Developing a forest bird indicator for Austria

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Teufelbauer, N., R. Büchsenmeister, A. Berger, B.S. Seaman, B. Regner, E. Nemeth & S.J. Butler 2017: Developing a forest bird indicator for Austria. Vogelwelt 137: 215–224.

Multi-species indicators combining the population trends of bird species, e.g. for a given habitat, are a valuable tool for bird conservation. A smart selection of the indicator species allows such indicators to provide a good summary of the changes occurring in the bird community as a whole in that habitat. In this paper we report on the development of a forest bird indicator for Austria, designed to act as a proxy for the population development of forest bird species overall. For the selection of indicator species we used an objective, niche-based approach following two simple rules: (1) all resources used by birds in forests should be covered by the indicator species set, and (2) the species selected should be as specialised as possible. This approach was developed by Wade *et al.* (2014) on a European scale, and our work constitutes its first-time application to the forest bird community at a single-country level. The indicator species set was selected from a list of all Austrian forest species with at least 200 breeding pairs and was shown to be ideally composed of 26 bird species. As yearly population trend data is currently not available for some of these species, we re-ran the selection procedure, restricting selection to species for which trend data is available from the Austrian common bird monitoring scheme. This resulted in two equally suited indicator species sets, each composed of 19 species and differing from the other in only one species. The trends of these indicator species sets from 1998-2012 did not differ significantly from one another, nor from the trend calculated for the full list of forest species for which data was available – a moderate decline in all cases, ranging from -1.13 %/year to -1.30 %/year. The indicator species finally selected were Stock Dove, Cuckoo, Black Woodpecker, Great Spotted Woodpecker, Wren, Robin, Nightingale, Blackbird, Western Bonelli's Warbler, Wood Warbler, Goldcrest, Firecrest, Collared Flycatcher, Marsh Tit, Crested Tit, Golden Oriole, Jay, Crossbill, and, interchangeably, Willow Warbler or Coal Tit.

Keywords: forest bird indicator, Austria, multi-species indicator, trends

1. Introduction

In the last decades common bird monitoring schemes (CMBS) have evolved in many countries in Europe (overview in European Bird Census Council 2016) as well as in North America (e.g. Sauer *et al.* 2014). These schemes are predominantly based on the counts of volunteer observers, an approach that has a long and successful history especially in bird conservation (see Greenwood 2007). CBMS enable the calculation of yearly population changes for a wide range of common and widely distributed bird species (e.g. Teufelbauer & Seaman 2016 for Austria). Beside single species trends, the wealth and quality of available data stimulated the development of multi-species indicators (see Ter Braak *et al.* 1994, Gibbons 2000, van Strien *et al.* 2001 and 2004, Gregory *et al.* 2003, 2005 and 2008). These summarise the changes of bird communities and act as state-indicators (Gregory *et al.* 2005). They are aimed at generalising complex information and thus providing simple, immediate information to policy-makers and the general public (Gregory *et al.* 2008). Such indicators usually stand for habitat categories like farmland or forest (e.g. Gregory *et al.* 2003, Achtziger *et al.* 2004, Zbinden *et al.* 2005, Szép *et al.* 2012, Eskildsen *et al.* 2013), but multi-species indicators have also been composed for montane areas (Lehikoinen *et al.* 2014) or for measuring the impact of climatic change (Gregory *et al.* 2009, Stephens *et al.* 2016). Furthermore, multi-species indicators have not only been developed for individual countries (see aforementioned references as examples), but also for larger regions and the whole of Europe (Gregory *et al.* 2007, Gregory *et al.* 2008, European Bird Census Council 2016).

Following the requirements of the European Commission, an indicator for farmland birds – the Farmland Bird Index (FBI) – has been established in Austria (Teufelbauer & Frühauf 2010). The FBI is used by the European Commission as a proxy for biodiversity in farmed habitats (Directorate General for Agriculture and Rural Development 2006) and is used to evaluate measures implemented under the Rural Development Program 2007-2013 [Regulation (EC) No 1974/2006] as well as in the new Program

[Regulation (EU) No 1306/2013]. However, for other habitats in Austria analogous indicators are missing. Forests cover 3.99 million hectares or 47.6 % of Austria (RUSS 2011) and are therefore of major importance for bird species. In this study, we report on the set-up of a multi-species bird indicator for Austrian forests. It was our aim to build an indicator in which the population trends of selected bird species stand as a proxy for the development of the whole community of bird species living in Austrian forests. We name this indicator 'Woodland Bird Index' (abbreviated 'WBI'), rather than using the better-fitting denomination 'Forest Bird Index', to enable an easy discrimination between this indicator and the Farmland Bird Index, which would have the identical acronym FBI.

A crucial part of the set-up of the WBI, as for any other indicator of this kind, is the selection of the indicator species. For existing multi-species indicators various approaches have been used, e. g. using existing knowledge on species' biology, often combined with expert judgement and the availability of trend data (e. g. ACHTZIGER *et al.* 2003, 2004, GREGORY *et al.* 2007, REIF *et al.* 2007, EUROPEAN BIRD CENSUS COUNCIL 2016), or splitting all common and widespread breeding bird species (GREGORY *et al.* 2003), or even all regularly breeding species (ZBINDEN *et al.* 2005), into habitat categories. Another alternative is the analysis of the habitat preferences of birds using the count data of existing CBMS (e. g. OSTASIEWICZ *et al.* 2011, SZÉP *et al.* 2012, ESKILDSEN *et al.* 2013), which has the advantage of an objective selection procedure. Anyway, in this approach – as well as in some of those mentioned above – it is only possible to include species which are counted regularly in a CBMS. Thus, potential indicator species which are not monitored are left out, which can lead to an indicator that does not cover all ecological needs of bird species living in the habitat of interest. Therefore we adopted the approach developed by BUTLER *et al.* (2012) and WADE *et al.* (2014), where (1) all species using a habitat are included in the selection procedure, and (2) the overlap between resource uses is minimised. This is the first-time application of this concept to the forest bird community at a single-country level.

2. Methods

2.1 Forest definition

For the purpose of our study we adopted the definition of 'forest' as used in the Austrian Forest Inventory (Österreichische Waldinventur), which includes all stands of an area ≥ 500 m^2, with a cover of > 30 % and a width ≥ 10 m (details see HAUK & SCHADAUER o. J., Fig. 1). Additionally, we included the zones of krummholz as well as of Dwarf Mountainpine *Pinus mugo* – both of which occur at high altitudes adjacent to forests, and often are highly interlocked with the latter.

