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Farmland bird indicator on the basis of abundance and landscape systematization

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Abstract – Information on the territory density of breeding birds in the context of land-use and biotope structures in the various landscapes are of particular value in habitat evaluation. For the development of a farmland bird indicator, abundances and populations of breeding birds should be therefore considered. For this purpose, a methodological approach was developed using the territory mapping method to get information for the agrarian landscape, and representative abundances of the breeding bird species in these areas. Development and testing of the method was done in Germany in the federal state of Brandenburg (30,000 km²) during 2005 and 2006. Starting with a GIS supported systematization and spatial marking off of the landscapes of the entire country, the agrarian landscape are defined in terms of the spatial location. Within the agrarian landscape, under particular consideration of the agricultural land use as well as the biotope structures, agrarian landscape types and agrarian landscape mosaic types are defined. In the agrarian landscape, then, proportionally to the defined landscape types, a number of 65 (1 km² - 100 hectares) study areas were chosen randomly. On the basis of the abundance data collected, as well as the area information drawn from the landscapes, the total populations of the breeding bird species are estimated. Using the Chi² Test, representative indicator species for the entire agrarian landscape as well as sub-indicators for the agrarian landscape types were selected. Through the use of target values for abundance of the indicator species, the current level of goal achievement for each of the species were calculated. From these values the farmland bird indicator was calculated. This serves to evaluate the agrarian landscape as a whole and the individual agrarian landscape types. Accordingly, in the federal state of Brandenburg, the grassland dominated landscapes feature somewhat more favourable habitat conditions in comparison to entire agrarian landscape, and are much more favourable in comparison to the arable dominated landscapes. In addition to the function as a state indicator, this farmland bird indicator can be used as a measure for the improvement and evaluation of existing agri-environment schemes.

INTRODUCTION

The most frequently used bird-parameters for modelling the habitat suitability are the occurrence and the abundance of the breeding bird species, as a point of reference the population density. With the abundance, measurement unit in territories × $10ha^{-1}$, whose inquiry is carried out with the help of the territory mapping method, the population density of individual bird species or species associations in the different biotope structure complexes, landscapes sections or landscapes gets obvious. With knowledge of the spatial relationship between abundance and landscape, species populations can be calculated, while changes in the bird population are considered a sensitive indicator for the quality of the habitat conditions (OECD/OCDE 1999).

The dominating landscapes in central Europe are the very differently faceted agrarian landscapes. They comprise the greatest proportion of land, with more than 50 percent of the total. Within the agrarian landscapes, the existence and abundance of breeding bird species is closely related to the different agricultural use forms together with the occurrence and characteristics of natural, semi-natural and anthropogenous non-cropped habitats. Subsequently, to develop a bird indicator, the abundance will be used together with existing spatially and structurally differentiated features of agrarian landscapes as the initial parameter. Going out of a systematized and spatial marking off of landscapes, as the basis of the indicator, a methodical concept shall be recommended for the representative field surveys for the abundances and be applied as an example on larger areas. Based on the determined species, abundances and the landscape data, a selection of indicator species and calculations of the bird populations shall be carried out. Ultimately, with the help of these results, a proposal shall be made for a bird indicator for agrarian landscapes, with which the total agrarian landscape as well as partial areas used mainly for agriculture can be evaluated with regard to their habitat quality for breeding birds.

METHODS

In Germany, the development of a indicator-based method together with its application is shown for the federal state of Brandenburg. The area comprises about 30,000 km². More than half of this area is farmland dominated.

To census the abundance of single bird species, the territory-mapping method (Dornbusch *et al.* 1968, Oelke 1968, Berthold 1976) was chosen. Data gathered on the territories are digitalised in the context of biotope structure and land use and placed in a GIS (Geographical Information System) supported database.

For representative abundance data, the majority of the bird species with habitats in the agrarian landscapes, the survey-plots are recommended to span from 50 to 150 hectares (Fischer *et al.* 2005). The geometry of the areas should be as compact as possible, in order to minimize possible edge-effects. For this reason, square areas (survey-plots), 100 hectares each, were selected for the survey. In every survey-plot, 5 visits (average residence time per visit about four hours) per year, were done.

