

Does Red Fox *Vulpes vulpes* affect bird species richness and abundance in an agricultural landscape?

Krzysztof KUJAWA & Rafał ŁĘCKI

Research Center for Agricultural and Forest Environment, Polish Academy of Sciences, Field Station, Turew, Szkolna 4, 64-000 Kościan, POLAND, e-mail: kkujawa@man.poznan.pl

Kujawa K., Łęcki R. 2008. Does Red Fox *Vulpes vulpes* affect bird species richness and abundance in an agricultural landscape? *Acta Ornithol.* 43: 167–178. DOI 10.3161/000164508X395289

Abstract. The aim of the study (carried out 25 km south of Poznań, western Poland) was to determine the impact of Red Fox on bird abundance on farmland. Bird abundance was studied in the years 1999–2000 and 2005–2007 in three categories of sampling plots: 1) in small woods — with or without active fox dens, 2) along transects — starting from dens and running across arable land, and 3) around points — located at dens and far from them. Thus, variability in bird density was analyzed in relation to the presence/absence of Red Fox (in woods) and to the intensity of Red Fox penetration of crops (approximated by distance from a den). Two groups of bird species were distinguished with respect to their vulnerability to Red Fox predation pressure: 1) potential fox prey, i.e. species nesting on the ground and in low vegetation; and 2) birds not threatened by foxes, i.e. species nesting in tree holes and in tall vegetation. To investigate the relationships between bird distribution and Red Fox dens in woods, a step-wise multiple regression of bird density and species number on woodland structure was first performed. The residuals derived from the model were used to evaluate the impact of foxes by analyzing the differences between woods with and without active dens. Neither the species number nor the bird density differed significantly between woods with and without active dens. The differences in bird density observed between years in woods with or without active dens were not significant, either. No relationship between bird density in crop fields and distance from fox dens was found. The results are contrary to those of earlier studies and show that Red Fox does not affect farmland bird distribution, diversity and abundance, at least in the short term.

Key words: Red Fox, *Vulpes vulpes*, Skylark, *Alauda arvensis*, bird community, farmland, predation, Poland

Received — Febr. 2008, accepted — Nov. 2008

INTRODUCTION

According to estimation by IUCN (2007), the Red Fox population size in Europe is generally increasing, which was shown in many regions of Europe (e.g. Tapper 1992, Gloor et al. 2001). The increase has most probably been caused by oral immunization of foxes against rabies (Stubbe 1999) and easy access to food, especially in suburban areas (Harris 1977, Macdonald & Newdick 1982). In some areas where food was superabundant, population density of the Red Fox reached a very high level of 30 individuals per 100 ha (Harris 1977).

In Poland, the Red Fox population size has also markedly increased in the last few decades, most probably as a result of widespread application of rabies vaccination (Panek & Bresiński 2002,

Gołdyn et al. 2003). For example, in the western part of the Wielkopolska region, population density of the species increased more than five-fold during three last decades of XX century (Panek & Bresiński 2002). At the same time, family dens started to be commonly observed even in open farmland, far from woodlands. Within their study area, Panek & Bresiński (2002) found 83% of fox dens in farmland (mainly in uncultivated patches, crop fields, stacks of straw, orchards and drainage ditches). According to Gołdyn et al. (2003), the Red Fox population density was high even in an open, deforested farmland, where most dens were dug in ditches, marsh edges and boundary strips between crop fields, but also in completely flat ground. The population increase and shifting in part to open farmland suggest that the species — regarded as an adaptable opportunistic

omnivore (Korpimäki & Norrdahl 1989a, b) — may at present constitute an important limiting factor for bird density and diversity in farmland habitats, such as crop fields and small woods located in farmland.

A long-term study carried out in western Poland showed that in comparison to the 1960s, population density of some bird species related to small wood islands (especially buntings, the Red-backed Shrike *Lanius collurio*, and others) declined by more than 20% (Kujawa 2002). The decline is likely to have been caused by intensification of farming practices, which is commonly regarded as a main factor responsible for the impoverishment of avifauna in farmland (O'Connor & Shrubbs 1986). However, an alternative hypothesis explaining partly these changes in avifauna connects the strong increase in Red Fox population density to some declining bird species building their nests on the ground or in low vegetation, which renders them particularly vulnerable to terrestrial predators, including the Red Fox.

The general role of predators in ecosystems has been studied in many countries for a long time (e.g. in Poland — Ryszkowski et al. 1971, 1973, Ryszkowski 1982). Predation is also commonly regarded as an important factor affecting animal communities, including birds (e.g., Newton 1998), but attempts to generalize the results of various studies lead to ambiguous conclusions (Evans 2004). Its importance for bird distribution was evidenced by Geer (1978), Suhonen et al. (1994), Norrdahl & Korpimäki (1998), and recently in Poland by Tryjanowski (2000) and Tryjanowski et al. (2002). However, most of the studies dealt only with the pressure of birds of prey on other birds.

It can be expected that during the breeding season, the bird species which are especially strongly threatened by Red Fox build their nests on the ground or in low plants and most strongly exposed are eggs, nestlings and adult birds at nests. Such an effect of Red Fox on birds nesting on ground was confirmed in a study on Grey Partridge *Perdix perdix*, which showed that mortality of females incubating eggs caused by mammals (mainly Red Fox) was the most important factor limiting breeding success of the species (Panek 2005). Thus, if the effect of Red Fox on birds is significant, one should expect lower bird population density in the area where predatory pressure is strong (permanent) as a result of predator avoiding behavior and/or enlarged mortality of birds.

So far, only a few studies on the role of the Red Fox for bird communities have been carried out in Europe, and they focused on birds occurring in crop fields. In Poland, studies on the impact of the Red Fox on bird species concerned mainly the Grey Partridge (Panek 2002, 2005). The influence of the Red Fox on bird communities was studied by Tryjanowski et al. (2002), who showed that two most common species in the study area, i.e. Skylark *Alauda arvensis* and Yellow Wagtail *Motacilla flava*, avoided close neighborhood of active fox dens. However, no complex study of Red Fox impact on birds has been done hitherto in forest islands, whose presence determines most strongly bird diversity in farmland areas (Kujawa & Tryjanowski 2000).

The aim of our study was to determine whether the Red Fox influences bird communities and — as a result — whether it can contribute to impoverishment of avifauna in farmland. Our general hypothesis was that Red Fox predatory pressure is a limiting factor for the distribution of breeding birds. We expected, that as a result of this pressure, the spatial and temporal pattern of changes in bird density and species richness should be related to the presence of active Red Fox dens as indicative of the areas where feeding intensity of this predator is strongest.