2.2 Indicator species selection

2.2.1 Species list

We used a list of 67 bird forest species as starting point for the selection procedure. The species list was based on a European list of 80 candidate indicator species compiled by WADE *et al.* (2014). From that list we selected species (1) which breed in Austria, (2) with a population size ≥ 200 breeding pairs, and (3) excluded all species being indicator species in the Austrian FBI (see TEUFELBAUER & FRÜHAUF 2010). Finally, we changed the status of three species based on expert judge-

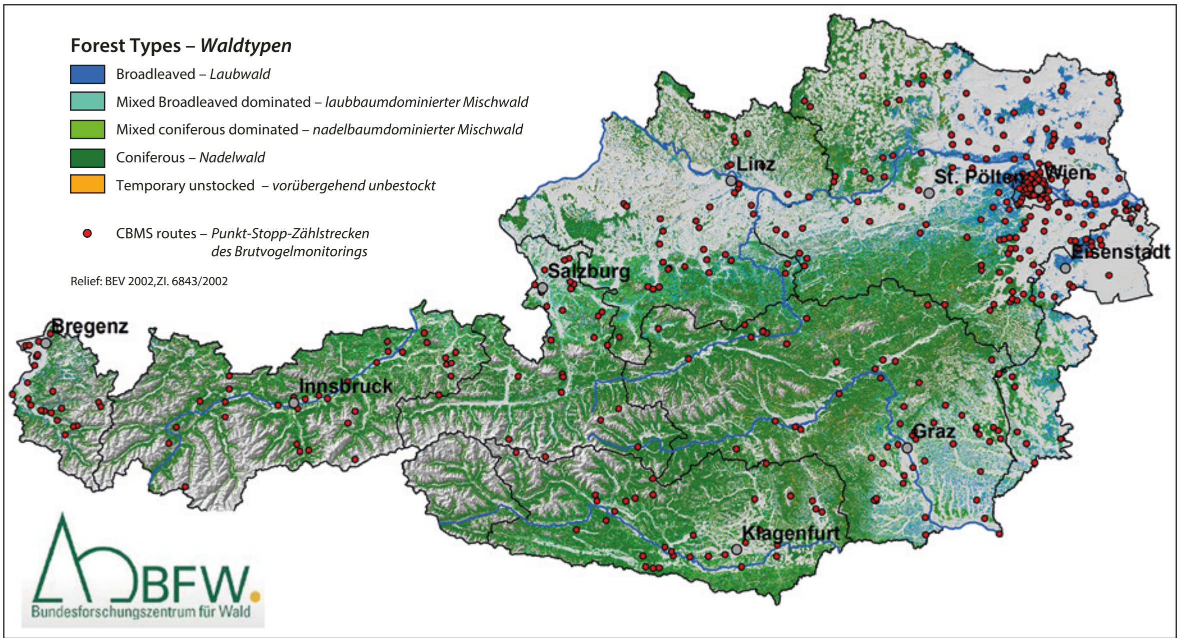

Fig. 1: Distribution of point count routes of the Austrian common bird monitoring scheme and different forest types in Austria. – *Verteilung der Punkt-Stopp-Zählstrecken des Monitoring der Brutvögel Österreichs.*

ment: on the one hand we removed Buzzard *Buteo buteo* and Greenfinch *Chloris chloris* from the list of forest species, as both show a strong linkage to other habitats (farmland and settlements, respectively), and on the other hand we added Lesser Whitethroat *Sylvia curruca* to the list because a substantial part of the Austrian population inhabits the zones of krummholz and Dwarf Mountainpine (Dvorak *et al.* 1993, BirdLife Austria unpublished data), which we included in our definition of forests (see above).

2.2.2 Resource use and sensitivity

The selection procedure was based on the work of Butler *et al.* (2012) and Wade *et al.* (2014), who used an objective, niche-based approach to (1) cover all resources in forests that are used by the forest bird species community, and (2) minimise the overlap of resource use between single indicator species. We categorised the resource use of each species in a resource requirements matrix. We used a simple binary code (0/1) for the categories summer diet, winter diet, summer foraging habitat, winter foraging habitat, nest type and nesting habitat. To include information of forest age we extended the original matrix of Wade *et al.* (2014) with information on successional stage. All categories used are shown in Table 1. For the categorisation we used the extensive overview on species' biology 'Handbuch der Vögel Mitteleuropas' (Glutz von Blotzheim *et al.* 1966-1997) as well as personal expertise on the situation in Austria.

In the groups diet and foraging habitat (each summer and winter) as well as nest type and nesting habitat all combinations which were theoretically possible and biologically useful were identified. The overall number of these resource combinations equals the range of ecological niches used by birds in forests in Austria. After the selection process each of these resource combinations should be represented by at least one species in the final indicator.

Each species of the initial list was classified according to its reliance on forests: species exclusively dependent on forests were classified with 1, species with intermediate dependence on forests with 2, and species with low dependence on forests were classified with 3, respectively. The classification was done independently by eight Austrian expert ornithologists, whose results were combined using modal value. A sensitivity score was calculated for each species after $S = N * R$, where N = number of used resources, R = reliance on forests, and S = sensitivity.

2.2.3 Selection procedure

Finally, a species selection algorithm using the concept of minimum dominating sets was applied to identify optimal species combinations for each possible number of indicator species (Wade *et al.* 2014). For each possible number of indicator species we selected the combination with the lowest average sensitivity score. By using a piecewise regression on these combinations we identified the optimal number of indicator species (Wade *et al.* 2014). We ran this selection procedure twice: firstly for all 67 forest species in our initial species list, resulting in the optimal indicator WBI_{opt}, and secondly only including those species for which data on population trends is available.

2.3 Trend data

2.3.1 Common Bird Monitoring

Data on common Austrian breeding birds was obtained from the common bird monitoring scheme 'Monitoring der Brutvögel Österreichs' (henceforth abbreviated with ACBMS). This scheme is run by BirdLife Austria and relies predominantly on volunteer observers ('citizen science'; see Greenwood 2007). Counts are done twice in the breeding season, with the first count conducted in the second half of April and the beginning of May, and the second count conducted in the second half of May and the beginning of June. At high altitudes (approx. above 1,200 m. a. s.l.) the two counts are done later in the season, individually adjusted to the local conditions (snow cover, danger of avalanches). The ACBMS uses point counts. The count points are grouped into routes which comprise 12.1 ± 3.3 points (mean ± std. dev.). On average, 236 ± 13 routes are counted every year (mean 2008–2012). The distribution of routes and the distribution of forest types in Austria are depicted in Fig. 1. More details on the ACBMS can be found e. g. in Teufelbauer (2010), Teufelbauer & Frühauf (2010) and Teufelbauer & Seaman (2016).