The position of the investigation areas was stratified and randomly selected in the agrarian landscape. For the systematization of the landscapes, a hierarchical classification approach was chosen (Hoffmann *et al.* 2007). The total land area of Brandenburg was classified into spatially differentiated landscape types according to the appropriate biotopes (Hoffmann and Kiesel 2007). For this purpose digitized results of the biotope-mapping were available for the entire area (LUA 2001). Agrarian land was distinguished from the other main habitats (forest, water bodies, and settlements), and then the agrarian landscapes were divided into four types:

1) arable crop
2) grassland
3) orchards or
4) heath dominated landscapes

The calculation and spatial marking off of the main habitats as well as the agrarian landscape types, took place with the help of a GIS supported calculation method (Kiesel *et al.* 2006) using the Moving Windows Technique (Silverman 1986), according to the dominance of existing biotopes. The size of cells was 12.5x12.5 m, surrounding radius 250 m.

Independently, in addition to this stratification a classification of Germany on the basis of natural areas was taken into account (Meynen *et al.* 1962), in order to characterize the bio-geographical differences among the parts of the land. According to that, four natural areas could be differentiated from each other, in which the potential of each of the agrarian landscape types has to be sampled. However, due to the small size of the areas of agrarian landscape type dominated by orchards and dominated by heath (see Fig. 1), survey-plots were located exclusively in the arable land and in the grassland landscapes.

Setting as a statistical minimum a number of 7 plots per stratum, this means that a minimum of 56 plots (7 plots x 2 landscape types x 4 natural areas) would have been necessary to sample the desired landscapes in a representative way. Furthermore it was strived for to keep the number of studied areas in proportion to the different landscape sizes, finally identifying 35 survey plots in arable land dominated landscape and 30 in grassland dominated landscape.

In their spatial geometry, all investigation areas could be completely positioned in individual agricultural use strata (arable land or grassland), without touching or overlapping with each other. In order to minimize edge-effects, a minimum distance of 50 m was set between the border of the single investigation area and the neighbouring stratum.

The field survey took place in 2005 and 2006. On the basis of the field data obtained, the abundance of individual breeding bird species in the study plots, the mean abundance in the strata and on all sampled areas is calculated. With the help of the territory data, the local population in the study plots as well as the total species populations in the entire agrarian landscape is then calculated (Hoffmann and Kiesel 2007).

As indicators for the agrarian landscape, a pre-selection of breeding bird species was done, selecting those for which the habitats are exclusively or largely in agrarian landscapes (Flade 1994, ABBO 2001, Bauer *et al.* 2005) and whose current population size and spatial distribution is representative for the entire agrarian landscape or for parts of it. On the basis of the received abundances, indicator species were selected by the use of the Chi² Test (Hoffmann *et al.* 2007). Testing criteria for the indicator species for the agrarian landscape as a whole is $P \geq 0.05$. Such indicator species are relatively equally distributed in the entire agrarian landscape. Testing criteria for the identification of sub-indicator species for different agrarian landscape types is $P < 0.05$, being those species unequally distributed within the entire agrarian landscape but with significant occurrence within single agrarian landscape types.

Abundances and population sizes of these indicator species serve as the basis for the bird indicators to be developed. For every indicator species, literature data and expert knowledge on abundances were used to define special target values (Hoffmann and Kiesel 2007). For *Alauda arvensis* these are, for example, the abundance (territories $\times$ 10 ha^{-1}) $\geq$ 3.0 as good (total population $\geq$ 478,000 terri-

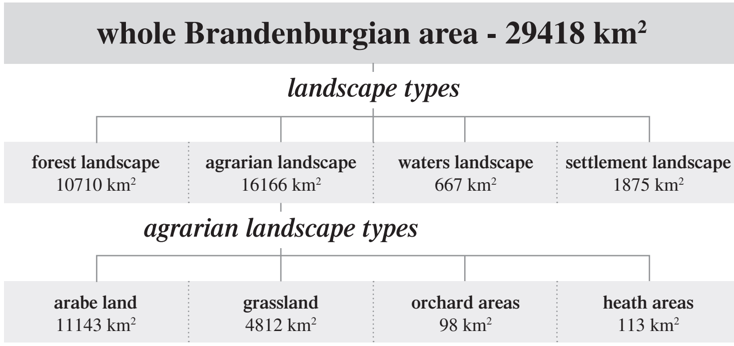

Figure 1. Landscape types and agrarian landscape types within the whole Brandenburg area and calculated land areas.

tories), and the abundance < 0.5 as poor habitat conditions (total population < 80,000 territories). The same process was used for the other selected indicator species. As a target value for the individual bird populations the abundance value for good living area conditions was used. Taking *Alauda arvensis* as an example, the abundance ≥ 3.0 corresponds to a target value of 100%, the abundance of 0.5 proportionally corresponds to a value of 17%.

