Ann. Zool. Fennici 47: 67–78 ISSN 0003-455X (print), ISSN 1797-2450 (online)
Helsinki 10 March 2010

A large scale survey of the great grey shrike *Lanius excubitor* in Poland: breeding densities, habitat use and population trends

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Received 8 Apr. 2008, revised version received 9 Feb. 2010, accepted 15 Apr. 2009

Kuczyński, L., Antczak, M., Czechowski, P., Grzybek, J., Jerzak, L., Zabłocki, P. & Tryjanowski, P. 2010: A large scale survey of the great grey shrike *Lanius excubitor* in Poland: breeding densities, habitat use and population trends. — *Ann. Zool. Fennici* 47: 67–78.

The great grey shrike *Lanius excubitor* is declining in western Europe but relatively stable, or even increasing populations still exist in central and eastern Europe. It is a medium-sized passerine living in diverse, low-intensity farmland. Being a predatory bird, it is especially susceptible to any changes in farming practices that affect its prey. In this paper, we provide estimates of density, national population size and trends and generate a habitat-use model; information which is all necessary for effective conservation. We used data gathered during 71 censuses made in the years 1978–2005 to document the past and present status of the great grey shrike population in Poland. The mean population density has more than doubled from 4.5 in the early period of the study (1978–1995) to 11.3 pairs/100 km^2 in the later period (1996–2005). The habitat use model shows that the great grey shrike avoids intensive arable fields and coniferous forests and prefers areas of extensively used farmland. We estimate the current size of the Polish breeding population to be 22 000–25 000 breeding pairs. Our results show that the Polish breeding population of the great grey shrike is still healthy. This can be attributed to high habitat heterogeneity and fragmentation, a slow rate of change in agricultural landscapes and recent mild winters which have had a positive effect on survival. We believe that our results can help to establish an effective conservation strategy for the species.

Introduction

Detailed and reliable data on trends, densities and population size are crucial for successful management and conservation. Of particular importance is the need for data on species which are considered to be indicators of overall environment health. The largest European shrike species, the predatory great grey shrike *Lanius excubitor* is undoubtedly such a "focal" species. Its numbers are limited by the availability of large areas of a threatened and rapidly disappearing ecosystem, i.e. diverse, low-intensity cultivated farmland (Yosef 1994, Harris & Franklin 2000).

Recently, conservationists, especially those in western Europe, have paid a lot of attention to this species because its population decreased markedly during the past decade (Tucker *et al*. 1994, Bassin 1995, Bechet 1995, Rothhaupt 1995, Schön 1995). Changes in land use, deterioration of breeding habitats and subsequent decreases in prey were suggested to be responsible for the dramatic decline (Tucker *et al*. 1994, Schön 1995, Lefranc & Worfolk 1997, Harris & Franklin 2000). As a consequence, several distribution gaps have appeared within the breeding range of this species (Hagemeijer & Blair 1997). For this reason, the great grey shrike received the status of a declining species in Europe (Tucker *et al*. 1994).

The effective application of protection policies requires precise and reliable data on population densities, trends and habitat use (for shrike examples *see* Chabot *et al*. 2001, Jobin *et al*. 2005). The great grey shrike is a predatory species and occurs at low densities relative to small passerines. Therefore, data collected during bird counts on small sample plots, such as national bird-monitoring schemes, do not provide reliable information on the species density, habitat use or distribution. Moreover, due to the secretive biology of the great grey shrike, only data from well studied plots using a specific counting methodology give accurate results (Tryjanowski *et al*. 2003). Fortunately, the great grey shrike is perceived as a charismatic species and many birdwatchers and ornithologists have surveyed local populations using standard methodology (but *see* remarks in Tryjanowski *et al*. 2003). To date, many such surveys have been done, giving a unique opportunity to compare recent results with older ones. With such a large database we can draw conclusions about habitat use, population density and density changes over a wide temporal and geographical range.

The goals of this study were two fold: (1) to provide reliable data on the breeding density, spatial variability and size of the Polish national population, and (2) to describe habitat use and discuss the factors which may be responsible for population changes.

Material

Bird data

All study plots were located in extensively used farmland in Poland. We analysed data from 71 censuses made on 32 plots during the years 1978–2005. Altogether over 5000 km^2 was censused, equating to 1.6% of the total country. Information on data used in this analysis is summarised in the Appendix.

Habitat data

Land cover information was derived from the Corine (Coordination of Information on the Environment) Land Cover 2000 database (CLC2000) produced by the European Environmental Agency (EEA). The database was created by photo-interpretation of satellite images obtained during the years 1999–2001 from Landsat 7 ETM+ (IMAGE2000 project). Data are distributed as country coverages in vector format and national projections. According to CLC specifications (Bielecka & Ciołkosz 2004, Nunes de Lima 2005), the spatial accuracy is better than 100 m; the minimum area of any land-cover polygon is 25 ha. Thematic accuracy is about 85%. At "level 3", there are 44 land cover classes, of which 31 occur in Poland. Only 12 classes with an area of at least 1 km^2 were included in the analysis.

The proportional cover of each habitat class was calculated for each study plot. The extraction was done using IDRISI Andes (Eastman 2006), a raster GIS (geographic information system) package.