2.3.2 Species trends and indicators

Population trends were calculated using the standard procedure suggested by van Strien & Soldaat (2008), using TRIM software (Pannekoek & van Strien 2001). Where possible, the trend for each indicator species was stratified and weighted according to population size in the nine Austrian federal states (post-hoc stratification; Gregory & Greenwood 2008; van Turnhout *et al.* 2008). For details see Teufelbauer (2010). In this paper we used ACBMS data from the starting year 1998 up to the year 2012. The multi-species indicators resulting from the selection procedure (WBI_a, WBI_b), as well as an indicator including all candidate indicator species with available trend data (WBI_{all}), were calculated using geometric mean (Gregory *et al.* 2005). The Austrian FBI, which we used for comparison, was redrawn from Teufelbauer (2013a).

We applied Monte-Carlo-Simulations to calculate trends and standard errors for the resulting multi-species indicators (MSI-tool for R, Soldaat 2016, Soldaat *et al.* submitted): This approach is based on the approximately log-normal distribution of the standard errors of index values. For each yearly index value and for each species we drew 10,000 times from a normal distribution $N(\mu, \sigma)$, with μ = the natural logarithm of the index and σ = the standard error of the index on the log scale. The standard error of the index on the log scale was assessed by the Delta-method (e. g. Agresti 1990). We calculated mean and standard error for the resulting 10,000 multi-species indicators. Information on trend of the multi-species indicators used in this paper comprises the overall trend and the standard error of the overall trend. The classification of trends follows the procedure used in the TRIM software for analysis of time series in biological data (Pannekoek & van Strien 2001). Finally, to test for differences in trends between the multi-species indicators, we calculated mean trends, standard errors and confidence limits of the trends from 10,000 draws from the normal distribution of the index values of the multi-species indicators, again using Monte-Carlo-Simulation (Soldaat 2016, Soldaat *et al.* submitted).

2.3.3 Representativeness

In a country with a large proportion of mountains like Austria it is hard to achieve a representative distribution of ACBMS routes. Uneven sampling of, for example high altitude forests, can be corrected to some extent by the use of post-hoc stratification (see above), but major imbalances might not be

Table 1: Categories used in the resource requirements matrix. – *In der Ressourcen-Anforderungs-Matrix verwendete Kategorien.*

Level 1 – *Ebene 1*	Level 2 – *Ebene 2*	Level 3 – *Ebene 3*
Summer diet – *Sommernahrung*	Below-ground invertebrates – *bodenlebende Evertebraten*	
	Above-ground invertebrates – *außerhalb des Bodens lebende Evertebraten*	
	Plant material – *Pflanzenmaterial*	
	Seeds – *Samen*	
	Vertebrates – *Wirbeltiere*	
Winter diet – *Winternahrung*	Below-ground invertebrates – *bodenlebende Evertebraten*	
	Above-ground invertebrates – *außerhalb des Bodens lebende Evertebraten*	
	Plant material - *Pflanzenmaterial*	
	Seeds – *Samen*	
	Vertebrates – *Wirbeltiere*	
Summer foraging habitat – *Nahrungshabitat Sommer*	Forest type – *Waldtyp*	Deciduous – *Laubwald*
		Coniferous – *Nadelwald*
		Mixed – *Mischwald*
	Successional stage – *Sukzessionsstadium*	Young/intermediate – *jung/mittel*
		Old – alt
		Need of dead wood – *Bedarf an Totholz*
	Horizontal habitat – *Habitat horizontal*	Edge – *Rand*
		Core – *Bestandesinneres*
	Vertical habitat – *Habitat vertikal*	Ground – *Boden*
		Shrub – *Strauch*
		Canopy – *Kronenbereich*
Winter foraging habitat – *Nahrungshabitat Winter*	Forest type – *Waldtyp*	Deciduous – *Laubwald*
		Coniferous – *Nadelwald*
		Mixed – *Mischwald*
	Successional stage – *Sukzessionsstadium*	Young/intermediate – *jung/mittel*
		Old – alt
		Need of dead wood – *Bedarf an Totholz*
	Horizontal habitat – *Habitat horizontal*	Edge – *Rand*
		Core – *Bestandesinneres*
	Vertical habitat – *Habitat vertikal*	Ground – *Boden*
		Shrub – *Strauch*
		Canopy – *Kronenbereich*
Nest type – *Nesttyp*		Hole - dead wood – *Höhle in Totholz*
		Hole - live wood – *Höhle in lebendigem Holz*
		External – *frei nistend*
Nest habitat – *Nisthabiat*	Forest type – *Waldtyp*	Deciduous – *Laubwald*
		Coniferous – *Nadelwald*
		Mixed – *Mischwald*
	Successional stage – *Sukzessionsstadium*	Young/intermediate – *jung/mittel*
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		Need of dead wood – *Bedarf an Totholz*
	Horizontal habitat – *Habitat horizontal*	Edge – *Rand*
		Core – *Bestandesinneres*
	Vertical habitat – *Habitat vertikal*	Ground – *Boden*
		Shrub – *Strauch*
		Canopy – *Kronenbereich*

overcome by the applied stratification approach. Therefore we checked the representativeness of the ACBMS counts using two simple parameters: altitude (≤600 m, 601–1,200 m and >1,200 m) and forest type (deciduous, coniferous, and mixed; data on both parameters from Bundesforschungszentrum für Wald unpublished). The locations of the ACBMS count points were assigned to these parameters using a geographical information system. We then calculated the number of count points for each class of the two parameters.

To assess the representation of different migration strategies in the selected indicator species we classified all candidate indicator species according to their migration strategy based on information in Glutz von Blotzheim *et al.* (1966–1997) and on personal expertise. For the three categories resident/partially migratory, short-distance migrant, and long-distance migrant we checked with Pearson's Chi Square test whether the distribution of migration strategies in the basket of the selected indicator species deviated from the initial pool of candidate indicator species.

3. Results

Together, the 67 candidate indicator species used 631 resource combinations of the resource requirements matrix. The set of 47 species for which data on population trends is available used 547 resource combinations (87 % of the total number of resource combinations). The ideal indicator, covering all 631 resource combinations, was composed of 26 species (WBI_{opt}). The indicator based only on species with available trend data comprised 19 species (Table 2). For the latter, two different species combinations with the same average sensitivity were obtained – one set contains Coal Tit *Parus ater* [Woodland Bird Index (a), or WBI_a], whereas in the other set this species was substituted by Willow Warbler *Phylloscopus trochilus* (WBI_b). The two indicators comprising 19 species are shown in Fig. 2. The two versions of the WBI did not differ significantly from one another (overall trend $WBI_a = -1.13 \pm 0.20$ %/year, $WBI_b = -1.26 \pm 0.19$ %/year). The trends of both indicators were significantly different from zero and showed a moderate decrease ($p < 0.05$). The trend of a multi-species indicator including all forest species with available trend data (WBI_{all}) did not differ significantly from the trends of WBI_a and WBI_b ($WBI_{all} = -1.30 \pm 0.15$ %/year; Fig. 2).