Attained target values serve as a measure for the classification of the abundance and population values of the indicator species found in the field surveys and for the calculation of the bird indicators. Here the extent to which the objectives were achieved in the individual indicators species, based on the current abundance data, summed together and divided by the number of indicator species. Result is a numerical value for the level of target achievement by the bird indicator.

RESULTS

With the help of the GIS systematization and spatial marking off of the landscapes, the necessary spatial and contextual area data for the landscapes is calculated for the positioning of the investigation areas. With the four landscape types the agrarian landscapes cover 16,166 km², about 55 percent of the total land area. This is formed almost completely by agrarian landscape types respectively dominated by arable land and by grassland (Fig. 1). In the landscape type dominated by arable land, areas without or with very small non-cropped habitats are prevalent. In agrarian landscapes dominated by grassland, there are in contrast more areas are dotted by numerous small water bodies (creeks, streams, small lakes).

Due to the small size of the areas of agrarian landscape type dominated by orchards and dominated by heath (see Fig. 1), survey-plots are located exclusively in the arable land and in the grassland landscapes. From the combination of the only two relevant strata from agrarian landscape types and the four strata of the natural space types, at least 56 study areas are needed on the total agrarian landscape, half arable and half grassland. Since the arable land area encompasses a larger land area, 35 survey-plots were selected in the arable land, and 30 in the grassland landscapes, with a total of 65 plots, randomly selected over each stratum.

In the two study years, a total of 112 breeding bird species were found. A minimum of 5 and maximum of 41 breeding bird species were found on individual survey-plots, with a mean of 22. The species composition differed between arable and grassland landscapes somewhat. The number of species was slightly larger in grassland, but density of all species in arable landscapes (Tab. 1).

For each bird species identified, the size of the local population was calculated as the sum of the recorded territories of all studied areas as well as the total population.

Table 1. Mean number of breeding bird species and territories in the study plots.

	arable	grassland	all study plots
mean no. species	19	24	23 (5-61)
mean no. territories	91	72	80 (23-230)

Table 2. Abundances (territories x 10ha^{-1}) and calculated populations of the top 33 breeding bird species 2006. **2**: agrarian landscape. **2.1**: agrarian landscape dominated by arable land. **2.2**: agrarian landscape dominated by grassland.

breeding bird species (top 33)	**abundances**			**populations**		
	2	2.1	2.2	2	2.1	2.2
Alauda arvensis	1.982	2.114	1.827	323500	235600	87900
Emberiza citrinella	0.488	0.486	0.490	77700	54100	23600
Fringilla coelebs	0.383	0.446	0.310	64600	49700	14900
Motacilla flava	0.351	0.431	0.257	60500	48100	12400
Emberiza schoeniclus	0.372	0.151	0.630	47200	16900	30300
Acrocephalus palustris	0.308	0.180	0.457	42100	20100	22000
Parus major	0.211	0.180	0.247	32000	20100	11900
Turdus merula	0.182	0.203	0.157	30100	22600	7500
Luscinia megarhynchos	0.174	0.203	0.140	29300	22600	6700
Emberiza calandra	0.151	0.234	0.053	28700	26100	2600
Sturnus vulgaris	0.192	0.140	0.253	27800	15600	12200
Sylvia communis	0.174	0.171	0.177	27600	19100	8500
Sylvia atricapilla	0.172	0.151	0.197	26400	16900	9500
Sylvia borin	0.171	0.154	0.190	26300	17200	9100
Anthus pratensis	0.231	0.003	0.497	24200	300	23900
Hippolais icterina	0.142	0.129	0.157	21800	14300	7500
Saxicola rubetra	0.166	0.074	0.273	21500	8300	13200
Parus caeruleus	0.137	0.114	0.163	20600	12700	7900
Acrocephalus scirpaceus	0.145	0.091	0.207	20100	10200	9900
Lanius collurio	0.125	0.103	0.150	18700	11500	7200
Passer montanus	0.103	0.106	0.100	16600	11800	4800
Emberiza hortulana	0.065	0.117	0.003	13300	13100	200
Carduelis chloris	0.071	0.086	0.053	12200	9600	2600
Passer domesticus	0.057	0.097	0.010	11300	10800	500
Phylloscopus collybita	0.074	0.037	0.117	9700	4100	5600
Columba palumbus	0.069	0.043	0.100	9600	4800	4800
Anas platyrhynchos	0.068	0.043	0.097	9500	4800	4700
Anthus trivialis	0.065	0.049	0.083	9400	5400	4000
Phylloscopus trochilus	0.060	0.040	0.083	8500	4500	4000
Sylivia curruca	0.049	0.060	0.037	8500	6700	1800
Carduelis carduelis	0.046	0.043	0.050	7200	4800	2400
Turdus philomelos	0.032	0.037	0.027	5400	4100	1300
Motacilla alba	0.035	0.029	0.043	5300	3200	2100