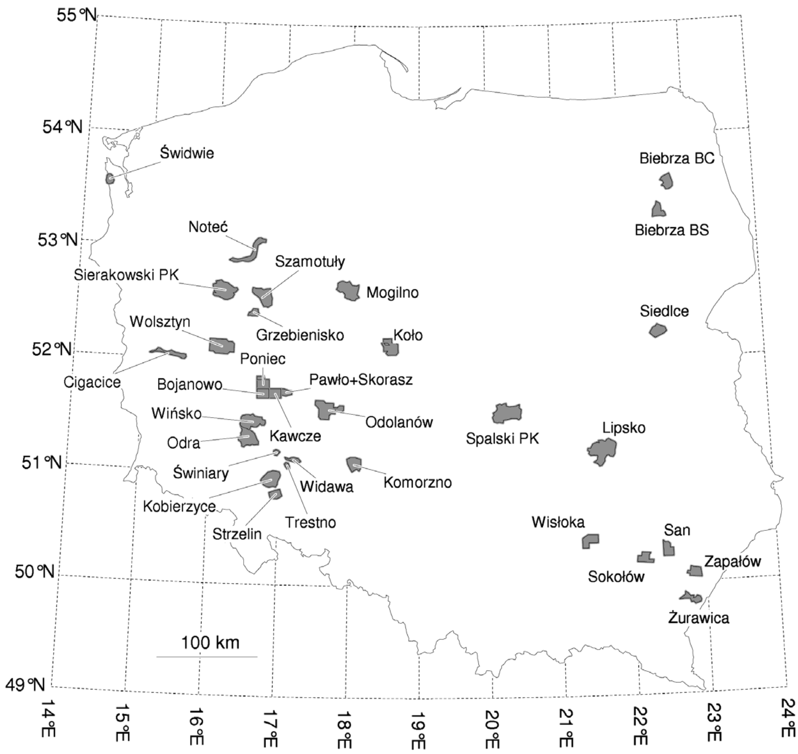

Fig. 1. Location of the study plots.

Digital elevation data

We used the digital elevation model dataset (GTOPO30) provided by the U.S. Geological Survey's EROS Data Center in Sioux Falls, South Dakota. The data were converted into the IDRISI file format by Clark Labs (Global DEM dataset). Elevations in GTOPO30 are regularly spaced at 30-arc seconds, which in Poland corresponds approximately to a 1-km resolution. Data were spatially queried and reprojected to the projection "Poland CS92" (EPSG 2180).

Study plots

The dominant landscape of the study plots was agricultural; dominated by arable fields (52% of the total area) and large pastures (12%). The mean cover of forests across study plots was 21%. Other habitat classes present were: complex cultivation patterns, extensive agriculture with natural elements and marshes (total: 10%). Human settlement accounted for 2% of the total study area.

The spatial distribution of the study plots (Fig. 1), as well the habitats present in them, were not representative of the whole country since the study plots were frequently established in areas with a high density of great grey shrikes. The habitat structure within the study plots was significantly different from the rest of Poland (Kolmogorov-Smirnov test = 0.25, $p > 0.8$; Fig. 2). For these reasons, we were unable to produce distribution maps and have limited scope to extrapolate our conclusions to certain types of landscape.

Methods

Field methods

Great grey shrikes were always censused from March to June. Territories were classified as occupied on the basis of territorial and breeding behaviour as well as the detection of nests. Observed bird locations were recorded on maps along with notes on territorial behaviour, hunting strategy, habitat selection and especially the

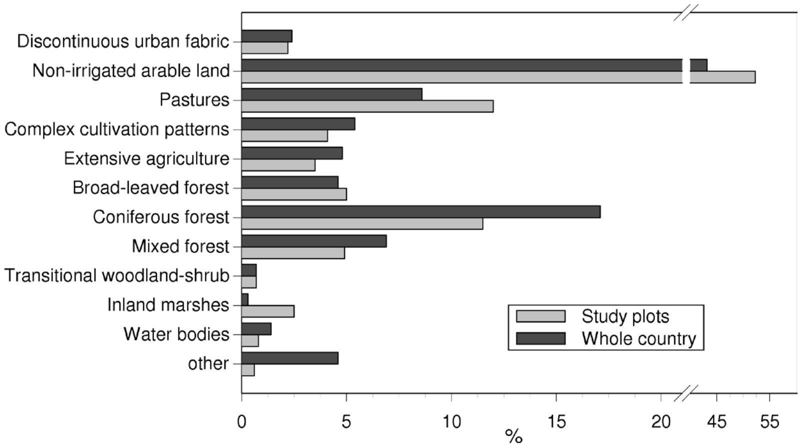

Fig. 2. Comparison of proportions of Corine Land Cover classes in Poland with those in the study plots.

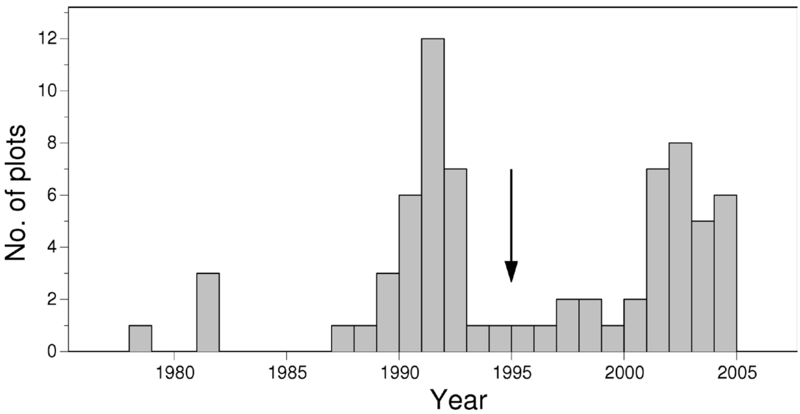

Fig. 3. The number of censuses taken over time. The arrow denotes the division between "recent" and "early" periods.

presence of nests. This method guarantees a high level of detection of breeding shrikes and gives reliable estimates of the population size (for further details *see* Tryjanowski *et al*. 2003).