STUDY AREA

The study was carried out in the Dezydery Chłapowski Landscape Park and adjacent area near Czempień (66–90 m a.s.l), located 25 km south of Poznań city (western Poland) and dominated by agricultural landscape. The area is flat, with slopes of less than 5%. The water system is poor. The density of small rivers and canals amounts to 0.4 km/km² and density of small water bodies is 1.3/km².

The landscape of the Park is characterized by a highly diversified structure, due to the presence of various non-farmed habitats: woodland, small woods, water bodies, wetlands, as well as a mosaic of small-sized crop fields in some regions. However, intensive farming dominates in the study area, which is reflected in the presence of large crop fields. Crop fields and grasslands cover about 74% and woodland about 15% of the Park area. Grasslands are mainly moist hay meadows located in lower parts of the Park and along the rivers and canals. Woods are numerous, but their size is generally small. The largest

two forest complexes cover about 960 and 420 ha. The area of other eleven woods varies from 8 to 115 ha. Additionally, there are many small wood islands in the study area. In most cases the small woods are composed of a mosaic of small forest stands dominated by either *Pinus sylvestris* or *Quercus robur*, sometimes with admixture of *Robinia pseudoacacia*, *Picea abies*, *Larix decidua*, *Alnus glutinosa*, *Betula pendula* and *Fraxinus excelsior*. The shrub layer consists mainly of *Padus serotina*. Most (65%) of the studied small (< 4 ha) woods were broad-leaved forest stands. Broad-leaved stands with admixture of conifers accounted for 17%, mixed stands for 11%, and coniferous stands for 7% of woods (Kujawa 2006). Mean area of studied forest islands amounted to 1.05 ha (SD = 0.88) and mean Shannon diversity index for tree species was equal to 0.49 (SD = 0.36). The unique, mosaic structure of the farmland rich in differentiated non-farmed habitats (small wood islands, wetlands, small water bodies) creates a favorable habitat for species-rich communities of birds (Kujawa 1994, 1997, 2000).

METHODS

Referring to some authors (Goszczyński 1985, 1995, Blanco 1986, Gołdyn 2001), we assumed (similarly to Tryjanowski et al. 2002) that an occupied Red Fox den is an indicator of the area where foraging intensity and predator pressure is most intensive and it decreases with the distance from the den, becoming insignificant in areas located far away (> 600 m) from the den.

With respect to the feeding ecology of the Red Fox, its impact on bird nests is assumed to differ between nesting guilds. Species that build their nests on the ground and in short vegetation are expected to be threatened by the Red Fox and are referred as EG ("exposed group"), while species building open nests in tall vegetation or in tree holes can be regarded as a group that is not threatened by this mammal and is referred as NG ("non-affected group"). A classification of species to both groups is shown in Appendix I.

Taking into account the information mentioned above, if the impact of Red Fox on birds is significant, some responses of bird communities to permanent presence of this predator may be expected. They are: 1) with respect to spatial pattern: a) species numbers and/or densities of EG should be lower in woods with dens than in woods without dens (and no difference for NG);

b) density of EG in crop fields should increase with increasing distance from the den; 2) with respect to temporal pattern density of EG in a given wood island is lower in the years when the wood is occupied by Red Fox compared to the years when Red Fox is absent (and no such difference for NG). The expected responses of birds were regarded as detailed hypotheses tested in our study.

To test the hypotheses, species composition and population density (or its index in case of transect and point count methods) of birds was studied in four categories of sampling plots: a) in wood islands with active Red Fox dens, b) in wood islands without active dens, c) along transects starting from occupied dens in crop fields and running across arable land (located far from extensive woods and smaller wood islands), d) in points located in arable land belonging to two categories: located at the fox dens and points located far (> 700 m) from the dens.

Bird counts

Forest bird counts. Our study was carried out in a total of 70 small wood islands, creating potential sites for Red Fox dens. The study covering all the small woods was carried out in 2005–2007. The results from this period were complemented with data on Red Fox occurrence and bird abundance collected in 1999–2000 in 40 woods belonging to the group mentioned above. The data from 2005–2007, as covering a larger number of small woods, were used for testing the impact of the Red Fox on birds in relation to spatial pattern (i.e. differences between the woods). In three consecutive years of the period, the dens were found in 22, 17 and 13 woods and no dens were recorded in 42, 30 and 36 woods, respectively. Combined data from the two datasets (1999–2000 and 2005–2007) were used for the analysis of the impact of changes in the presence/absence of Red Fox in given woods on changes in bird abundance. As many as 27 woods were selected, for which the Red Fox status (presence or absence) was recognized in the four or five years in respect to each woods. Bird density in each wood was estimated with the aid of mapping method (for details, see Kujawa 1997), on the basis of nine early-morning visits per year.

Transects. Bird density index in crop fields was evaluated along transects ($n = 27$ for two years). Transects started from dens were 1000–1200 m long (depending on the configuration of the area) and 300 m wide, and were divided into 200-m

sections with the aid of a GPS receiver. Birds (mainly singing males, in few cases also pairs) were censused once a year, either at the beginning (in April 2006) or at the end (in early July 2005) of the breeding season. In line with recommendations by Bibby et al. (1992), the observer moved at a rate of about 2 km/h. Bird density index was estimated for each 200 m section of transects.

Point counts. Estimation of bird density index in crop fields with point count method was done early morning between 25 and 27 May 2007. All birds seen and heard within fixed radius of 100 m from given point were counted during 10 minutes. Set of 17 points located at dens (ca. 50 m) was used to recognize a response of birds to permanent presence of foxes, while set of 17 points located far from the dens was regarded as "control" area. The points in "control" area were located in the places which were as similar to places at the dens as possible. To verify the similarity in habitat structure between two sets of points, we quantified habitat structure of area around each point (< 100 m) with two variables: number of habitats (mainly number of cropped plant species, roads and ditches) and Shannon diversity index estimated on basis of proportion of encountered habitats. For both variables the differences in habitat structure were statistically non-significant ($p > 0.3$ in Mann-Whitney U-test). An invited observer who counted the birds did not know which points were located at the den to avoid some auto-suggestion effects which could bias the results to some extent.

The Red Fox den status

It was defined during visits performed from March to July. In early spring, before the start

of the growing season, the dens were inventoried and their locations were recorded with the GPS receiver, if they were built in crop fields. Afterwards, they were again controlled during the cub-rearing period. Their status was defined during each visit with regard to the presence of tracks, food remnants, excrements, scents and fresh sand at the den. For further analyses, only permanently used dens were selected (with young foxes or without them) and those with doubtful status were excluded from the analysis.

Data analysis

For controlling the effect of habitat structure on birds breeding in woods, ten variables, recognized by Kujawa (2006) as significant for birds in small woods, were used to describe quantitatively wood structure (for details see Kujawa 2006) (Table 1).