Accordingly, in 2005/2006, the most frequent breeding bird species were *Alauda arvensis* with 318,500/323,500 territories, *Emberiza citrinella* with 83,500/77,700, *Fringilla coelebs* with 70,200/64,600, *Emberiza schoeniclus* with 54,500/47,200 und *Motacilla flava* with 40,900/60,500 territories. The top 33 breeding bird species with abundances and total population sizes are shown in Tab. 2.

From the total number of breeding birds, *Alauda arvensis, Emberiza citrinella, Sylvia communis, Lanius collurio, Motacilla flava* and *Passer montanus* are identified as indicator species for the entire agrarian landscape. These species occur with relatively equal frequency in all parts of the agrarian landscape, are currently among the most frequently found common bird species (see Tab. 2) with a statistically secure representation, all of them with $P \geq 0.05$.

The comparison of earlier estimates (ABBO 2001) with the currently assessed population shows, in some cases, important differences in the population sizes. For some of the indicator species, the current population estimate is much lower than the earlier estimated values, for example in the case of *Alauda arvensis* and *Passer montanus*, for

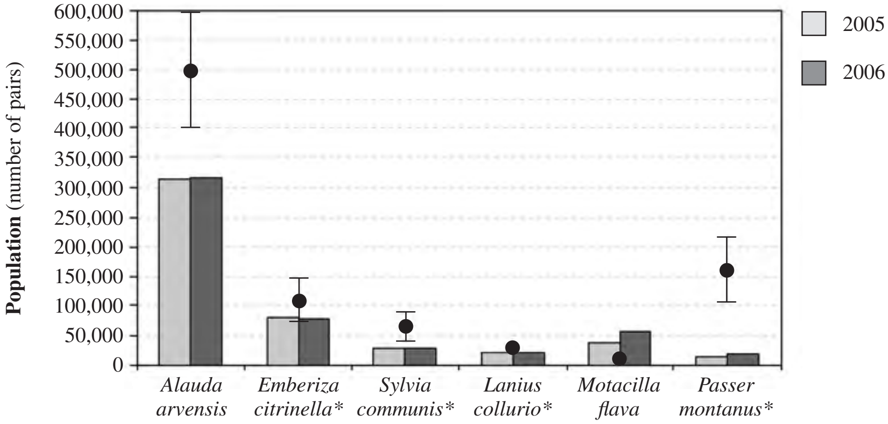

Figure 2. Populations of the indicator species for the whole agrarian landscape, line and dot: former estimated populations by ABBO (2001); * species with sub-populations in other landscape types.