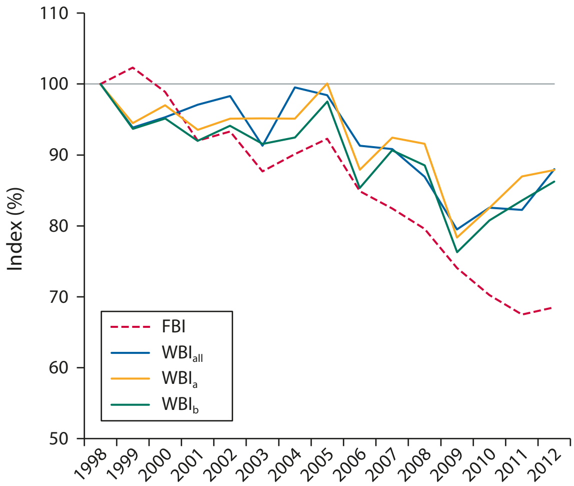

Fig. 2: Woodland Bird Index comprising the 19 indicator species identified in the selection procedure (WBI_a, WBI_b) and the multi-species indicator comprising all forest species with available trend data (WBI_{all}). For comparison the trend of the Austrian Farmland Bird Index is also drawn (FBI). Note that for the sake of increased perceptibility the Y-Axis does not include zero. – *Woodland Bird Index bestehend aus den Bestandstrends jener 19 Vogelarten, die im Auswahlprozess selektiert wurden (WBI_a, WBI_b) sowie ein Summenindikator, der sich aus allen Waldvogelarten mit verfügbaren Bestandstrends zusammensetzt (WBI_{all}). Zum Vergleich ist auch der österreichische Farmland Bird Index dargestellt (FBI). Zur besseren Unterscheidung der Trends ist die Y-Achse nicht bis zum Nullpunkt gezeichnet.*

The checks of representativeness showed that the sample effort is unevenly distributed within the two tested parameters, with effort being lowest at high altitudes and also in mixed and coniferous forests (Fig. 3). The selection procedure did not favour any of the migration strategies of the candidate indicator species set: Whereas the figures indicate a slight preference of migratory over residential bird species in both, the optimal indicator WBI_{opt} as well as the two indica-

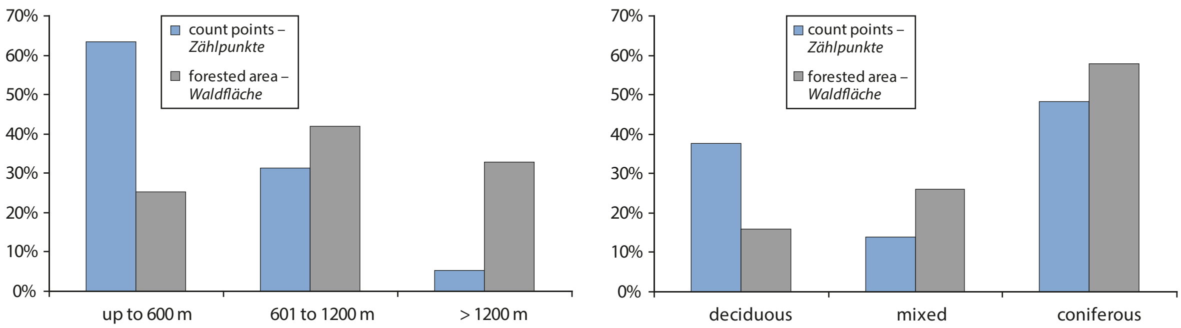

Fig. 3: Sampling effort of the Austrian common bird monitoring scheme in relation to altitude (left) and altitude (right). Total forest area: 3.99 million hectares, total number of count points: 1,032. – *Zählaufwand des österreichischen Brutvogel-Monitoring in Bezug auf Seehöhenklassen (links) und Waldtypen (rechts). Waldfläche gesamt: 3,99 Mio. Hektar, Anzahl Zählpunkte gesamt: 1.032.*

Table 2: Selected indicator species: (1) Ideal indicator, i. e. selection based on all candidate species, (2) indicator that is feasible at the moment, i.e. selection based only on candidate species with available trend data. [1] the selection procedure resulted in two species sets with identical sensitivity which differ in the marked species. – *Ausgewählte Indikatorarten: (1) Idealer Indikator: Artenauswahl basierend auf allen Arten der Vorauswahl, (2) im Moment realisierbarer Indikator: Artenauswahl basierend nur auf jenen Arten der Vorauswahl, für die derzeit Daten zur Bestandsentwicklung vorliegen. [1] Der Auswahlprozess lieferte zwei Artensets mit identischer Sensibilität, die sich nur in den beiden gekennzeichneten Arten unterscheiden.*

English name – ***Englischer Name***	**Scientific name –** ***Wissenschaftlicher Name***	**all species –** ***alle Arten***	**species with trend data** ***– Arten mit Daten zur Bestandsentwicklung***
Black Stork	*Ciconia nigra*	x	
Woodcock	*Scolopax rusticola*	x	
Stock Dove	*Columba oenas*	x	x
Cuckoo	*Cuculus canorus*	x	x
Pygmy Owl	*Glaucidium passerinum*	x	
Tawny Owl	*Strix aluco*	x	
Black Woodpecker	*Dryocopus martius*	x	x
Great Spotted Woodpecker	*Dendrocopos major*	x	x
Middle Spotted Woodpecker	*Dendrocopos medius*	x	
Lesser Spotted Woodpecker	*Dryobates minor*	x	
Three-toed Woodpecker	*Picoides tridactylus*	x	
Wren	*Troglodytes troglodytes*	x	x
Robin	*Erithacus rubecula*	x	x
Nightingale	*Luscinina megarhynchos*	x	x
Blackbird	*Turdus merula*	x	x
Western Bonelli's Warbler	*Phylloscopus bonelli*	x	x
Wood Warbler	*Phylloscopus sibilatrix*	x	x
Willow Warbler	*Phylloscopus trochilus*		(x)[1]
Goldcrest	*Regulus regulus*	x	x
Firecrest	*Regulus ignicapilla*	x	x
Red-breasted Flycatcher	*Ficedula parva*	x	
Collared Flycatcher	*Ficedula albicollis*	x	x
Marsh Tit	*Parus palustris*	x	x
Crested Tit	*Parus cristatus*	x	x
Coal Tit	*Parus ater*		(x)[1]
Golden Oriole	*Oriolus oriolus*	x	x
Jay	*Garrulus glandarius*	x	x
Crossbill	*Loxia curvirostra*	x	x

tor versions WBI_a and WBI_b obtained from the group of species where trend data is available (Fig. 4), these differences were statistically not significant in all cases (all species vs. WBI_{opt}: $\chi^2 = 0.15741$, df = 2, p = 0.9243; WBI_{all} vs WBI_a: $\chi^2 = 0.61238$, df = 2, p = 0.7362; WBI_{all} vs WBI_b: $\chi^2 = 1.108$, df = 2, p = 0.5747).