Data treatment and analysis

The censuses were divided into two roughly equal groups based on date: "early" (1978 to 1995) and "recent" (1996 to 2005) (Fig. 3).

Population density

Confidence intervals for densities were computed using the bootstrap method (Efron & Tibshirani 1993). Spatial trends in densities were assessed by fitting a local trend surface using a locally-weighted regression (Cleveland & Devlin 1988). Only the plots surveyed in the "recent" period were used in this analysis (n = 34). Residuals from the spatial trend analysis were subsequently used for testing habitat use.

Habitat use

Corine Land Cover data used in this analysis were collected in the years 1999–2001. To match temporal boundaries of bird data to the land cover information, habitat use analysis was performed using the data from the 34 recent studies (i.e. those conducted between 1995 and 2005). The explanatory variables were principal components extracted from percentages of land cover classes within each study plot. PCA was used in order to remove strong intercorrelations inherently present within the explanatory dataset. Another advantage of this technique is data reduction, which is extremely important in the case of small sample size and a large number of predictors. Four principal components were extracted, explaining more than 90% of the total variance (Table 1).

A Generalized Additive Model (GAM) was used to fit resource selection functions (Hastie & Tibshirani 1990). The response was the residual density (RD): the difference between the observed density and the one predicted by the spatial loess model (locally weighted regression) (Fig. 4). RD represents the variation in population density not explained by spatial trends itself. Predictors were: digital elevation and four habitat variables extracted by PCA. The most parsimonious model was selected using the Akaike information criterion (AIC; step.gam function in S-PLUS 7.0; Insightful 2005), from options excluding each predictor, linearizing it or including it as a polynomial spline with 4 degrees of freedom (Hastie & Tibshirani 1990, Burnham & Anderson 2002). Cases were weighted by the plot size (expressed in hundreds of km^2). A Gaussian distribution of errors and an identity link function were applied. As a measure of deviance reduction, the D^2 coefficient was used (Weisberg 1980), which is equivalent to R^2, well known from a least squares estimation.

Spatial autocorrelation

A spatial autocorrelation was examined by computing spatial correlograms using Moran's *I* coefficient. Correlograms were computed for raw densities, for residual densities after trend removal, as well as for residuals from the habitat use model.

Population trends

To visualise population dynamics, the locally-weighted running-line regression (Cleveland & Devlin 1988) was fitted to the raw densities using time as a predictor. Goodness of fit was tested using the R^2 statistics. Its significance was assessed by comparing its value with values obtained by permutation (Monte Carlo simulation). The dependent variable (population density) was randomly shuffled, then the loess model was fitted to the random data and R^2 was computed. This procedure was repeated 10 000 times, forming the empirical distribution of the test statistic under the null hypothesis of no trend. Then, the probability of obtaining the value of a test statistic greater or equal to that obtained from data was calculated.

For computing trends and density comparisons only data from 37 study plots which were surveyed in both study periods were used; these plots each had 2–7 estimates of great grey shrike population size. The time gaps between counts in the "recent" and "early" periods were always more than 8 years (mean = 15.0, 95%CI = 12.2–17.6). As a trend measure we used the slope of the line fitted to the density data *vs*. time. This index (density change rate = DCR) expresses

Table 1. PCA loadings of Corine Land Cover (CLC) variables.

CLC class	Comp.1	Comp.2	Comp.3	Comp.4
Discontinuous urban fabric	–0.01	0.09	–0.02	–0.23
Non-irrigated arable land	–0.79	–0.51	0.01	0.14
Pasture	0.05	0.24	0.84	0.30
Complex cultivation patterns	–0.02	0.15	–0.09	–0.50
Land principally occupied by agriculture, with significant areas of natural vegetation	0.00	0.14	–0.05	–0.42
Broad-leaved forest	0.03	0.20	–0.18	0.36
Coniferous forest	0.60	–0.73	0.01	0.06
Mixed forest	0.07	0.25	–0.50	0.52
Transitional woodland-shrub	0.03	0.00	0.00	–0.03
Inland marshes	0.00	0.02	0.03	0.01
Water bodies	0.02	0.04	–0.02	–0.03
Percentage of variance explained	65.5	14.6	7.0	3.8

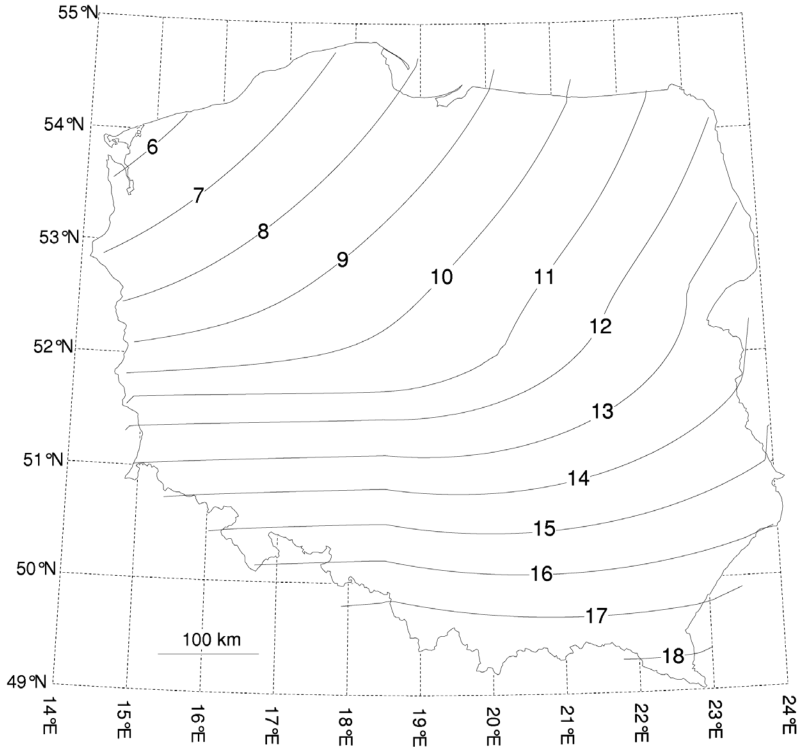

Fig. 4. Two-dimensional population density trends. Function loess is fitted to the raw densities (no. of pairs per 100 km²).

the mean yearly change in number of territories per 100 km². Confidence intervals for DCR were computed using the bootstrap method (Efron & Tibshirani 1993).