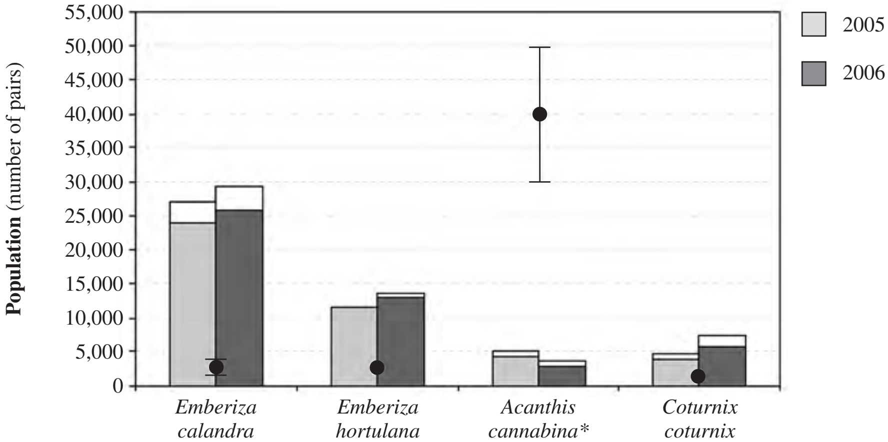

Figure 3. Populations of the sub-indicator species for the agrarian landscape type arable land, line and dot: former estimated populations by ABBO (2001); pale gray (2005) and medium warm gray (2006); white, populations form all other parts of the agrarian landscape; *species with sub-populations in other landscape types.

others is higher as, for example, *Motacilla flava* (Fig. 2). The breeding birds typical of the agrarian landscapes, *Emberiza calandra, Emberiza hortulana, Carduelis cannabina, Coturnix coturnix* are identified as indicator species for the arable land dominated agrarian landscape. The surveys and statistical analyses showed that the territories of these species are not equally distributed over the complete agrarian landscape ($P < 0.05$). They are almost completely concentrated on the agrarian landscape type dominated by arable land and are thus not representative for the entire agrarian landscape. These species thus serve as a sub-indicator for the agrarian landscape dominated by arable land and at the same time as differential species to agrarian landscapes dominated by the grassland areas. In comparison to the earlier estimated populations, the current population sizes for *Emberiza calandra, Emberiza hortulana, Coturnix coturnix* are much higher, and those for *Carduelis cannabina* much lower (Fig. 3).

The species *Anthus pratensis, Saxicola rubetra, Locustella naevia* and *Vanellus vanellus* were identified as sub-indicators for the grassland-dominated landscapes. Their populations can be found almost exclusively, or largely (*Saxicola rubetra*), in the grassland areas ($P < 0.05$). The comparisons of the currently calculated populations with the earlier estimates again show significant differences (Fig. 4), while, i.e., the population of *Anthus pratensis* is much larger and that of *Locustella naevia* is much smaller.

The abundance and population statistics for the indicator species as well as their defined target values serve

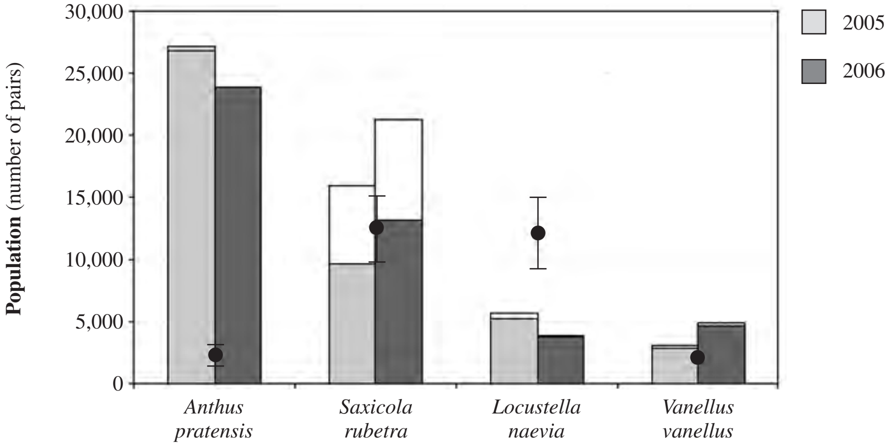

Figure 4. Populations of the sub-indicator species for the agrarian landscape type grassland, line and dot: former estimated populations by ABBO (2001); pale gray (2005) and medium warm gray (2006); white, populations form all other parts of the agrarian landscape.

as the basis information for building the bird indicator for agrarian landscapes (Tab. 3). The indicator is presented via the position of a pointer on a scaled circle, similar to the face of a clock. The placement of the pointer should indicate the situation of the habitat conditions for the indicator species in the whole agrarian landscape (Fig. 5, left). In addition, with the sub-indicators (Fig. 5, centre, right) different evaluations for the landscapes, dominated by arable land and grassland are possible. Within individual study areas of agrarian landscapes dominated by arable land and by grassland areas, use-specific variations in the level of target achievement for the indicator species emerge, as do differences with indicators themselves.