To verify relationships between bird distribution and presence of Red Fox dens in woods, first a forward stepwise multiple regression of bird densities and species number on vegetation structure was performed. After that, standardized residuals derived from the model were used for evaluation of Red Fox impact by analyzing differences in residuals between woods with and without active dens. The significance of the differences was estimated with the use of an ANOVA in the General Linear Model (GLM).

To test the statistical significance of differences in the bird community occurring in given woods ($n = 27$) between the years with and without Red Fox dens, first the mean species number and density of birds were estimated for each wood, both for the years with and without any active den. After that, the differences between estimated

Table 1. Description of the variables used to control the effects of habitat structure on birds breeding in woods.

Variable	Description
AREA	wood area (in ha)
SHAPE	shape index — the ratio of perimeter of a circle having the same area as the given wood to wood perimeter
STAND	forest stand, ranked according to a four-point scale, quantifying (by eye) increasing share of broad-leaved trees: 1 = coniferous, 2 = mixed, 3 = broad-leaved with admixture of coniferous species, 4 = broad-leaved (coniferous with admixture of broad-leaved species were absent)
TREE_1	percentage cover (evaluated by eye) of the upper tree layer (in %)
TREE_2	percentage cover (evaluated by eye) of the lower tree layer (in %)
SHRUB	percentage cover (evaluated by eye) of the shrub layer (in %)
HERB	percentage cover (evaluated by eye) of the herb layer (in %)
SHANNON	Shannon diversity index of forest stand species composition $\sum_{i=1}^n p_i \ln(p_i)$ where p_i = share of the i -th species in the forest stand
DICOTYL	share (evaluated by eye) of dicotyledons in the herb layer, as an index of diversity of the layer (in %)
WATER	presence/absence of surface water (binominal scale: 1 or 0).

means were tested with Wilcoxon test for matched pairs. All statistical analyses were performed with Statistica 7.1.

RESULTS

Comparison of avifauna composition in forest islands with and without active fox dens

The breeding bird community of studied wood islands consisted of 54 species occurring with a total mean density of 116.2 pairs per 10 ha. The most abundant species (> 5% of the community) include the Chaffinch *Fringilla coelebs*, Yellowhammer *Emberiza citrinella*, Blackcap *Sylvia atricapilla*, and Great Tit *Parus major* (Appendix I). The number of species per wood per year ranged between 1 and 18 (mean ca. 7.0–7.5). The breeding bird community of those wood islands was described in more detail by Kujawa (2006).

The data gathered in the years 2005–2007 show that Red Fox built their dens in studied woods (n = 70) with no strict relation to some habitat features. No difference in habitat variables between woods with and without den was statistically significant in all three years. In two years (2006 and 2007) foxes preferred woods with coniferous stands (t-test, p < 0.05 and p < 0.001, respectively). In the case of some variables (AREA and SHRUB) the difference was significant (t-test, p < 0.05) but only in single years, when foxes preferred woods with slightly larger area (2005) and shrub layer covering larger proportion of the wood (2006).

Residuals (derived from the “vegetation model” — see Appendix II) of bird species number in

Table 2. An ANOVA (in the General Linear Model) for number of bird species and density (residuals from the models described in Appendix 1 and 2) in relation to Red Fox presence, nesting guild, and year. Values of tested effects: fox — 0/1, nesting guild — tree holes, high, low, ground. Year — 2005, 2006, 2007.

Effect	Degrees of freedom	Number of species		Density	
		F	p	F	p
Constant	1	0.01	0.94	0.00	0.97
Fox	1	0.02	0.88	0.37	0.54
Guild	3	0.28	0.84	0.27	0.85
Year	2	0.32	0.72	0.36	0.70
Fox*Guild	3	0.45	0.72	0.56	0.64
Fox*Year	2	0.73	0.48	0.10	0.90
Guild*Year	6	0.19	0.98	0.13	0.99
Fox*Guild*Year	6	0.69	0.65	0.44	0.86

studied woods were not related to Red Fox presence, nesting guild, and year (Table 2). The pattern of the differences in bird species number between the woods with and without Red Fox dens was similar for species exposed to Red Fox (EG — building their nests on ground or in low vegetation) and non-affected by Red Fox (NG), i.e. building nests in tree-holes or in tall shrubs or trees (Fig. 1a). The same was found for comparison of residuals of bird density (see Appendix III) between woods with and without dens (Fig. 1b).

Birds and distance to fox dens

The relationships between bird density and distance from a fox den in crop fields were studied at the beginning and towards the end of the breeding season. Early in the season (2006), the total density amounted to 4–6 bird males/ha. Density of the Skylark (the most abundant species in crop fields) ranged from 3.5 to 4.8, and

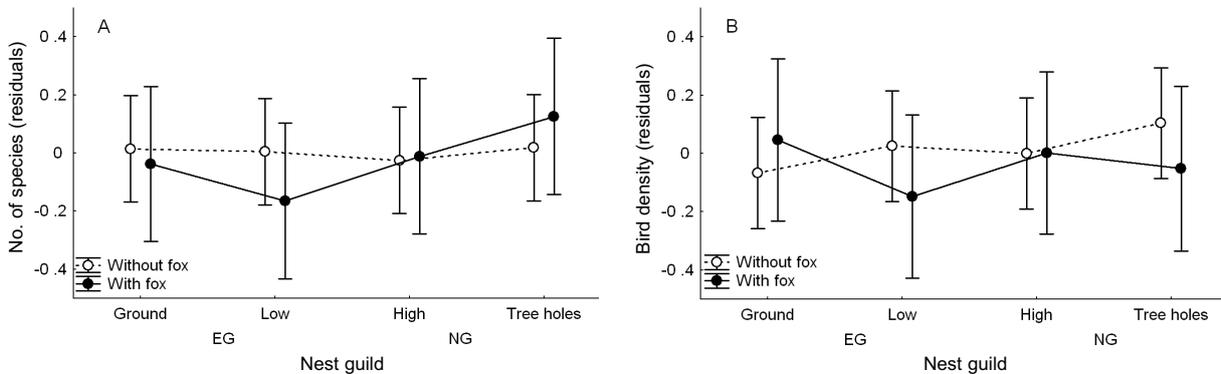


Fig. 1. Bird species numbers (A) and density (B) in relation to nesting guilds and Red Fox den presence in small woods. Figures present residuals derived from the “vegetation model” (see Appendix II i III) with 95% confidence intervals (vertical lines) in the General Linear Model. EG — guilds exposed to Red Fox pressure, NG — guilds non-affected by Red Fox.