Results

Population density

The mean density computed using the data from all study plots was 7.5 pairs/100 km² (95%CI = 5.4–9.1, n = 71). In the "early" period the mean density was 4.5 breeding pairs (95%CI = 3.0–6.2, n = 37) and during the "recent" period 11.3 breeding pairs (95%CI = 9.2–13.0, n = 34). Confidence intervals for these estimates do not overlap, so they can be regarded as statistically different.

After the Bonferroni correction a significant spatial autocorrelation in the density of the great grey shrike was revealed. The highest autocorrelation occurred in the first distance class (< 50 km, $r = 0.54$, $p < 0.01$). Spatial autocorrelation in the residuals was reduced to a non-significant level after trend removal.

The spatial trend, assessed by the fit of the loess model to geographic coordinates, was weak (it was responsible for 19% of the variance in densities), but it effectively removed spatial autocorrelation (Fig. 4).

Habitat use

The original data on land cover was summarised using PCA (Table 1). The first principal component (Comp.1) primarily related to the proportion of area covered by forests in contrast to arable fields. High values of this component are indicative of sites with a strong dominance of forest (mainly coniferous) and a small percentage of arable fields. The second component (Comp.2) was positively correlated with extensive agriculture (pastures, heterogeneous farmland habitats) and mixed and deciduous forests. The high values of this component indicated valuable and semi-natural areas with a high level of landscape heterogeneity. In contrast, low values of this component were typical of intensive farmland and coniferous forest plantations.

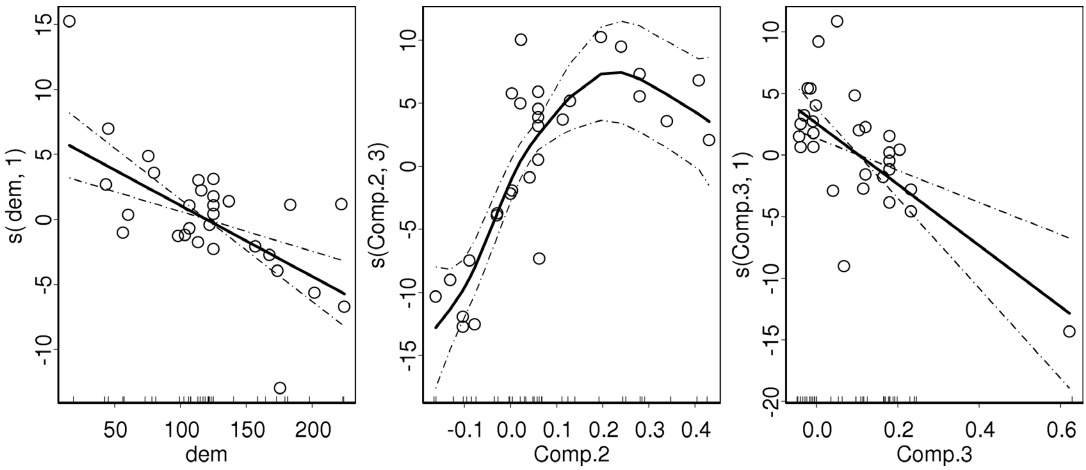

Fig. 5. GAM fit to Residual Density. The dashed lines represent standard error bands of the estimated curves. The values fitted are partial residuals.

The third component reflected the proportion of pastures and other land classes, especially deciduous and mixed forests. High values of the fourth component (Comp.4) were characteristic of areas with a high coverage of arable fields, pastures and forests. Low values of this component indicated areas with scattered human settlements and less farming.

The most parsimonious model of the GAM fit to the residual density (RD) included the smooth fit to Comp.2 and linear fits to DEM and Comp.3 (Fig. 5). The overall fit of this model, measured by D^2 was 70%. The most important factor was Comp.2 ($F = 11.6$, $p < 0.001$), revealing a unimodal shape of the response function with the maximum corresponding to positive values of this axis. Comp.2 measures the amount of habitat types other than arable fields and coniferous forests (which are the dominant land cover classes in Poland). This suggests that the great grey shrike avoids these habitats and prefers areas of extensively used farmland, dominated by pastures, complex cultivation patterns and patches of scattered fields with elements of natural vegetation. This component also positively correlates with the amount of deciduous and mixed forests. However, there is an optimum to this function, suggesting that too much deciduous forest is avoided.

The second important variable selected was elevation ($F = 1.4$, $p < 0.001$). The great grey shrike prefers lowlands and its density decreases at higher elevations. The last variable was Comp.3 ($F = 0.7$, $p < 0.03$), which reflects the amount of pasture comparing to other habitats. Densities of the great grey shrike are lower at sites dominated by pasture.

Population trends

The population of the great grey shrike has increased since the late 1980s (Fig. 6). The mean DCR (density change rate) was 0.44 territories per 100 km^2 per year (95%CI = 0.09–0.75). The confidence interval does not include zero, so the trend can be regarded as significant.