DISCUSSION AND CONCLUSIONS

The territory mapping method, in contrast to point-count and line-transects, was found to be the method achieving the best and most conclusive information on the territories and abundances of breeding birds (Südbeck and Fischer 2005). However, this method for the development of a bird

Table 3. Abundances, populations, target values and degree of the target values of the indicator species in the landscape types. **2**: agrarian landscape. **2.1**: agrarian landscape dominated by arable land. **2.2**: agrarian landscape dominated by grassland.

landscape type	**indicator species**	**abundances** (territories x $10ha^{-1}$)		**populations** (pair)		**target value for abundances**	**target value for populations**	**degree of the target value** (%)	
		2005	2006	2005	2006			2005	2006
2	*Alauda arvensis*	1.96	1.98	318500	323500	≥ 3.0	≥ 478700	66.5	67.6
2	*Emberiza citrinella*	0.51	0.49	83500	77700	≥ 0.8	≥ 127600	65.4	60.9
2	*Sylvia communis*	0.17	0.17	27100	27600	≥ 0.7	≥ 111700	24.3	24.7
2	*Lanius collurio*	0.12	0.12	18100	18700	≥ 0.3	≥ 47900	37.8	39.0
2	*Motacilla flava*	0.24	0.35	40900	60400	≥ 0.3	≥ 47900	85.4	126.1
2	*Passer montanus*	0.07	0.10	12000	16600	≥ 0.5	≥ 79800	15.0	20.8
2.1	*Emberiza calandra*	0.22	0.23	24300	26100	≥ 0.5	≥ 55700	43.5	46.9
2.1	*Emberiza hortulana*	0.10	0.12	11500	13100	≥ 0.15	≥ 16700	68.9	78.4
2.1	*Carduelis cannabina*	0.04	0.03	4300	2900	≥ 0.5	≥ 55700	7.6	5.1
2.1	*Coturnix coturnix*	0.03	0.05	4000	5700	≥ 0.2	≥ 22300	17.6	25.7
2.2	*Anthus pratensis*	0.56	0.50	26900	23900	≥ 0.3	≥ 14400	186.2	165.6
2.2	*Saxicola rubetra*	0.20	0.27	9600	13200	≥ 0.3	≥ 14400	66.7	91.1
2.2	*Locustella naevia*	0.11	0.08	5300	3700	≥ 0.3	≥ 14400	36.8	25.5
2.2	*Vanellus vanellus*	0.06	0.10	2800	4700	≥ 0.2	≥ 9600	29.3	48.3

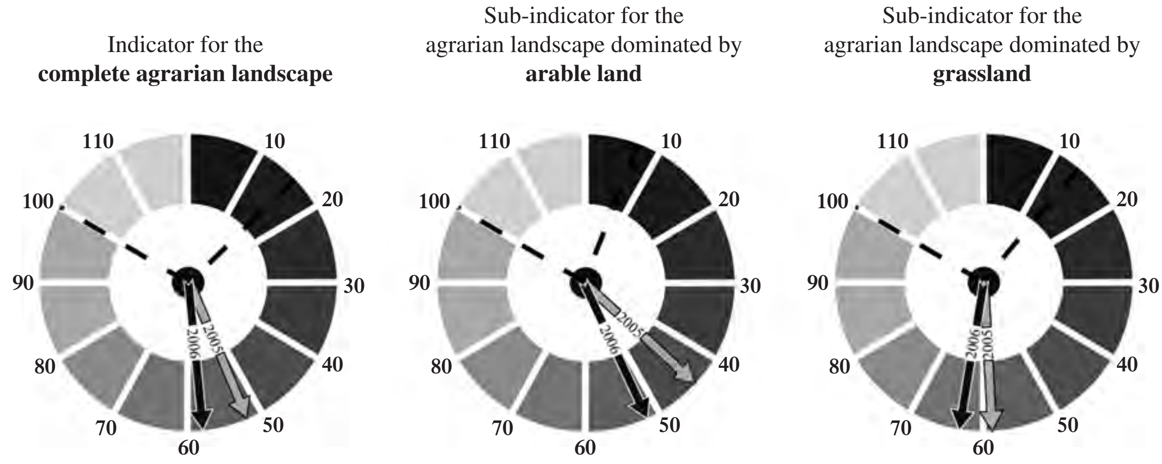

Figure 5. The farmland bird indicator in the State of Brandenburg 2005/2006 for the agrarian landscape (left) and sub-indicators for the agrarian landscape types (centre, right).