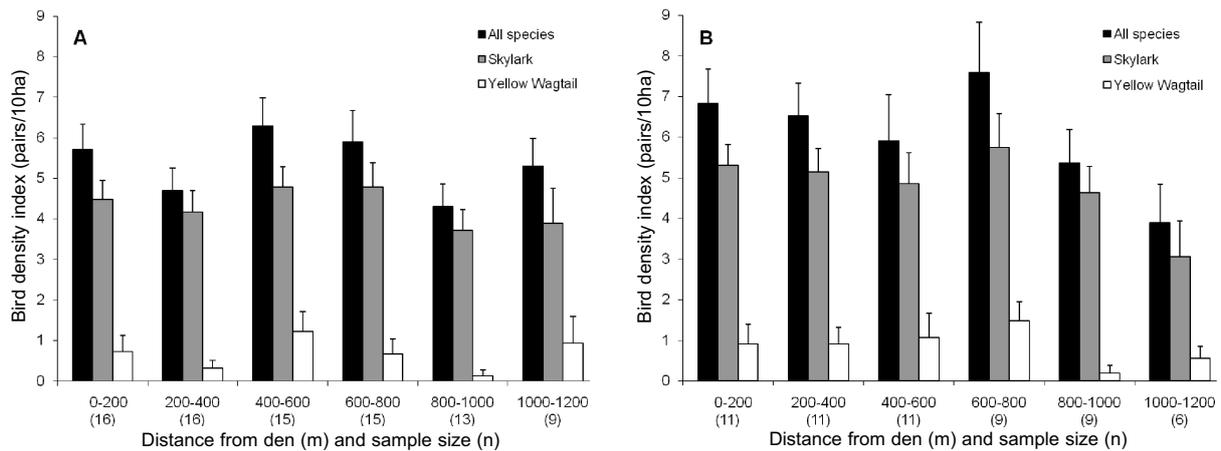


Fig. 2. Bird density index (mean number of singing males per 10 ha, with 95% confidence intervals) in relation to distance from an occupied red fox den at the beginning of the breeding season — in April 2006 (A) and towards the end of the breeding season — in May/June 2005 (B).

that of the Yellow Wagtail (the second-ranking species), from 0.1 to 1.3 males/ha (Fig. 2a). Coefficients of correlation between the distance and total density (Spearman correlation: $r = -0.06$) or density of the most abundant species, i.e. Skylark (Spearman correlation: $r = -0.06$) and Yellow Wagtail (Tau-Kendall correlation $r = -0.41$) were statistically insignificant ($p > 0.3$ in all cases).

Towards the end of the breeding season (studied in 2005), bird density was more differentiated. Total bird density index amounted to 3.6–7.2, for Skylark — 3.1–5.7 and for Yellow Wagtail — 0.2–1.5 (Fig. 2b). Contrary to expectations, the correlation between density and distance from the den for total bird density was significantly negative (Spearman correlation: $r = -0.36$, $p < 0.0001$). For Skylark and Yellow Wagtail analyzed separately, the correlation coefficient was statistically insignificant (Spearman correlation: $r = -0.36$, $p > 0.1$ and Tau-Kendall correlation $r = -0.41$, $p > 0.8$, respectively).

No dependence of bird abundance on Red Fox presence was recorded with use of point count method, too. Mean density of Skylark amounted

to 0.6 pairs/ha both close to Red Fox dens and far from the dens, while total density of birds was slightly higher at dens (0.9 pairs/ha) than in “control” area (0.7 pairs/ha) but this difference was statistically insignificant (Mann-Whitney U-test, $U = 123.5$, $p > 0.4$).

Changes in bird species number and density within studied guilds between years were not related to the presence of active dens. Differences in number of species and bird density observed in given woods between the years with active den and the years without any active den were insignificant for birds from group of species threatened (EG) as well as non-affected (NG) by Red Fox (Table 3).

DISCUSSION

In a review of studies on the influence of habitat changes and predation on bird population decline, Evans (2004) noticed that although there is convincing evidence for the effect of predation on bird population density, the studies

Table 3. Comparison of bird species number and density (pairs/ha) in studied forest islands ($n = 27$) between years with and without Red Fox dens groups: EG — exposed, NG — non-affected. T — Wilcoxon test value, p — statistical significance.

Group	Nesting guild	Species number		T	p	Density		T	p
		(mean \pm 95% confidence)				(mean \pm 95% confidence)			
		Years with dens	Years without dens			Years with dens	Years without dens		
NG	High	2.9 \pm 0.8	3.2 \pm 0.6	127	0.5	5.6 \pm 1.4	6.4 \pm 1.5	122	0.4
	Holes	1.9 \pm 0.8	2.0 \pm 0.8	89	0.8	2.6 \pm 1.0	2.3 \pm 0.8	88	0.5
EG	Low	0.8 \pm 0.3	0.9 \pm 0.2	56	0.5	1.5 \pm 0.8	1.8 \pm 0.7	114	0.7
	Ground	1.8 \pm 0.4	2.1 \pm 0.4	67.5	0.09	3.9 \pm 1.3	4.1 \pm 1.1	131	0.3

dealt mainly with game birds and ducks. For passerine birds the evidence is much poorer. That author cites Crick et al. (1994), who noted a decline in the Yellowhammer population, which was not accompanied by any increase in nest predation, as well as Thomson et al. (1998), who found that population trends of song birds were not correlated with Sparrowhawk *Accipiter nisus* and Magpie *Pica pica* population densities. Little is known about the direct effect of mammal predators on long-term changes in bird communities. Tryjanowski (2000), in a long-term study carried out in the Wielkopolska region, showed that Skylark density was negatively correlated with numbers of Red Foxes. On the basis of these data, a conclusion may be formulated that the importance of predators for bird abundance is strongly differentiated.

The foraging theory predicts that predators should optimize their strategy of feeding to achieve as high an energy income as possible. From that point of view, most passerine species are too small for the Red Fox to be profitable food items for the species. According to Dickman (1996), the impact of fox predation on the fauna seems to be greatest for medium-sized animals (450–5000 g), e.g. ground-dwelling and semi-arboreal mammals or ground-nesting birds. However, numerous studies carried out in the past showed that the Red Fox is an omnivorous, opportunistic predator feeding on many kinds of food, mainly on small rodents but also on other small animals and fruits (Korpimäki & Norrdahl 1989a, b).

Even though predator pressure (measured by per cent of the population eliminated by the predator) on a given species is relatively low, the appearance of some anti-predator adaptations may be expected. Explanation of that evolutionary effect of limited predator pressure comes from an analysis of losses of predator and its prey in the "game for surviving". When the predator fails (does not catch its prey), in most cases it can repeat searching for another food item. On the contrary, when the prey fails (is caught by a predator), it cannot continue the "game". That is why anti-predator adaptations occur commonly in animals, even though in fact the effect of predator pressure is relatively low.