Discussion

Breeding densities and population trends

According to the Polish Breeding Bird Atlas (Sikora *et al*. 2007) and other information (Lorek 1995, Tomiałojć & Stawarczyk 2003) the great grey shrike breeds throughout Poland. However, it is less abundant in the mountains, in the north-east, south-east and central areas.

It is very difficult to estimate the size of the national breeding population since the data used in the present analysis are opportunistic and do not originate from a representative and properly designed survey. However, some approximate

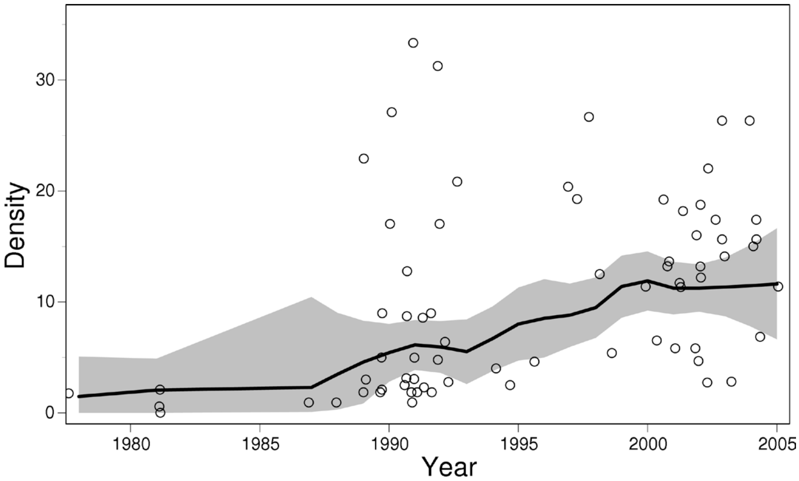

Fig. 6. Changes in great grey shrike population density in the years 1978–2005. The breeding density was weighted by the census plot size. Locally weighted regression was used to fit the line (df = 5. R^2 = 0.19, p < 0.0001, n = 71). The shaded region is the pointwise two-SE band.

figures can be given. Assuming that our habitat and elevation model is reasonable, we can predict the national population size by summing predicted densities in each 100 km^2 square. This gives the clearly overestimated figure of 31 600 breeding territories. However, based on the values of principal components computed from the habitat data, our sample can be regarded as representative of about 64% of the total country. This part contains an estimated 20 300 breeding territories. Even assuming that the mean density in the rest of the country is very low and ranges between 1 and 4 territories/100 km^2, we can roughly estimate the size of the Polish breeding population of the great grey shrike at 22 000–25 000 breeding pairs.

Former estimates suggested a population size of 2000–6000 breeding pairs (Tucker *et al*. 1994) or 4000–5000 pairs in the mid-1990s (Lorek 1995). These big differences in estimates of the total population probably arise from the strongly increasing trend (Fig. 6). However, we cannot exclude that an improvement in census methodology has also influenced these results (Tryjanowski *et al*. 2003).

The long-term data presented in this paper showed a significant increasing trend in population size of the great grey shrike. This is a complete surprise since this species has declined in western Europe. Several factors responsible for the observed trend in Poland might be suggested. Probably the most important reason can be attributed to the slow rate of change in agricultural landscapes. In Poland, traditional small family farms still dominate with low pesticide use, a mixed structure of crops and high habitat heterogeneity. Some other studies on shrikes also reported a clear negative impact of intensification of agriculture on their populations (Yosef 1994, Schön 1995, Lefranc & Worfolk 1997, Leugger-Eggimmann 1997, Giralt & Valera 2007). Secondly, increased winter temperatures might have had a positive effect on survival of birds from the breeding population since severe winters, especially periods with prolonged snow cover, may be the most important cause of mortality (Kowalski 1985, Lefranc & Worflock 1997). In addition, a local increase in prey populations, especially voles *Microtus* sp., might result in increased success of breeding great grey shrikes as noted by Pugacewicz (2000) in north-eastern Poland.

The majority of study sites were located in extensively used farmland and medium-sized river valleys with a high proportion of meadows and a high diversity of microhabitats. Such a habitat seems to be optimal for the great grey shrike since it offers suitable nesting and foraging areas (Lorek 1995, Tryjanowski *et al*. 1999). The distribution of this kind of habitat across the country corresponds to the geographical pattern of the great grey shrike distribution, with highest densities in southern Poland, where diverse topography generates habitat fragmentation. Relatively low densities of the great grey shrike in north-western Poland are probably also affected by habitat since in these areas large coniferous forests dominate.

Habitat use

Our analysis showed that the great grey shrike definitely prefers extensively used farmland, dominated by pastures, complex cultivation patterns and patches of scattered fields with elements of natural vegetation. The next important environmental component was elevation. The great grey shrike prefers lowland and avoids areas of higher elevation. Finally, the great grey shrike avoided areas dominated only by pastures. In general, our findings support previous results (Tryjanowski *et al*. 1999, Hromada *et al*. 2002) and clearly show the importance of extensively used farmland with areas of high heterogeneity. Tryjanowski *et al*. (1999) showed that meadows, a mixture of spring crops and the total length of ecotones are important foraging areas for breeding shrikes. Interestingly, the current study indicates that shrikes avoided large, open areas dominated by pasture, probably due to the lack of suitable nesting sites, since the majority of breeding birds nested in small, mainly coniferous, woodlots.The patterns of habitat use revealed by our study are in agreement with numerous studies performed on other shrike species in farmland habitats, including the lesser great grey shrike *Lanius minor* (Krištin *et al*. 2000, Wirtitsch *et al*. 2001), the red-backed shrike *Lanius collurio* (Dombrowski *et al*. 2000, Reino *et al*. 2006) and the loggerhead shrike *Lanius ludovicianus* (Chabot *et al*. 1995, Chabot *et al*. 2001, Jobin *et al*. 2005, Collister & Wilson 2007).