4. Discussion

4.1 Selected indicator species and covered time span

In this study we have selected indicator species for the Austrian Woodland Bird Index based on an objective approach. We identified the optimal indicator species, but, given that yearly trend data was not available for some of these, we decided to build a preliminary indicator. This indicator is based on species for which trend data is already available and therefore it is ready-to-use. Moreover, it covers the time span from 1998 onwards – the starting year of the ACBMS – which is of great importance, because long time-series help to detect changes in a timely manner (see Gregory *et al.* 2008). This currently feasible indicator covers a large proportion of all forest resources used by birds (87 %) and we therefore believe it is able to deliver valuable information on the status of the birds in this habitat, even if some species are not included. In the long-term the aim should be to collect data for all species of the optimal indicator. As some of these birds are difficult to monitor (see below) this will be a major task for both, NGO work and governmental nature conservation bodies. Nevertheless, without these species some resources remain unrepresented in the WBI, which could lead to the situation that changes relevant for birds in Austrian forests might remain undetected. This would hamper one of the major tasks of the WBI, namely acting as an early warning system (Gregory *et al.* 2008).

4.2 Representativeness

4.2.1 Indicator species with no available trend data

All of the ideal indicator species for which no trend data is available are hard to monitor with the standard

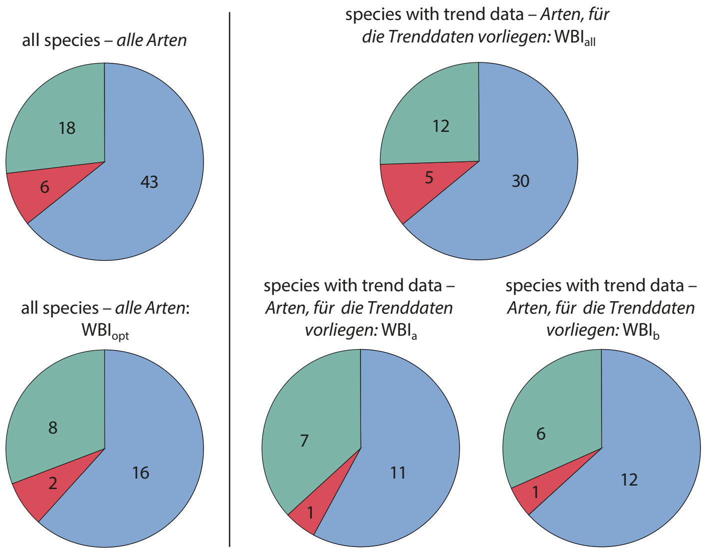

Fig. 4: Ratios of migration strategies in different indicator species sets. Left: All 67 candidate species used in this study (top), and the set of 26 indicator species that were selected for the optimal WBI_{opt} (bottom). Right: The 47 candidate indicator species for which trend data is available (top) and the 19 species selected for the two indicator versions (WBI_a, WBI_b). Blue: resident and partly migratory species, red: short distance migrants, green: long-distance migrants. – *Anteile der Zugstrategien in verschiedenen Sets von Indikatorarten. Links: Alle 67 Arten der Vorauswahl (oben), sowie jene 26 Indikatorarten, die zusammen den idealen Indikator bilden (unten). Rechts: Die 47 Vogelarten der Vorauswahl, für die Trenddaten vorliegen (oben), sowie jene 19 Arten, die für die beiden Versionen des Indikators ausgewählt wurden (WBI_a, WBI_b). Blau: Standvögel und Teilzieher, rot: Kurzstreckenzieher, grün: Langstreckenzieher.*

method of the ACBMS: (1) Some are crepuscular or nocturnal (Pygmy Owl *Glaucidium passerinum*, Tawny Owl *Strix aluco*, Woodcock *Scolopax rusticola*, Glutz von Blotzheim *et al.* 1966–1997) and are thus regularly missed by the counts that are conducted in the morning (Teufelbauer 2010). (2) Most of them have rather large territories and generally occur in low densities (all except Middle Spotted Woodpecker *Dendrocopos medius*, Glutz von Blotzheim *et al.* 1966–1997) and are therefore registered only rarely during the point counts of the ACBMS. (3) Some are habitat specialists and therefore have restricted breeding ranges (Middle Spotted Woodpecker, Red-breasted Flycatcher *Ficedula parva*, see Dvorak *et al.* 1993) which makes it even harder to reach sample sizes that enable a trend calculation. Feeding on vertebrates is a characteristic trait shown by three of these seven species (Black Stork *Ciconia nigra*, Pygmy Owl, Tawny Owl; Glutz von Blotzheim *et al.* 1966–1997). This resource use is not covered by any of the species of WBI_a or WBI_b. Furthermore, these seven species show a more or less pronounced restriction to old growth forests, some additionally bound to the occurrence of substantial amounts of dead wood. It is crucial to keep this in mind when interpreting the trend of the current indicator, as changes in these resources – subsequently influencing bird populations – might remain undetected by the WBI.

4.2.2 Distribution of the point counts

A further potential pitfall in the interpretation of the trend of the WBI is the current distribution of ACBMS count routes in Austria. Mixed forests and coniferous forests are undersampled, as well as forests at higher altitudes (Fig. 3). Although a stratification and weighting procedure is applied in the analysis of the count data (see methods), it should be noted that, due to this uneven distribution, the resulting WBI might be biased to lowland deciduous forests. We therefore recommend – beside the aforementioned collection of trend data for some species currently not monitored on a yearly basis – an extension of the ACBMS counts in higher altitudes, where the proportion of coniferous forests per se is higher than in lowland forests (Kilian *et al.* 1994).

4.2.3 Indicator species with different migration strategies

The applied selection procedure slightly prefers migratory over resident and partly-migratory species, although this preference is statistically not significant. This effect is caused by the number of resources used per species: In the resource requirements matrix the resource use in summer is dealt with separately from resource use in winter. The total number of used resources is therefore on average higher in species which are present all year round ($N_{res} = 60 \pm 55$, $N_{mig} = 22 \pm 22$, mean ± std. dev, n = 67 candidate indicator species) This leads to better, i. e. lower, sensitivity scores for migratory species ($S_{res} = 77 \pm 80$, $S_{mig} = 38 \pm 64$) and, because the algorithm per definition selects the most specialised species, migratory species are preferred over residential ones (see method). A preference for long-distance migrants can be problematic, because it has been reported repeatedly that bird species migrating long-distances, i.e. to Africa south of the Sahara, experience more negative declines than short-distance migratory or resident bird species (e. g. Sanderson *et al.* 2006, Vickery *et al.* 2014). Nevertheless, this finding does not seem to be valid for Austria (Teufelbauer/BirdLife Austria, unpublished data), and furthermore the proportions of migratory strategies in the baskets of indicator species do not differ significantly from the baskets of the candidate indicator species. Thus we think that the overall influence of this characteristic of the selection algorithm on the WBI is negligible.