One of well-known adaptations is avoidance of predators. For example, in the Białowieża Primeval Forest, where predator pressure is extremely high because of a high diversity of mammal and avian predators, the population density of many bird

species is very low, which is regarded as an anti-predator adaptation. For example, this was shown for Great Tit (Wesołowski et al. 1997).

Some evidence for behavioral reaction (predator avoidance) of passerine birds to the presence of active fox dens was reported by Tryjanowski et al. (2002). They found that for farmland bird communities, the presence of a Red Fox played a much more important role than habitat structure. They showed that the presence of fox dens influenced negatively the potential prey species (in contrast to non-prey species), including the most abundant species, such as the Skylark and Yellow Wagtail (but not Corn Bunting *Miliaria calandra*). As a result, total bird density was also found to be negatively affected by the Red Fox. According to our knowledge, this is the only direct evidence that the Red Fox plays a significant role for the distribution of common passerine birds in farmland.

The Red Fox can affect birds in two different ways: it may limit their population size by increased bird mortality (i.e. adults and their broods) or it may influence the distribution of potential prey species. When the density of potential prey is lower in areas with high predation (as reported by Tryjanowski et al. 2002), both mechanisms mentioned above may be involved. However, those authors argued that predator avoidance is much more likely responsible for the observed differences, because small passerines are seldom recorded (they were found in several per cent of samples) in foxes' dietary samples (Goszczyński 1974, 1995, Kożena 1988, Gołdyn 2001).

The results of our study on farmland birds are contrary to the research by Tryjanowski et al. (2002). The Red Fox population density in our study area was not measured but in adjacent area near Czempiń (partly overlapping with our sampling plot) it amounted to about 1–2 ind./km² in winter season (Panek, unpubl. data) and was similar to that observed in compared study, where during winter period it was equal to 2.1 ind./km² (Gołdyn et al. 2003). Thus, it seems that this inconsistency between the results reported by Tryjanowski et al. (2002) and the data presented here can be explained by the methods used or by some factors, which were not taken into account. Tryjanowski et al. (2002) studied 18 plots with dens in crop fields and 18 control plots without dens, with the aid of point-count methods. In our study, 27 dens were investigated with the aid of the transect method, which allowed us to gather much more abundant data. Although sample sizes (18 versus 27) did not differ strongly, it should be noted that

both the total number of birds (Skylark and Yellow Wagtail together) and the area used for bird density estimation in our study were much larger, except for bird number in 2005 compared with bird number used for analysis by Tryjanowski et al. (2002). The total number of birds censused in our study was 3.5-fold higher and the area covered by our study was 3–4.5-fold larger in 2005–2006, respectively, than in the cited study. Consequently, the study by Tryjanowski et al. (2002) could be more biased because of the smaller sampling effort. Additionally, their study was carried out only in one breeding season. Finally, the point count method, which was applied in our study in 2007, similarly as in the study by Tryjanowski et al. (2002), did not confirm the results reported in cited paper.

With regard to bird communities of small forest islands, no other studies on Red Fox impact are known to us, so there is no possibility to compare our results with others. However, consistency of gathered results in respect to group of species (“exposed” and “non-affected”) and to time (3 years of study) strongly suggests a lack of relationships between Red Fox presence and bird diversity and population density in small forest islands. It is also noteworthy that the lack of evidence for avoidance of predators cannot be regarded as direct evidence that the predator does not affect population size.

Summing up, the results did not confirm any of the tested hypotheses on the effect of the Red Fox on bird communities: a) species number and/or density of “exposed group” (EG) were not lower in woods with dens, b) density of EG in crop fields did not increase with increasing distance from the den, c) density of EG in given woods was not lower in the years when they were occupied by Red Foxes.

In conclusion, the results of our study suggest that the role of the Red Fox for shaping bird communities may be of little importance, in line with the suggestion of Evans (2004) about a presumably minor impact of mammal predators on bird communities.

ACKNOWLEDGEMENTS

This study was supported by the Polish Committee for Scientific Research (grant No. 2 P04F 06428). We thank Paweł Banaszak who counted birds on the points. We are grateful to Drs. Katarzyna Biała, Marek Panek, and Prof. Piotr

Tryjanowski for their helpful critical comments on earlier versions of the paper, and to anonymous reviewers for valuable comments, which markedly contributed to the improvement of statistical analysis and discussion. We also acknowledge the help of Sylwia Ufnalska, MSc, MA, who corrected our English and made some useful suggestions. Mrs. Sylwia Sobczyk from our Research Centre helped in field work and in elaboration of gathered data.

REFERENCES

- Bibby C. J., Burgess N. D., Hill D. A. 1992. Bird Census Techniques. Academic Press, London.
- Blanco J. C. 1986. On the diet, size and use of home range and activity patterns of a red fox in Central Spain. *Acta Theriol.* 31: 547–556.
- Crick H. Q. P., Dudley C., Evans A. D. 1994. Causes of nest failure among buntings in the UK. *Bird Study* 41: 88–94.
- Dickman C. R. 1996. Overview of the impact of feral cats on Australian native fauna. Australian Nature Conservation Agency. Canberra.
- Evans K. L. 2004. The potential for interactions between predation and habitat change to cause population declines of farmland birds. *Ibis* 146: 1–13.
- Geer T. A. 1978. Effects of nesting sparrowhawks on nesting tits. *Condor* 80: 419–422.
- Gloor S., Bontadina E., Hegglin D., Deplazes, P., Breitenmoser U. 2001. The rise of urban fox populations in Switzerland. *Mammalian Biology* 66: 155–164.
- Goldyn B. 2001. The dynamics and distribution of the red fox population and its influence on farmland bird community. MSc thesis, Adam Mickiewicz University, Poznań.
- Goldyn B., Hromada M., Surmacki A., Tryjanowski P. 2003. Habitat selection and diet of the red fox *Vulpes vulpes* in an agricultural landscape in Poland. *Z. Jagdwiss.* 49: 191–200.
- Goszczyński J. 1974. Studies on the food of foxes. *Acta Theriol.* 21: 527–534.
- Goszczyński J. 1985. The effect of structural differentiation of ecological landscape on the predator-prey interaction. *Rozprawy naukowe i monografie SGGW-AR* 46: 1–80.
- Goszczyński J. 1995. [Fox]. *Oikos*, Warszawa.
- Harris S. 1977. Distribution, habitat utilization and age structure of a suburban fox (*Vulpes vulpes*) population. *Mammal Review* 7: 25–39.
- IUCN 2007. *Vulpes vulpes*. In: IUCN 2007. European Mammal Assessment <http://ec.europa.eu/environment/nature/conservation/species/ema/>. Downloaded on 11 May 2007.
- Korpimäki E., Norrdahl K. 1989a. Avian predation on mustelids in Europe 1: occurrence and effects on body size variation and life traits. *Oikos* 55: 205–215.
- Korpimäki E., Norrdahl K. 1989b. Avian predation on mustelids in Europe 2: impact on small mustelids and microtine dynamics — a hypothesis. *Oikos* 55: 273–276.
- Kožena I. 1988. Diet of the red fox (*Vulpes vulpes* L.) in agrocenoses in southern Moravia. *Acta Sci. Nat. Brno* 22: 1–24.
- Kujawa K. 1994. Influence of land-use change within agricultural landscapes on the abundance and diversity of breeding bird communities. In: Ryszkowski L., Bałazy S. (eds). *Functional Appraisal of Agricultural Landscapes in Europe (EUROMAB and INTECOL Seminar)*. ZBSRIL PAN, Poznań, pp. 183–196.