indicator has not received adequate attention in Germany until now because simpler methods were preferred in monitoring of breeding birds in agrarian landscapes. In Germany, the point-count method was first applied (Schwarz and Flade 2000) and after 2005 successively replaced with the modified line transect method (Mitschke et al 2005). Both, point-count and line-transect are used within monitoring programs for the calculation of index values for breeding bird species and population index too. These index values as surrogates for abundance estimates are used in calculation of a farmland bird population index (Achtziger *et al.* 2004). Required abundances from point-count surveys can hardly be reliably gathered (Südbeck *et al.* 2005), extrapolations of territory data from line-transects on landscapes are for a number of bird species too vague, because her territories are not sufficing to identify. In addition, minimum requirements of studied areas for landscape representative abundances are as a rule multiple not fulfilled. Abundances provided in the literature, for example, in Bauer et al (2005) show the problems on the sample area sizes. As a rule, high (maximum) abundance is received on too small sample areas with only a few hectares (Scherner 1981). With an increase in land area the abundance values drop. “Large areas density” > 100 km² serve for Bauer *et al.* (2005) as a reference for landscape, but without more detailed differentiation of the landscape according to the main types of habitats for breeding birds, for example missing differentiations of forests or of agrarian landscape types. In addition to this, the point-count and the line taxation methods use unique, particularly interesting breeding bird biotope structures to chart the route of the mapping, which in the context of the total landscape structure can easily lead to misinterpretations of territorial densities. In contrast, territory mapping method on sample areas of 1 km² ensures a link between bird populations and landscape structures (Fischer *et al.* 2005). Impacts of land-use and biotope- structure changes on different breeding bird species and their abundances as well as on the complete breeding bird community can be directly observed and analyzed (Bellebaum 1996). An extrapolation based on the local populations on the testing areas to entire populations will be adequately reliable, when the according spatial information on the entire landscape is available. In comparison to previous estimates in the federal state of Brandenburg (ABBO 2001), which were made without a systematic monitoring approach, this approach allowed more objective abundance and population data to be prepared for common and also for scarce breeding birds of the agrarian landscapes.

In comparison to the population index used as a bird indicator on farmland (Achtziger 2004, PECBM 2006) which allows indirect conclusions on populations and their changes over-time, with the indicator based on abundances (territories per area), direct conclusions are possible. Index values presented by Achtziger (2004) and PECBM (2006) show both for Germany as well as for the entire EU neither a positive nor negative trend of these indicators for agricultural areas in the past 15 to 20 years. This statement is in contrast to the population changes of a great number of typical farmland birds, e.g. *Perdix perdix, Carduelis cannabina* and *Vanellus vanellus*, species showing drastic population losses. The increasing intensification of areas with high yielding soils, the closure of many areas with low soils-fertility as well as partly a lack of efficiency in the agri-environmental schemes (Kleijn *et al.* 2001, Kleijn and Sutherland 2003) have tended to have a negative effect on the populations development of many typical field birds. This trend is at present partially strengthened by the increase in so-called energy plant crops, i.e., maize and rape, which are often large area, very densely planted mono-cultures, virtually unsuitable as habitats for birds.

An other important advantage of the direct density estimate is the possibility to use GIS to more closely analyze cause-effect relationships between bird populations and land-use features via multivariate analyses to draw conclusions on significant factors influencing farmland bird-populations. Based on the habitat requirements of individual indicator species, recommendations for agricultural environment measures are possible as a feedback to the practiced methods of agricultural production and land use (Hoffmann and Greef 2003). In addition to the indicator function as state indicator, it can be used as a measure for the improvement of existing agri-environment schemes from a nature conservation point of view. For this purpose, furthermore, information from individual investigation areas can be attained to show what presently serves as good habitats and land-use forms for the bird species.

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