In conclusion, our study showed that the local population of the great grey shrike in Poland is numerous, increasing and in good condition. Our conclusions, based on data gathered on large temporal and geographical scales, provide the evidence of the importance of the Polish population for this species rapidly declining in other European countries, especially in the western part of the continent. Further monitoring of population densities and trends of the great grey shrike might be highly advisable; especially following the adoption of Common Agriculture Policy rules by Poland.

Acknowledgements

During our study on shrikes many people and institutions helped us. We are most grateful to: Tim Sparks and Richard Wadsworth for reviewing the manuscript and providing many ideas, Jacek Tabor, Artur Goławski, Andrzej Dombrowski, Daniel Grula, Jaroslav Ilek, Paweł Dolata, Jolanta Lorek, Grzegorz Bobrowicz, Tadeusz Drazny, Magdalena Janicka, Paweł Kołodziejczyk, Marcin Bocheński, Andrzej Zalisz, Tadeusz Sobuś, Paweł Kaczorowski, Damian Kaczorowski, Przemysław Wylegała, Przemysław Żurawlew, Anna Skoracka and especially Martin Hromada and Grzegorz Lorek for assistance in the field and providing the data. Studies in western Poland were supported by grants KBN 6PO4F04621 & 3PO4F05325, GEF/SGP Poland for PT, GAJU 60/2001/P-BF and SGA 2003 of the University of South Bohemia for MA.

References

Bassin, P. 1995: Status and trends of shrikes in Switzerland with special reference to the Great Grey Shrike. — *Proc. West Found. Vertebr. Zool*. 6: 45–48.

Bechet, G. H. 1995: Status and habitat structure of the Great Grey Shrike in Luxembourg. — *Proc. West. Found. Vertebr. Zool*. 6: 49–54.

Bednorz, J. & Kupczyk, M. 1995: Ptaki doliny Noteci [Birds of the Noteć River valey]. — *Pr. Zakł. Biol. Ekol. Ptaków UAM* 8: 1–68. [In Polish with English summary].

Bielecka, E. & Ciołkosz, A. 2004: *CORINE Land Cover in Poland. Final report*. — IGiK Warszawa, available at http://www.igik.edu.pl/clc_final_report_pl.pdf.

Burnham, K. P. & Anderson, D. R. 2002: *Model selection and multimodel inference: a practical information theoretic approach*, 2nd ed. — Springer, New York.

Chabot, A., Titman, R. D. & Bird, D. B. 1995: Habitat selection and breeding biology of Loggerhead Shrike in eastern Ontario and Quebec. — *Proc. West. Found. Vertebr. Zool*. 6: 155–157.

Chabot, A.,Titman, R. D. & Bird, D. B. 2001: Habitat use by Loggerhead Shrikes in Ontario and Quebec. — *Can. J. Zool*. 79: 916–925.

Cleveland, W. S. & Devlin, S. J. 1988: Locally weighted regression: an approach to regression analysis by local fitting. — *J. Am. Statist. Assoc*. 83: 596–610.

Collister, D. M. & Wilson, S. 2007: Territory size and foraging habitat of Loggerhead Shrikes (*Lanius ludovicianus excubitorides*) in southeastern Alberta. — *Journal of Raptor Research* 41: 130–138.

Dombrowski, A., Goławski, A., Kuźniak, S. & Tryjanowski, P. 2000: Stan i zagrożenia populacji gąsiorka *Lanius* *collurio* w Polsce [Status and threats of the Red-backed Shrike *Lanius collurio* in Poland]. — *Not. Orn.* 41: 139–148. [In Polish with English summary].

Dyrcz, A., Okulewicz, J. & Witkowski, J. 1984: Bird communities of the Biebrza Valley. — *Pol. Ecol. Stud.* 10: 403–423.

Eastman, J. R. 2006: *Idrisi Andes GIS, user guide and software*. — Clark Labs, Clark University, USA.

Efron, B. & Tibshirani, R. J. 1993: *An introduction to the bootstrap*. — Chapman & Hall, London.

Furmanek, M. 2002: Liczebność lęgowej populacji srokosza *Lanius excubitor* w północnej części powiatu Lipsko (woj. mazowieckie). — *Kulon* 7: 103–110.

Giralt, D. & Valera, F. 2007: Population trends and spatial synchrony in peripheral populations of the endangered Lesser Grey Shrike in response to environmental change. — *Biodiversity and Conservation* 16: 841–856.

Hagemeijer, J. M. & Blair, M. J. (eds.) 1997: *The EBCC Atlas of European breeding birds: their distribution and abundance*. — T. & A.D. Poyser, London.

Harris, T. & Franklin, K. 2000: *Shrikes and Bush-Shrikes*. — Christopher Helm, A. & C. Black, London.

Hastie, T. & Tibshirani, R. 1990: *Generalized additive models*. — Chapman and Hall, London.

Hordowski, J. 1998: Atlas ptaków lęgowych gminy Żurawica. — *Bad. Orn. Ziemi Przem.* 6: 7–90.

Hromada, M., Tryjanowski, P. & Antczak, M. 2002: Presence of the great grey shrike *Lanius excubitor* affects breeding passerine assemblage. — *Ann. Zool. Fennici* 39: 125–130.