- Kujawa K. 1997. Relationships between the structure of mid-field woods and their breeding bird communities. *Acta Ornithol.* 32: 175–184.
- Kujawa K. 2000. [Avifauna of Dezydery Chłapowski Landscape Park]. In: Winięcki A. (ed.). [Birds of the Landscape Park in Wielkopolska]. *Wielkopolskie Prace Ornitologiczne* 9: 89–121.
- Kujawa K. 2002. Population density and species composition changes for breeding bird species in farmland woodlots in western Poland between 1964 and 1994. *Agric. Ecos. Envir.* 91, 1–3: 261–271.
- Kujawa K. 2006. [Effect of afforestation and agricultural landscape structure on breeding bird communities in afforestations]. *Rozpr. nauk. AR im. A. Cieszkowskiego* 381. Poznań.
- Kujawa K., Tryjanowski P. 2000. Relationships between the abundance of breeding birds in Western Poland and the structure of agricultural landscape. *Acta Zool. Hung.* 46: 103–114.
- Macdonald D. W., Newdick M. T. 1982. The distribution and ecology of foxes, *Vulpes vulpes* (L.), in urban areas. In: Bornkamm R., Lee J. A., Seaward M. R. D. (eds). *Urban ecology*. Blackwell Scientific Publications, Oxford, pp. 123–135.
- Newton I. 1998. *Population limitation in Birds*. Academic Press Ltd., London.
- Norrdahl K., Korpimäki E. 1998. Fear in farmland: how much does predator avoidance affect bird community structure? *J. Avian Biol.* 29: 79–85.
- O'Connor R. J., Shrubbs M. 1986. *Farming and birds*. Cambridge Univ. Press, Cambridge.
- Panek M. 2002. Space use, nesting sites and breeding success of grey partridge (*Perdix perdix*) in two agricultural management systems in western Poland. *Game Wildl. Sci.* 19: 313–326.
- Panek M. 2005. Demography of grey partridges *Perdix perdix* in Poland in the years 1991–2004: reasons for population decline. *Eur. J. Wildlife Res.* 51: 14–18.
- Panek M., Bresiński W. 2002. Red fox *Vulpes vulpes* density and habitat use in a rural area of western Poland in the end of 1990s compared with turn of 1970s. *Acta Theriol.* 47: 433–442.
- Ryszkowski L. 1982. Structure and function of the mammal community in an agricultural landscape. *Acta Zool. Fenn.* 169: 45–59.
- Ryszkowski L., Goszczyński J., Truszkowski J. 1973. Trophic relationship of the common vole in cultivated fields. *Acta Theriol.* 18: 125–165.
- Ryszkowski L., Wagner C. K., Goszczyński J., Truszkowski J. 1971. Operation of predators in a forest and cultivated fields. *Ann Zool. Fenn.* 8: 160–169.
- Stubbe M. 1999. *Vulpes vulpes*. In: Mitchell-Jones A. J., Amori G., Bogdanowicz W., Krystufek B., Reijnders P. J. H., Spitzenberger F., Stubbe M., Thissen J. B. M., Vohralík J., Zima J. (eds). *The Atlas of European Mammals*. Academic Press, London.
- Suhonen J., Norrdahl K., Korpimäki E. 1994. Avian predation risk modifies breeding bird community on a farmland area. *Ecology* 75: 1626–1634.
- Tapper S. 1992. Game heritage — an ecological review from shooting and gamekeeping records. *Game Conservancy Ltd., Fordingbridge*.
- Thomson D. L., Green R. E., Gregory R., Baillie S. R. 1998. The widespread declines of songbirds in rural Britain do not correlate with the spread of their avian predators. *Proc. Royal Soc. London B* 265: 2057–2062.
- Tryjanowski P. 2000. Changes in breeding bird populations of some farmland birds in W Poland in relation to change in crop structure, weather conditions and number of predators. *Folia Zool.* 49: 305–315.
- Tryjanowski P., Gołdyn B., Surmacki A. 2002. Influence of red fox (*Vulpes vulpes*, Linnaeus 1758) on the distribution and number of breeding birds in an intensively used farmland. *Ecol. Res.* 17: 395–399.
- Wesołowski T., Tomiałojć L., Stawarczyk T. 1987. Why low numbers of *Parus major* in Białowieża Forest — removal experiments. *Acta Ornithol.* 23: 303–316.

STRESZCZENIE

[Czy lis wpływa negatywnie na bogactwo gatunkowe awifauny terenów rolniczych?]

Liczebność populacji lisa w Europie, w tym także w Polsce, rośnie od lat siedemdziesiątych. Jednocześnie obserwuje się coraz liczniejsze jego występowanie w małych zadrzewieniach śródpolnych i na polach uprawnych nawet z dala od lasu. Celem badań było sprawdzenie prawdziwości tezy, że lis negatywnie wpływa na zagęszczenie i różnorodność ptaków krajobrazu rolniczego. Badania prowadzono na terenie Parku Krajobrazowego im. gen. Dezyderego Chłapowskiego. Przyjęto, że presja lisa jest największa blisko nor (< 600 m). Założono także, że różni się ona pomiędzy grupami gniazdowymi: jest znacząca dla gatunków budujących gniazda na ziemi i nisko nad ziemią (oznaczonych łącznie jako EG) i słaba w grupie dziuplaków oraz gatunków, których gniazda umieszczane są wysoko (wspólnie oznaczonych jako NG) (zob. Appendix I). Testowano trzy hipotezy: 1) liczba gatunków i zagęszczenie ptaków EG powinny być niższe w zadrzewieniach z czynnymi norami, niż w zadrzewieniach bez takich nor, przy braku takiej zależności dla ptaków NG, 2) zagęszczenie ptaków na polach uprawnych (występują tam wyłącznie gatunki z grupy EG) powinno zwiększać się wraz ze wzrostem odległości od czynnych nor, 3) zagęszczenie ptaków EG w danym zadrzewieniu powinno być niższe w latach, w których zadrzewienie jest zasiedlone przez lisy, przy braku takich różnic w grupie ptaków NG. W celu zweryfikowania tych hipotez skład gatunkowy oraz zagęszczenie populacji ptaków badano: w latach 1999–2000 oraz 2005–2007 — metodą kartograficzną w zadrzewieniach (n = 70) z czynnymi norami i bez takich nor, w latach 2005–2006 — na transektach (n = 27) położonych na polach uprawnych, i w roku 2007 — na terenach uprawnych wokół 34 punktów położonych przy norach i z dala (> 700m) od nich. Status nor oceniano na podstawie obserwacji prowadzonych od marca do czerwca, podczas których zbierano informacje