4.3 Trend of the WBI

We found no significant difference between the trends of the WBI based on the species selection (WBI_a, WBI_b) and the indicator incorporating all species for which trend data is available (WBI_{all}). Thus, at first glance the performed selection procedure might appear unnecessary. However, it should be noted that this estimation is only true for (1) the current length of the time series – theoretically this can change with the addition of every single year of data – and (2) the current set of species with available trend data. Contrary to the first-sight impression, we believe that conducting the selection procedure is crucial for the aims of the WBI, because we were able to identify resources which are currently not covered by the indicator. This is a finding that would have been impossible if we had simply combined the available population trends of forest bird species. Furthermore, the approach minimises redundancies in the resource use, which is a very valuable asset for potential future developments in forests.

The trends of the WBI (WBI_a, WBI_b) are significantly less negative than the trend of the Austrian FBI, although the trend of the FBI still qualifies as a 'moderate decrease' only (FBI = -2.96 ± 0.21 %/year; Fig. 2). The more negative development of farmland birds is in line with the results of both other European countries (e. g. Reif *et al.* 2007, Ostasiewicz *et al.* 2011) as well as the European level as a whole (Gregory *et al.* 2007). The majority of the WBI's indicator species exhibits statistically significant negative population trends (Teufelbauer/BirdLife Austria unpublished data), which all in all drive the trend of the WBI. Negative trends occur in particular in all species living predominantly or exclusively in coniferous forests (Goldcrest *Regulus regulus*, Firecrest *Regulus ignicapilla*, Crested Tit Parus cristatus, Coal Tit, Common Crossbill *Loxia curvirostra*; Teufelbauer 2013b). This is in line with an ongoing decline of the area forested with coniferous trees since the 1980s, which on the other side has been more than balanced by a gain of deciduous trees (Russ 2011). Nevertheless, it is possible that the WBI is drawing too negative a picture, at least in part: The decline of both coniferous forests as well as of spruce, the major species of coniferous forests in Austria, is largest in forests below 900 m. a. s. l. (BFW 2016). Together with the current distribution of count routes of the ACBMS, which leads to an oversampling of lowland forests and an undersampling of high altitude forests (see Fig. 3), it is likely that this effect is exaggerated in the trend of the WBI, but is somewhat weaker in reality. More work is needed to secure this hypothesis, as well as to gain a general understanding of the population trends of Austrian forest birds. In any case, we recommend intensifying the efforts of common bird monitoring in Austria to be able to document the trends of Austria's forest birds with higher certainty. Emphasis should be put on (1) increasing the sampling effort in higher altitude mixed and coniferous forests, and (2) collecting data for those indicator species of the optimal forest bird indicator (WBI_{opt}) which are currently not monitored on a yearly basis.

Acknowledgements: We thank Gábor Wichmann for various support during the course of this study. Furthermore, we thank Katharina Bergmüller, Christine Medicus, Remo Probst, Norbert Pühringer, Norbert Ramsauer, and Hans Uhl for their expertise in classifying reliance of bird species on Austrian forests. Christoph Bauerhansl helped us with the production of the maps of forest types. Major parts of this work have been supported by the Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management (Woodland Bird Index: BMLFUW-LE.1.3.7/0029-II/5/2012, Farmland Bird Index: BMLFUW-LE.1.3.7/0018-ll/5/2011).

5. Zusammenfassung

Teufelbauer, N., R. Büchsenmeister, A. Berger, B. S. Seaman, B. Regner, E. Nemeth & S. J. Butler 2017: Entwicklung eines Waldvogelindikators für Österreich. Vogelwelt 137: 215–224.

Summenindikatoren kombinieren die Bestandsentwicklungen von Vogelarten, beispielsweise in einem ausgewählten Lebensraum. Sie sind ein wertvolles Werkzeug für den Naturschutz, denn über eine kluge Auswahl der Indikatorarten liefern sie eine Zusammenfassung der Veränderungen, die in der gesamten Vogelartengemeinschaft dieses Lebensraumes passieren. In dieser Arbeit berichten wir von der Entwicklung eines Waldvogelindikators für Österreich, der stellvertretend über eine Gruppe von Indikatorarten die Populationsentwicklung aller Waldvogelarten darstellen soll. Zur Auswahl der Indikatorarten verwendeten wir einen objektiven Ansatz, der auf den jeweils von den Arten genutzten ökologischen Nischen basiert. Dieser Ansatz wurde von Wade *et al.* (2014) für Waldvogelarten auf europäischer Ebene entwickelt und unsere Arbeit ist die erste Anwendung auf Waldvogelarten auf Ebene eines Einzelstaates. Die Auswahl der Indikatorarten erfolgte nach zwei Regeln: (1) Alle Ressourcen, die von Waldvogelarten genutzt werden, sollten von den Indikatorarten abgedeckt werden. Dazu wurde die Ressourcennutzung der untersuchten Vogelarten für die Kategorien Sommernahrung, Winternahrung, Nahrungshabitat im Sommer, Nahrungshabitat im Winter, Nesttyp und Nisthabitat mit jeweils mehreren möglichen Klassen definiert. (2) Die ausgewählten Arten sollten so spezialisiert wie möglich sein. Dazu benutzten wir die errechnete Sensitivität der untersuchten Vogelarten, ausgehend einerseits von ihrer Abhängigkeit vom Lebensraum Wald und andererseits von der Zahl der jeweils von ihnen genutzten Ressourcen.

