patch density in JU region was smaller than in all other regions in respect to all distinguished habitats. The analysis of habitat edge density showed similar results. Grassland habitat edge density was clearly lowest in JU and highest in Perleberg and Forst, which supports that the fragmentation of open landscape part is different in particular regions.

Table 5. Indices of land cover fragmentation: mean patch size of main habitats, the density of habitat patches, the density of habitat edge and index "d" of spatial distribution of patches. Abbreviations of area names – see Fig.1.

Variable	PBG	BFW	JU	SRB	SEE	Forst
Mean patch size (ha) for:						
Grassland	5.9	2.8	5.8	2.1	2.3	2.0
Woods	3.4	3.9	6.2	3.9	2.9	4.9
Crop field	16.5	23.9	35.2	23.9	31.8	10.1
Parks, garden	1.7	1.6	1.6	1.5	1.3	1.5
Settlement, traffic	2.3	1.9	2.6	3.7	1.1	3.2
Density of patches (no. of patches×total study area^{-1}) for:						
Grassland	3.7	3.2	2.0	4.2	3.7	4.8
Woods	7.8	7.1	5.1	8.8	4.1	9.2
Crop field	2.6	2.2	1.4	1.7	2.2	2.6
Parks, garden	1.1	1.3	0.8	1.2	2.2	0.9
Settlements, traffic	1.8	2.7	1.7	2.8	3.6	2.9
Grassland	3.3	2.6	1.9	2.4	2.2	3.4
Woods	5.4	6.6	5.8	7.7	3.1	9.3
Crop field	3.9	4.6	3.3	3.3	5.0	3.5
Density of habitat edge (km×km^{-2}) for:						
Grasslands	3.3	2.6	1.9	2.4	2.2	3.4
Woods	5.4	6.6	5.8	7.7	3.1	9.3
Crop fields	3.9	4.6	3.3	3.3	5.0	3.5
Index "*d*" (see Methods) for:						
Grasslands	3.1	3.7	3.4	4.0	4.1	3.4
Crop fields	1.4	1.6	1.4	2.0	1.3	2.3

3.2. White Stork density

In general, most relationships between stork density (StD) and variables quantifying landscape composition were weak and/or insignificant ($|r_s| < 0.7$, $P>0.1$) but grassland composition influenced StD markedly. PC1 was negatively linked with StD (Table 6), what means that proportion of slightly moist pasturelands and intensively used sown grasslands was important factor (Table 4). The effect of proportion of the latter one on StD was positive but for the former one – negative. Moist grasslands which are very often regarded as very suitable for White Stork, in our study did not play a role at all.

It seems that most important factor (excluding share of grasslands) affecting StD is fragmentation of its main feeding areas, i.e., crop fields and grasslands. StD was strictly and positively correlated with density of crop field patches as well as positively but somewhat weakly correlated with combined density of grassland and crop field patches. On the other hand StD was negatively correlated with average size of crop field patches. StD

Table 6. Relationships between White Stork density and composition of grasslands. PC1, PC2 – principal components for grassland composition (see Table 4). r_s= correlation coefficient; $T_{(N-2)}$: degrees of freedom, *P* – statistical significance.

Variable	r_s	$T_{(N-2)}$	*P*
PC1	–0.83	–2.96	0.04
PC2	–0.03	–0.06	0.96

Table 7. Relationships between stork density (StD) and indices of landscape fragmentation of the six study areas, n=6; r_s= correlation coefficient; $T_{(N-2)}$: degrees of freedom; *P* – statistical significance.

Variable	r_s	$T_{(N-2)}$	*P*
Mean patch size			
Grasslands	0.03	0.06	0.96
Woods	–0.52	–1.22	0.29
Crops	–0.75	–2.29	0.08
Parks	0.12	0.24	0.82
Built-up area	–0.26	–0.53	0.62
Patch density			
Crops and grasslands	0.82	2.49	0.09
Grasslands	0.49	1.13	0.32
Woods	0.31	0.66	0.54
Crops	0.97	2.42	0.07
Parks	0.14	0.29	0.79
Built-up areas	0.31	0.66	0.54
Habitat edge density			
Grasslands	0.77	2.42	0.07
Woods	–0.14	–0.29	0.79
Crops	0.54	1.29	0.27

also showed a significant positive correlation with grassland edge density (Table 7). All these results indicate that more fragmented crop fields and grasslands affect StD positively.

The spatial distribution of crop field patches and grassland patches did not affect StD. There were no significant correlation ($r_s = 0.3$ at $P > 0.5$, $T_{(N-2)} = 0.54$) between stork density and the index "*d*" of spatial pattern of crop fields and grasslands (Table 5) for five areas (without Perleberg) which were similar in respect to share of grasslands.