o tropach i innych śladach obecności lisów, w tym młodych. Zgrupowanie ptaków lęgowych w zadrzewieniach składało się z 54 gatunków, średnie zagęszczenie ptaków wynosiło 115 par/10 ha (Appendix I), a liczba gatunków w zadrzewieniach wynosiła od 1 do 18 (średnio 7–7.5). Lisy zakładały nory w zadrzewieniach bez żadnych wyraźnych preferencji siedliskowych. Aby przetestować hipotezę (1), najpierw za pomocą modelu regresji krokowej oceniono, jaka część zmienności awifauny zadrzewień zależy od struktury środowiska (Tab. 1). Reszty tego modelu (jego szczegóły — zob. Appendix II) zarówno w odniesieniu do liczby gatunków, jak i zagęszczenia, w żaden sposób nie zależały od obecności nor lisa, grupy gniazdowej, a także roku (Tab. 2). Różnice w liczbie gatunków i zagęszczeniu ptaków między zadrzewieniami z norami i bez nor były podobne dla obu grup gatunków, czyli EG i NG (Fig. 1a, 1b). Hipoteza (2): na polach uprawnych w początkowym okresie sezonu lęgowego zagęszczenie ptaków nie było istotnie statystycznie związane z odległością od nor ($|r| < 0.4$, $p > 0.3$). Dotyczyło to zarówno całego zgrupowa-

nia (Fig. 2a), jak i gatunków dominujących — skowronka i pliszki żółtej (Fig. 2b). Przeciwnie do oczekiwań, pod koniec sezonu lęgowego zagęszczenie łączne ptaków było skorelowane z odległością od nor ujemnie ($r = -0.36$, $p < 0.001$), przy nieistotnych zależnościach dla skowronka ($r = -0.36$, $p > 0.1$) i pliszki żółtej ($r = -0.41$, $p > 0.8$) (Fig. 2b). Również różnice w zagęszczeniu ptaków w sąsiedztwie nor (0.9 par/punkt) i z dala od nich (0.7 par/punkt) ocenianym za pomocą metody punktowej były nieistotne statystycznie (test U, $p > 0.4$). Hipoteza (3): różnice w liczbie gatunków i zagęszczeniu ptaków w danych zadrzewieniach między latami z czynnymi norami a latami bez takich nor były nieistotne statystycznie zarówno dla gatunków EG, jak i NG (Tab. 3). Wyniki badań nie potwierdziły zatem żadnej z testowanych hipotezi świadczą o tym, że wpływ lisa na zdecydowaną większość gatunków występujących w krajobrazie rolniczym jest znikomy. Tym samym opinie o dużym negatywnym znaczeniu lisa dla różnorodności awifauny terenów uprawnych nie znalazły potwierdzenia.

Appendix I. Composition of the breeding bird community of studied forest islands. Density in pairs/10ha. Nest location: H — high, G — ground, L — low, TH — tree holes. G, L — nesting groups exposed to Red Fox pressure, TH, H — groups non-affected by Red Fox.

Species	Nest	Density	Species	Nest	Density
<i>Fringilla coelebs</i>	H	24.6	<i>Buteo buteo</i>	H	0.5
<i>Emberiza citrinella</i>	G	14.8	<i>Erithacus rubecula</i>	G	0.5
<i>Sylvia atricapilla</i>	L	14.3	<i>Sylvia communis</i>	L	0.4
<i>Parus major</i>	TH	7.5	<i>Ficedula hypoleuca</i>	TH	0.4
<i>Luscinia megarhynchos</i>	G	5.5	<i>Corvus corone cornix</i>	H	0.3
<i>Turdus merula</i>	H	5.0	<i>Garrulus glandarius</i>	H	0.3
<i>Hippolais icterina</i>	H	4.7	<i>Lanius excubitor</i>	H	0.3
<i>Sturnus vulgaris</i>	TH	4.3	<i>Coccothraustes. coccothraustes</i>	H	0.2
<i>Phylloscopus collybita</i>	G	3.8	<i>Parus palustris</i>	TH	0.2
<i>Passer montanus</i>	TH	3.7	<i>Sylvia curruca</i>	L	0.2
<i>Cyanistes caeruleus</i>	TH	3.0	<i>Acrocephalus scirpaceus</i>	L	0.1
<i>Emberiza hortulana</i>	G	2.8	<i>Dryocopus martius</i>	TH	0.1
<i>Muscicapa striata</i>	TH	2.5	<i>Serinus serinus</i>	H	0.1
<i>Turdus philomelos</i>	H	1.6	<i>Turdus pilaris</i>	H	0.1
<i>Miliaria calandra</i>	G	1.5	<i>Aegithalos caudatus</i>	H	0.1
<i>Certhia brachydactyla</i>	TH	1.3	<i>Corvus corax</i>	H	0.1
<i>Carduelis carduelis</i>	H	1.2	<i>Gallinula chloropus</i>	G	0.1
<i>Dendrocopos major</i>	TH	1.2	<i>Jynx torquilla</i>	TH	0.1
<i>Anthus trivialis</i>	G	1.0	<i>Luscinia luscinia</i>	G	0.1
<i>Lanius collurio</i>	H	1.0	<i>Certhia familiaris</i>	TH	0.1
<i>Phylloscopus trochilus</i>	G	1.0	<i>Periparus montanus</i>	TH	0.1
<i>Carduelis chloris</i>	H	0.9	<i>Passer domesticus</i>	TH	0.1
<i>Oriolus oriolus</i>	H	0.9	<i>Phylloscopus sibilatrix</i>	G	0.1
<i>Acrocephalus palustris</i>	L	0.8	<i>Pica pica</i>	H	0.1
<i>Sitta europaea</i>	TH	0.8	<i>Streptopelia decaocto</i>	H	0.1
<i>Columba palumbus</i>	H	0.7	<i>Streptopelia turtur</i>	H	0.1
<i>Sylvia borin</i>	L	0.6	<i>Sylvia nisoria</i>	L	0.1
			Total		116.2

Appendix II. Statistics for “vegetation model”: results of stepwise multiple regression of bird species number on wood island structure in 2005–2006. For explanation of the terms: “high”, “tree holes”, “low”, “ground”, and variables (AREA, HERB etc.) — see Methods and Table 1, df — degrees of freedom, SE — standard error, significance: ns — $p > 0.05$, * — $p < 0.05$, ** — $p < 0.01$, *** — $p < 0.001$.