Der Auswahlprozess basierte auf einer Liste aller österreichischen Waldvogelarten mit einem Bestand von mindestens

200 Brutpaaren. Der Auswahlprozess lieferte 26 Vogelarten, die zusammen das optimale Set an Indikatorarten bildeten. Allerdings waren jährliche Daten zur Bestandsveränderung für acht dieser Arten nicht verfügbar: Schwarzstorch, Waldschnepfe, Sperlingskauz, Waldkauz, Mittelspecht, Kleinspecht, Dreizehenspecht und Zwergschnäpper. Aus diesem Grund führten wir den Auswahlprozess ein zweites Mal durch, diesmal eingeschränkt auf jene Arten, für die jährliche Daten zur Bestandsveränderung vorliegen. Die Datenquelle dafür war das Zählprogramm „Monitoring der Brutvögel Österreichs“ von BirdLife Österreich, das seit 1998 jährlich durchgeführt wird. Dieser Auswahlprozess lieferte zwei Sets an Indikatorarten, die nach den Kriterien der Auswahl beide gleich gut geeignet waren. Die Sets bestanden beide aus 19 Indikatorarten, und sie unterschieden sich lediglich in einer einzigen Art: Hohltaube, Kuckuck, Schwarzspecht, Buntspecht, Zaunkönig, Rotkehlchen, Nachtigall, Amsel, Berglaubsänger, Waldlaubsänger, Wintergoldhähnchen, Sommergoldhähnchen, Halsbandschnäpper, Sumpfmeise, Haubenmeise, Pirol, Eichelhäher, Fichtenkreuzschnabel und entweder Fitis oder Tannenmeise.

Die Trends der aus diesen beiden Sets gebildeten Waldvogelindikatoren unterschieden sich nicht signifikant voneinander. Ebensowenig unterschieden sich diese beiden Trends von der Bestandsentwicklung aller Vogelarten der Auswahlliste, für die Daten zur Bestandsentwicklung vorlagen. Alle drei Trends rangierten in einem Bereich von -1,13 %/Jahr bis -1,30 %/Jahr. Trotz dieses Ergebnisses halten wir es für wichtig, zur Erstellung des Waldvogelindikators für Österreich einen objektiven und formellen Auswahlprozess durchzuführen. Insbesondere das Ergebnis des optimalen Indikators zeigt klar auf, welche ökologischen Nischen derzeit in dem Indikator nicht abgebildet werden können. Das betrifft insbesondere Vogelarten, die Wirbeltiere als Nahrungsgrundlage nutzen, sowie Arten, die als Lebensraum alte und totholzreiche Wälder benötigen. Des Weiteren zeigte sich, dass die Datenerfassung aus dem Monitoring der Brutvögel Österreichs besonders Misch- und Nadelwälder in höheren Lagen untererfasst. Daher empfehlen wir die Ausweitung des Vogelmonitorings, um in einem zukünftigen Waldvogelindikator die gesamte Vogelartengemeinschaft von Österreichs Wäldern gut abbilden zu können.

6. References

Achtziger, R., H. Stickroth & R. Zieschank 2003: F+E Projekt Nachhaltigkeitsindikator für den Naturschutzbereich. Ber. Landesamtes für Umweltschutz Sachsen-Anhalt Sonderheft 1/2003: 138-142.

Achtziger, R., H. Stickroth & R. Zieschank 2004: Nachhaltigkeitsindikator für die Artenvielfalt – ein Indikator für den Zustand von Natur und Landschaft in Deutschland. Angew. Landschaftsökol. 63: 1-137.

Agresti, A. 1990: Analysis of categorical data. Wiley, New York.

BFW 2016: Österreichische Waldinventur. Wien, Bundesforschungs- und Ausbildungszentrum für Wald, Naturgefahren und Landschaft (BFW). Retrieved 5.12.2016, from http://www.waldinventur.at.

Butler, S. J., R. P. Freckleton, A. R. Renwick & K. Norris 2012: An objective, niche-based approach to indicator species selection. Methods Ecol. Evol. 3: 317-326.

Directorate General for Agriculture and Rural Development 2006: Rural Development 2007–2013: Handbook on Common Monitoring and Evaluation Framework. Guidance document. Retrieved 07.11.2007, from http://ec.europa.eu/agriculture/rurdev/eval/index_de.htm.

Dvorak, M., A. Ranner & H.-M. Berg 1993: Atlas der Brutvögel Österreichs. Umweltbundesamt, Wien.

Eskildsen, A., J. Dyhrberg Larsen & H. Heldbjerg 2013: Use of an objective indicator species selection method shows decline in bird populations in Danish habitats. Dansk Ornithol. Foren. Tidsskr. 107: 191-207.

European Bird Census Council 2016: Pan-European Common Bird Monitoring Scheme. Retrieved 21.09.2016, from http://www.ebcc.info/index.php?ID=28.

Gibbons, D. W. 2000: Development of Pan-European Breeding Bird Monitoring. Ring 22: 25-33.

Glutz von Blotzheim, U. N., K. M. Bauer & E. Bezzel 1966-1997: Handbuch der Vögel Mitteleuropas, Bände 1-14. Akad. Verlagsges., Wiesbaden und Aula-Verlag, Wiesbaden.

Greenwood, J. J. D. 2007: Citizens, science and bird conservation. J. Ornithol. 148: 77-124.

Gregory, R. D. & J. J. D. Greenwood 2008: Counting common birds. In: Voříšek, P., A. Klvaňová, S. Wotton & R. D. Gregory (eds.): A best practise guide for wild bird monitoring schemes: p. 21-55. CSO/RSPB, Czech Republic.

Gregory, R. D., D. G. Noble, R. Field, J. Marchant, M. Raven & D. G. Gibbons 2003: Using birds as indicators of biodiversity. Ornis Hungarica 12–13: 11-24.

Gregory, R. D., A. van Strien, P. Voříšek, A. W. G. Meyling, D. G. Noble, R. P. Foppen & D. W. Gibbons 2005: Developing indicators for European birds. Phil. Trans. R. Soc. B 360: 269-288.

Gregory, R. D., P. Voříšek, D. G. Noble, A. van Strien, A. Klvaňová, M. Eaton, A. W. Gmelig Meyling, A. Joys, R. P. B. Foppen & I. J. Burfield 2008: The generation and use of bird population indicators in Europe. Bird Conserv. Int. 18 (S1): 223-244.

Gregory, R. D., P. Voříšek, A. van Strien, A. W. Gmelig Meyling, F. Jiguet, L. Fornasari, J. Reif, P. Chylarecki & I. J. Burfield 2007: Population trends of widespread woodland birds in Europe. Ibis 149: 78-97.

Gregory, R. D., S. G. Willis, F. Jiguet, P. Voříšek, A. Klvanova, A. van Strien, B. Huntley, Y. C. Collingham, D. Couvet & R. E. Green 2009: An indicator of the impact of climatic change on European bird populations. PLoS One 4: e4678.

Hauk, E. & Schadauer K. o.J.: Instruktion für die Feldarbeit der Österreichischen Waldinventur 2007–2009 (Fassung 2009). Retrieved 07.08.2013, from http://bfw.ac.at/700/pdf/DA_2009_Endfassung_klein.pdf.

Kilian, W., F. Müller & F. Starlinger 1994: Die forstlichen Wuchsgebiete Österreichs. Eine Naturraumgliederung nach forstökologischen Gesichtspunkten. Forstliche Bundesversuchsanstalt Berichte 82, Forstliche Bundesversuchsanstalt, Wien.