Insightful 2005. *S-PLUS 7.0 for Windows Professional Edition*. — Insightful, Seattle, WA.

Jobin, B., Grenier, M. & Laporte, P. 2005: Using satellite imagery to asses breeding habitat availability of the endangered Loggerhead Shrike in Quebec. — *Biodiv. Conserv.* 14: 81–95.

Kowalski, H. 1985: Zur Bestandssitaution des Raubwurgers. — *Ber. Dtsch. Int. Rat. Vogelschutz* 25: 137–149.

Krištin, A., Hoi, H., Valera, F. & Hoi, C. 2000: Breeding biology and breeding success of the Lesser Grey Shrike (*Lanius minor*). — *Ibis* 142: 305–311.

Kuźniak, S., Lorek, G., Lorek, J., Sibiński, P. & Stankowski, A. 1995: Zagęszczenia lęgowe srokosza *Lanius excubitor* w krajobrazie rolniczym Południowej Wielkopolski. — *Przegl. Przyr.* 6: 61–70.

Lefranc, N. & Worfolk, T. 1997: *Shrikes. The guide to the shrikes of the world*. — Pica Press Sussex.

Leugger-Eggimann, U. 1997: *Parental expenditure of Red-backed Shrike Lanius collurio in habitat of varying farming intensity*. — Swiss Ornithological Institute, Allschwil.

Lorek, G. 1995: Breeding status of the Great Grey Shrike in Poland. — *Proc. West. Found. Vertebr. Zool.* 6: 98–104.

Maciorowski, G., Mizera, T., Ilków, M., Statuch, T. & Kujawa, D. 2000: Awifauna Sierakowskiego Parku Krajobrazowego. — *Wielkop. Pr. Ornitol.* 9: 39–67.

Nunes de Lima, M. V. (ed.) 2005: *CORINE Land Cover updating for the year 2000: IMAGE2000 and CLC2000: products and methods*. — European Communities.

Pugacewicz, E. 2000: Wysoka liczebność srokosza *Lanius excubitor* w Kotlinie Biebrzańskiej w 1997 roku. — *Not. Orn.* 41: 176–179.

Reino, L., Beja, P. & Heitor, A. C. 2006: Modelling spatial and environmental effects at the edge of the distribution: the red-backed shrike *Lanius collurio* in northern Portugal. — *Diversity Distrib.* 12: 379–387.

Rothaupt, G. 1995: Current status and habitat of the Great Grey Shrike in Germany. — *Proc. West. Found. Vertebr. Zool.* 6: 122–128.

Schön, M. 1995: Habitat structure, habitat changes, and causes of decline in the Great Grey Shrike (*Lanius excubitor*) in southwestern Germany. — *Proc. West. Found. Vertebr. Zool.* 6: 142–149.

Sikora, A., Rohde, Z., Gromadzki, M., Neubauer, G. & Chylarecki, P. 2007: *Polski Atlas Ornitologiczny [Polish Breeding Bird Atlas]*. — Bogucki Wyd. Nauk., Poznań. [In Polish with English summary].

Staszewski, A. & Czeraszkiewicz, R. 2000: Awifauna lęgowa rezerwatu "Świdwie" i okolic w latach 1990–1998. — *Not. Orn.* 41: 115–138.

Tabor, J. 2006: Występowanie srokosza w okresie lęgowym w Spalskim Parku Krajobrazowym. — *Kulon* 11: 29–38.

Tomiałojć, L. & Stawarczyk, T. 2003: *Ptaki Polski. Rozmieszczenie i liczebność [The avifauna of Poland. Distribution, numbers and trends]*. — PTPP "pro Natura" Wrocław. [In Polish with English summary]

Tryjanowski, P., Hromada, M. & Antczak, M. 1999: Breeding habitat selection in the Great Grey Shrike *Lanius excubitor* — the importance of meadows and spring crops. — *Acta Orn.* 34: 59–63.

Tryjanowski, P., Hromada, M., Antczak, M., Grzybek, J., Kuźniak, S. & Lorek, G. 2003: Which method is most suitable for census of breeding populations of shrikes, *Lanius collurio* and *Lanius excubitor*? — *Ornis Hung.* 12–13: 11–16.

Tucker, G. M., Heath, M. F., Tomiałojć, L. & Grimmet, R. F. A. 1994: *Birds in Europe. Their conservation status*. — Cambridge University Press Cambridge.

Weisberg, S., 1980: *Applied linear regression*. — Wiley New York.

Wirtitsch, M., Hoi, H., Valera, F. & Krištin, A. 2001: Habitat composition and use of Lesser Grey Shrike (*Lanius minor*). — *Folia Zool.* 50: 137–150.

Wylegała, P. 2003: Zmiany liczebności wybranych gatunków ptaków w dolinie Dolnej Noteci na odcinku Ujście–Wieleń w latach 1980–2003. — *Not. Orn.* 44: 187–194.

Yosef, R. 1994: Evaluation of the global decline in the True Shrike (Family *Laniidae*). — *Auk* 111: 228–233.

Appendix. Data used in the analysis. *See* Figure 1 for location of the study plots. For unpublished data, only the names of observers are provided.