	Beta	SE (Beta)	t	p
		High 2005: $R^2 = 0.26$, $F_{(1,67)} = 23.8^{***}$		
Constant			15.06	***
AREA	0.51	0.10	4.88	***
		High 2006: $R^2 = 0.45$, $F_{(3,53)} = 16.4^{***}$		
Constant			4.14	***
AREA	0.49	0.10	4.76	***
TREE_2	0.36	0.10	3.50	***
SHRUB	0.23	0.10	2.26	*
		High 2007: $R^2 = 0.41$, $F_{(3,48)} = 13.0^{***}$		
Constant			4.86	***
TREE_2	0.47	0.11	4.39	***
AREA	0.42	0.11	3.81	***
TREE	-0.25	0.11	-2.26	*
		Tree holes 2005: $R^2 = 0.16$, $F_{(3,65)} = 5.3^{**}$		
Constant			2.38	*
AREA	0.55	0.10	5.42	***
STAND	0.22	0.10	2.23	*
		Tree holes 2006: $R^2 = 0.42$, $F_{(3,53)} = 14.4^{***}$		
Constant			0.88	ns
AREA	0.52	0.10	4.96	***
SHAPE	0.30	0.10	2.94	**
SHANNON	0.27	0.10	2.55	*
		Tree holes 2007: $R^2 = 0.38$, $F_{(3,48)} = 11.3^{**}$		
Constant			0.53	ns
AREA	0.48	0.12	4.12	***
SHAPE	0.33	0.11	2.99	**
SHANNON	0.26	0.11	2.67	*
		Low 2005: $R^2 = 0.29$, $F_{(3,65)} = 10.2^{***}$		
Constant			1.84	ns
WATER	0.31	0.11	2.90	**
AREA	0.38	0.11	3.69	***
STAND	0.23	0.11	2.14	*
		Low 2006: $R^2 = 0.14$, $F_{(2,54)} = 5.6^{**}$		
Constant			1.61	ns
WATER	0.27	0.13	2.16	*
TREE_2	0.26	0.13	2.04	*
		Low 2007: $R^2 = 0.36$, $F_{(3,48)} = 10.5^{***}$		
Constant			3.11	**
AREA	0.38	0.11	3.36	**
TREE_2	0.30	0.11	2.60	*
WATER	0.29	0.11	2.53	*
		Ground 2005: $R^2 = 0.25$, $F_{(2,54)} = 10.5^{***}$		
Constant			7.41	***
AREA	0.52	0.12	4.42	***
TREE_1	-0.25	0.12	-2.11	*
		Ground 2006: $R^2 = 0.27$, $F_{(1,67)} = 25.6^{***}$		
Constant			15.17	***
AREA	0.53	0.10	5.06	***
		Low 2007: $R^2 = 0.32$, $F_{(2,49)} = 13.13^{***}$		
Constant			6.88	***
AREA	0.51	0.12	4.42	***
TREE_2	0.27	0.12	2.34	*

Appendix III. Statistics for “vegetation model”: results of stepwise multiple regression of bird density on wood island structure in 2005–2006. For explanation of the terms: “high”, “tree holes”, “low”, “ground” and variables (AREA, HERB etc.) — see Methods and Table 1, df — degrees of freedom, SE — standard error, significance: ns — $p > 0.05$, * — $p < 0.05$, ** — $p < 0.01$, *** — $p < 0.001$.

	Beta	SE (Beta)	df (65)	p
			High 2005: $R^2 = 0.36$, $F_{(3,65)} = 13.7$ ***	
Constant			5.23	***
AREA	-0.52	0.10	-5.14	***
HERB	-0.37	0.10	-3.76	***
SHAPE	0.21	0.10	2.15	*
			High 2006: $R^2 = 0.46$, $F_{(4,52)} = 12.8$ ***	
Constant			3.96	***
AREA	-0.58	0.10	-5.73	***
HERB	-0.34	0.10	-3.37	**
SHAPE	0.26	0.10	2.64	*
WATER	0.21	0.10	2.06	*
			High 2007: $R^2 = 0.57$, $F_{(4,47)} = 18.9$ ***	
Constans			1.76	ns
AREA	-0.62	0.09	-6.62	***
TREE_2	0.28	0.10	2.91	**
SHAPE	0.28	0.09	2.97	**
HERB	-0.21	0.10	-2.18	*
			Tree holes 2005: $R^2 = 0.16$, $F_{(3,65)} = 5.3$ **	
Constant			1.96	ns
STAND	0.29	0.11	2.55	*
AREA	-0.30	0.11	-2.65	*
HERB	-0.27	0.12	-2.37	*
			Tree holes 2006: $R^2 = 0.24$, $F_{(2,54)} = 9.8$ ***	
Constant			-1.68	ns
SHAPE	0.41	0.12	3.43	**
STAND	0.25	0.12	2.15	*
			Tree holes 2007: $R^2 = 0.17$, $F_{(2,49)} = 6.1$ **	
Constant			-0.06	ns
SHAPE	0.32	0.13	2.49	*
AREA	-0.27	0.13	-2.08	*
			Low 2005: $R^2 = 0.13$, $F_{(2,66)} = 6.0$ **	
Constant			-0.25	ns
STAND	0.30	0.11	2.67	**
TREE_2	0.23	0.11	2.07	*
			Low 2006: $R^2 = 0.22$, $F_{(3,53)} = 6.2$ **	
Constant			-0.32	ns
AREA	-0.38	0.12	-3.17	**
WATER	0.28	0.12	2.30	*
TREE_2	0.26	0.12	2.13	*
			Low 2007: $R^2 = 0.28$, $F_{(3,48)} = 7.6$ **	
Constant			0.08	ns
TREE_2	0.37	0.12	3.04	**
WATER	0.33	0.12	2.67	*
AREA	-0.27	0.12	-2.22	*
			Ground 2005: $R^2 = 0.19$, $F_{(1,67)} = 17.4$ ***	
Constant			7.63	***
AREA	-0.45	0.11	-4.17	***
			Ground 2006: $R^2 = 0.31$, $F_{(3,53)} = 9.2$ ***	
Constant			4.04	***
SHRUB	0.35	0.11	3.10	**
AREA	-0.30	0.11	-2.62	*
TREE_1	-0.25	0.11	-2.19	*
			Ground 2007: $R^2 = 0.15$, $F_{(1,50)} = 9.7$ **	
Constant			8.02	***
AREA	-0.40	0.23	-3.12	**