Lehikoinen, A., M. Green, M. Husby, J. A. Kålås & Å. Lindström 2014: Common montane birds are declining in northern Europe. J. Avian Biol. 45: 3-14.

Ostasiewicz, M., T. Chodkiewicz, P. Chylarecki, G. Neubauer & B. Woźniak 2011: Index of common forest birds – what can we accomplish using data from common breeding bird monitoring scheme in State Monitoring of Environment? Studia i Materiały CEPL w Rogowie 13: 65-76.

Pannekoek, J. & A. van Strien 2001: TRIM 3 Manual. Trends and Indices in monitoring data. Statistics Netherlands, Voorburg.

Reif, J., P. Voříšek, K. Šťastný, V. Bejček & J. Petr 2007: Population increase of forest birds in the Czech Republic between 1982 and 2003. Bird Study 54: 248-255.

Russ, W. 2011: Mehr Wald in Österreich. BFW Praxis Information 24: 3-5.

Sanderson, F.J., P.F. Donald, D.J. Pain, I.J. Burfield & F.P.J. van Bommel 2006: Long-term population declines in Afro-Palearctic migrant birds. Biol. Conserv. 131: 93-105.

Sauer, J.R., J.E. Hines, J.E. Fallon, K.L. Pardieck, D.J. Ziolkowski Jr. & W.A. Link 2014: The North American Breeding Bird Survey, Results and Analysis 1966–2013. Version 01.30.2015. Retrieved 21.09.2016, from http://www.mbr-pwrc.usgs.gov/bbs/.

Soldaat, L. (2016): Methodology workshop: A practical method to test for trends in multi-species indicators. In: Busch, M. & K. Gedeon (eds.): Bird Numbers 2016: Birds in a changing world: 101. Dachverband Deutscher Avifaunisten, Halle (Saale), Germany.

Soldaat, L.L., J. Pannekoek, R.J.T. Verweij, C. van Turnhout & A.J. van Strien Submitted: A Monte Carlo method to account for sampling error in multi-species indicators.

Stephens, P.A., L.R. Mason, R.E. Green, R.D. Gregory, J.R. Sauer, J. Alison, A. Aunins, L. Brotons, S.H. Butchart, T. Campedelli, T. Chodkiewicz, P. Chylarecki, O. Crowe, J. Elts, V. Escandell, R.P. Foppen, H. Heldbjerg, S. Herrando, M. Husby, F. Jiguet, A. Lehikoinen, A. Lindstrom, D.G. Noble, J.Y. Paquet, J. Reif, T. Sattler, T. Szep, N. Teufelbauer, S. Trautmann, A.J. van Strien, C.A. van Turnhout, P. Voříšek & S.G. Willis 2016: Consistent response of bird populations to climate change on two continents. Science 352: 84-87.

Szép, T., K. Nagy, Z. Nagy & G. Halmo 2012: Population trends of common breeding and wintering birds in Hungary, decline of longdistance migrant and farmland birds during 1999–2012. Ornis Hungarica 20: 13-63.

Ter Braak, C.J.F., A. van Strien, R. Meijer & T.J. Verstrael 1994: Analysis of monitoring data with many missing values: which method? In: Hagemeijer E.J.M. & T.J. Verstrael (eds.): Bird Numbers 1992. Distribution, monitoring and ecological aspects. Proceedings of the 12th International Conference of IBCC and EOAC, Noordwijkerhout, The Netherlands: p. 663-673. Statistics Netherlands, Voorburg/Heerlen & SOVON, Beek-Ubbergen.

Teufelbauer, N. 2010: Der Farmland Bird Index für Österreich – erste Ergebnisse zur Bestandsentwicklung häufiger Vogelarten des Kulturlandes. Egretta 51: 35-50.

Teufelbauer, N. 2013a: Farmland Bird Index für Österreich: Landschaftselemente und Indikator 2011/12 – 2. Teilbericht: Farmland Bird Index 2012 für Österreich. Im Auftrag des Lebensministeriums. BirdLife Österreich, Wien.

Teufelbauer, N. 2013b: Monitoring der Brutvögel Österreichs – Bericht über die Saison 2012. BirdLife Österreich, Wien.

Teufelbauer, N. & J. Frühauf 2010: Developing a national Farmland Bird Index for Austria. In: Anselin, A. (ed.): Bird Numbers 2010. Monitoring, indicato rs and targets. Proceedings the 18th Conference of the European Bird Census Council, Cáceres, Spain (partim). Bird Census News 23: 87-97.

Teufelbauer, N. & B. Seaman 2016: Monitoring der Brutvögel Österreichs – Bericht über die Saison 2015. BirdLife Österreich, Wien.

van Strien, A., J. Pannekoek & D.W. Gibbons 2001: Indexing European bird population trends using results of national monitoring schemes: a trial of a new method. Bird Study 48: 200-213.

van Strien, A., J. Pannekoek, W. Hagemeijer & T. Verstrael 2004: A loglinear Poisson regression method to analyse bird monitoring data. Bird Census News 13: 33-39 (Bird Numbers 1995: Proceedings of the International Conference and 13th Meeting of the European Bird Census Council, Pärnu, Estonia, 25–29 September 1995).

van Strien, A. & L. Soldaat 2008: Calculating indices and trends using TRIM. In: Voříšek, P., A. Klvaňová, S. Wotton & R.D. Gregory (eds.): A best practise guide for wild bird monitoring schemes: 87-92. Czech Republic, CSO/RSPB.

van Turnhout, C., F. Willems, C. Plate, A. van Strien, W. Teunissen, A. van Dijk & R. Foppen 2008: Monitoring common and scarce breeding birds in the Netherlands: applying a posthoc stratification and weighting procedure to obtain less biased population trends. Revista Catalana d'Ornitologia 24: 15-29.

Vickery, J.A., S.R. Ewing, K.W. Smith, D.J. Pain, F. Bairlein, J. Škorpilová & R.D. Gregory 2014: The decline of Afro-Palaearctic migrants and an assessment of potential causes. Ibis 156: 1-22.

Wade, A.S., B. Barov, I.J. Burfield, R.D. Gregory, K. Norris, P. Voříšek, T. Wu & S.J. Butler 2014: A niche-based framework to assess current monitoring of European forest birds and guide indicator species' selection. PLoS One 9: e97217.

Zbinden, N., H. Schmid, M. Kéry & V. Keller 2005: Swiss Bird Index SBI. Artweise und kombinierte Indices für die Beurteilung der Bestandsentwicklung von Brutvogelarten und Artengruppen in der Schweiz 1990–2003. Schweizerische Vogelwarte, Sempach.

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