Name of the plot	Year	Early/ recent	Area (km^2)	No. of territories	Density per 100 km^2	Source
Biebrza 80	1978	early	1370.0	24	1.8	Dyrcz *et al.*1984
Biebrza 91	1991	early	350.0	8	2.3	Pugacewicz 2000
Biebrza BC	1997	recent	109.0	21	19.3	Pugacewicz 2000
Biebrza BS	1997	recent	108.0	22	20.4	Pugacewicz 2000
Bojanowo	1991	early	108.1	2	1.9	Kuźniak *et al.* 1995
Cigacice	2002	recent	104.5	23	22.0	P. Czechowski
Grzebienisko	2001	recent	51.6	3	5.8	L. Kuczyński
Grzebienisko	2002	recent	51.6	3	5.8	L. Kuczyński
Kawcze	1991	early	108.1	2	1.9	Kuźniak *et al.* 1995
Kawcze	1992	early	108.1	2	1.9	Kuźniak *et al.* 1995
Kobierzyce	2004	recent	219.0	15	6.8	P. Zabłocki
Koło	1994	early	175.2	7	4.0	J. Grzybek
Koło	2001	recent	175.2	20.5	11.7	J. Grzybek
Komorzno	1991	early	141.0	7	5.0	Lorek 1995
Komorzno	1992	early	141.0	9	6.4	Lorek 1995
Lipsko	2001	recent	406.0	46	11.3	Furmanek 2002
Mogilno	2002	recent	256.1	7	2.7	P. Kaczorowski
Noteć	1981	early	178.0	1	0.6	Bednorz & Kupczyk 1995
Noteć	2003	recent	178.0	5	2.8	Wylegała 2003
Odolanów	1992	early	220.0	10.5	4.8	M. Antczak
Odolanów	2000	recent	220.0	25	11.4	M. Antczak
Odolanów	2001	recent	220.0	30	13.6	M. Antczak
Odolanów	2002	recent	220.0	29	13.2	M. Antczak
Odolanów	2003	recent	220.0	31	14.1	M. Antczak
Odolanów	2004	recent	220.0	33	15.0	M. Antczak
Odolanów	2005	recent	220.0	25	11.4	M. Antczak
Odra	1990	early	245.0	22	9.0	Lorek 1995
Odra	1991	early	245.0	21	8.6	Lorek 1995
Odra	1992	early	245.0	22	9.0	Lorek 1995
Pawłowice + Skoraszewice	1990	early	80.2	4	5.0	Kuźniak *et al.* 1995
Pawłowice + Skoraszewice	1991	early	80.2	2	2.5	Kuźniak *et al.* 1995
Poniec	1987	early	108.1	1	0.9	Kuźniak *et al.* 1995
Poniec	1988	early	108.1	1	0.9	Kuźniak *et al.* 1995
Poniec	1989	early	108.1	2	1.9	Kuźniak *et al.* 1995
Poniec	1990	early	108.1	2	1.9	Kuźniak *et al.* 1995
Poniec	1991	early	108.1	1	0.9	Kuźniak *et al.* 1995
Poniec	1992	early	108.1	3	2.8	Kuźniak *et al.* 1995
San	2001	recent	110.0	20	18.2	J. Grzybek
Siedlce	1981	early	130.0	0	0.0	A. Dombrowski & A. Goławski
Siedlce	1999	recent	130.0	7	5.4	A. Dombrowski & A. Goławski
Sierakowski PK	1996	recent	304.1	14	4.6	Maciorowski *et al.* 2000
Sokołów	2001	recent	104.1	20	19.2	J. Grzybek
Spalski PK	1995	early	361.0	9	2.5	Tabor 2006
Spalski PK	2002	recent	361.0	44	12.2	Tabor 2006
Strzelin	1990	early	96.0	2	2.1	Lorek *et al.* 1995
Strzelin	1991	early	96.0	3	3.1	Lorek *et al.* 1995
Szamotuły	1991	early	230.0	7	3.0	P. Tryjanowski & P. Wylegała
Szamotuły	2000	recent	230.0	15	6.5	P. Tryjanowski & P. Wylegała
Świdwie	1998	recent	60.0	16	26.7	Staszewski & Czeraszkiewicz 2000
Świniary	1990	early	23.5	4	17.0	Lorek *et al.* 1995

continued

Appendix. Continued.

Name of the plot	Year	Early/ recent	Area (km^2)	No. of territories	Density per 100 km^2	Source
Świniary	1991	early	23.5	3	12.8	Lorek *et al.* 1995
Świniary	1992	early	23.5	4	17.0	Lorek *et al.* 1995
Świniary	2002	recent	32.0	6	18.8	P. Zabłocki
Świniary	2003	recent	32.0	5	15.6	P. Zabłocki
Świniary	2004	recent	32.0	5	15.6	P. Zabłocki
Trestno	2003	recent	19.0	5	26.3	P. Zabłocki
Trestno	2004	recent	19.0	5	26.3	P. Zabłocki
Widawa	1989	early	48.0	11	22.9	Lorek *et al.* 1995
Widawa	1990	early	48.0	13	27.1	Lorek *et al.* 1995
Widawa	1991	early	48.0	16	33.3	Lorek *et al.* 1995
Widawa	1992	early	48.0	15	31.3	Lorek *et al.* 1995
Widawa	1993	early	48.0	10	20.8	Lorek *et al.* 1995
Widawa	2003	recent	69.0	12	17.4	P. Zabłocki
Widawa	2004	recent	69.0	12	17.4	P. Zabłocki
Wińsko	1991	early	252.5	22	8.7	Lorek *et al.* 1995
Wisłoka	2001	recent	106.0	14	13.2	J. Grzybek
Wolsztyn	1989	early	300.0	9	3.0	P. Tryjanowski
Wolsztyn	2002	recent	300.0	14	4.7	P. Tryjanowski
Zapałów	2002	recent	100.0	16	16.0	J. Grzybek
Żurawica	1981	early	96.0	2	2.1	Hordowski 1998
Żurawica	1998	recent	96.0	12	12.5	Hordowski 1998
TOTAL			11467.7	864	7.5	