It can be concluded that high StD in Perleberg is most likely linked with very high proportion of grasslands (22%). However, more interesting finding is the large difference in stork density (up to 9-fold) between all other study areas (besides Perleberg) while proportion of grasslands is almost the same, ranging from 8.4 to 11.4%. Results of our analyses indicate that in the cases where grasslands percentage is moderate, important factor positively influencing StD may be composition of grassland types as well as higher fragmentation of crop fields and grasslands.

4. DISCUSSION AND CONCLUSIONS

The results of present study confirm that high percentage of grasslands support high density of White Stork population. Most probably, high population density in Perleberg (Fig. 1) was related to high share of grasslands. This is in agreement with findings of Löhmer and Harms (1999) who noticed that grasslands constitute most suitable feeding grounds for this species. Otherwise it has to be mentioned that when the proportions are analyzed a decline in one habitat is matched by an increase in another. Thus testing for preference to particular habitat is fraught with difficulty when determining if a species prefers or merely avoids one habitat. In this study it had not been tested.

The landscape management also should be taken into account as the factor influencing stork density. Land use intensity of arable land seems to be not of decisive importance. Some of recent publications also point out that bird densities are correlated more with structural attributes of landscape than with variables relating to farming system (Fuller *et al.* 1997). On the other hand the management of grasslands seems to be of importance. The cultivation of the grasslands by mowing or grazing leads to an interruption of vegetation development. White stork, as a stepping bird, with its long thin legs, prefers the low-height vegetation. It is able to find more food, because intensively mowed grassland and slightly moist pasture land are characterized by higher food availability (Johst *et al.* 2001). In opposition to other publications (Schneider 1988), in our study stork density was not related to share of moist meadows in the area.

Although the diversity of a landscape (expressed by Shannon-Weaver index) showed strong effect on occurrence of White Stork nest sites (Latus *et al.* 2000), no coherent correlation between the index of diversity and Stork density was found in the present study. It may indicate that ultimate factor affecting breeding area selection is large-scale landscape pattern (i.e., the share of grasslands, settlement areas, woods and crop fields), but proximate factor regulating occurrence of White Stork nests is local landscape pattern diversity (in sense reflected by Shannon-Weaver index).

Agricultural landscape is characterized by heavy human impacts which affect the structure of landscape together with natural conditions. Kaatz (1999) mentioned that built-up areas are important disturbances for distribution of white storks in whole Germany. In Brandenburg (East Germany) the buil-up areas amount to less than 8%, while in other parts (West Germany) it is 10% and more. In general bird distribution is influenced directly by infrastructure noise and destruction of the environment as Kuitunen *et al.* (1998) have analyzed. In the present study no such effects of indices of landscape structure on stork density were recorded. It is likely because of relatively small variability of these landscape features among six studied areas.

For getting more precise resolution of the effect of landscape features, finer scales of landscape pattern is necessary to use, especially in relation to fragmentation of the land cover (Forman and Godron 1981, Wiens *et al.* 1993). In our study fragmentation effects have been distinguished like patch size and edge density (Johnson 2001). The results prove that patch size of crop field and – to a smaller degree – wood patch size tend to correlate negatively with stork density. The density of crop field patches was significantly and positively correlated with stork population. These findings emphasized the significance of fragmentation of the open land areas which leads to creation of smaller patches (Blaschke 1999). The study results support that white storks prefer smaller areas of crop fields as well as high density of grassland edges, which could be also an indicator of landscape fragmentation (Winter and Faaborg 1999). Grassland edges may create better signals of food resource for stork fledglings in early time of its stay (May and June). Thus, a more fragmented landscape may have higher value for White Stork and other species because of presence of higher density of ecotones which are mostly very rich in different animals (incl. potential preys of White Stork) (Saunders *et al.* 1991) like large insects, grasshoppers and earth worms (Profus 1986, Pinowska and Pinowski 1989). The ruderal vegetation adjacent to crop fields, grasslands or woods within agricultural landscape belong also to the habitat of preys of White Stork.

Higher fragmentation may be adventageous, because in this case the patches are distributed more or less across whole area and they are more available for storks than in case of less fragmented land cover. Alonso *et al.* (1991) showed the problem of the distance to overcome for food acquisition. Therefore location of patches and spatial pattern of all patches within a landscape is necessary as mentioned by Webb (1994).

Within the policy of nature conservation there is the tendency to keep the large fragments of some habitats under protection. This reasoning is based on the application of species-area relationships. Large habitat patches are associated with the greater concentration of food resources. Estades (2001) proved it in the simulation model of the location of food and nest sites and the relationship between habitat patch size and bird population density.

These study results on White Stork as an open land species are in opposition to results for forest breeding birds where a negative correlation between degree of fragmentation and bird density was found (e.g., Donovan and Flather 2002). The results of our study support the importance of viewing more scales also for one species to understand its complex habitat demands.

It was shown in this study that more fragmented arable landscape and a landscape characterized by more fragmented grassland can have a high nature conservation value. It is in opposition to prevailing opinion about negative role of fragmentation.

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