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Effect of agri-environment measure for the aquatic warbler on bird biodiversity in the extensively managed landscape of Biebrza Marshes (Poland)

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ABSTRACT

Farming intensification is one of the main factors responsible for bird populations declining in agricultural landscapes. Therefore, many countries implement agri-environment schemes (AES) to protect farmland biodiversity. However, recent studies showed that the effectiveness of AES varies between positive and negative.

In this study we evaluated the effect an agri-environment measure, designed for aquatic warblers (AWM), has on bird biodiversity in a marginal, extensively managed landscape under strong succession pressure. We applied a point-count method to survey birds in areas within the AWM and outside the AWM and described habitat characteristics around these points.

We found that AWM areas had a positive effect on the occurrence of aquatic warblers and six other bird species, meadow and Polish AES bird species richness; negatively affected the occurrence of three bird species and the all bird species richness, and was neutral for the occurrence of another ten bird species and for farmland bird species richness. We also show the diverse and sometimes mutually exclusive habitat preferences of the various species.

The AWM implemented in extensively managed landscape successfully encouraged farmers to conduct extensive mowing of meadows and so stopped the habitat succession process. Simultaneously, if AWM is considered on a micro scale, it strongly supported some species but also eliminated others. Therefore, we suggest that management plans should be created at a landscape level. Such approach enables the determination of areas in which different species or groups of species are prioritised before others, allowing for the conservation of overall biodiversity.

1. Introduction

Agricultural landscapes cover more than 40% of European Union countries (Eurostat 2015) and are highly diverse, ranging from extensive, traditional farming to industrial production (Meeus et al., 1990). In the last century fundamental changes in agriculture have been observed, including shifts in land cover, scale enlargement, intensification of farming and abandonment of marginal lands (Meeus et al., 1990; Henle et al., 2008). These changes turned out to be unfavourable for many farmland bird species and the overall biodiversity (Donald et al., 2001). Therefore, various activities have been implemented on regional, national or international levels to help reduce the decline in populations of particular species, protect habitats or to react against the loss in biodiversity (Kleijn and Sutherland, 2003; Batáry et al., 2015). Due to the EU Common Agricultural Policy, EU countries implemented agri-environmental schemes (AES) to promote environment-friendly farming. Some of these AES are focused on the protection of birds found in the agricultural landscape. In general, areas under AES are managed according to the preferences of a target in need of protection, which could be a species, group of species or type of habitat (Kleijn and Sutherland, 2003; Pywell et al., 2012; Batáry et al., 2015) and farmers get payments for such environment-friendly activities. Current experiences with AES in the EU show that a lot of them were successful and protected unique habitats, stopped population declines of target species or reduced biodiversity loss (Newton, 2004; Pywell et al., 2012; Batáry et al., 2015). However, in some cases, implemented activities have not yielded the expected benefits with the impact of AES being marginal, insignificant (Kleijn et al., 2006;

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Zmihorski et al., 2016; Bellebaum and Koffijberg, 2018) or even managing to cause a decrease in species richness and abundance (Kleijn and Sutherland, 2003). The varying effectiveness of AES found in different studies may result from a few factors. The first one is the lack of biological and ecological knowledge about the target of protection and, as a consequence, inappropriate activities are implemented under AES. Therefore, conservation actions supervised by scientists or volunteers are often more successful than those without such support (Batáry et al., 2015). Another issue is related with the target of protection and the measure which is used to evaluate the effectiveness of AES. Some AES are dedicated to a particular species (usually rare or endangered), while others are focused on broad environmental objectives and general biodiversity protection (Pywell et al., 2012). It was shown that habitat enhancement methods designed to provide the preferred requirements of target species consistently increased the richness and abundance of both rare and common species, while more general conservation measures are less successful and only lead to small increases in biodiversity, usually of common species (Pywell et al., 2012). Biodiversity of common species may be enhanced even when farming practices are only modified in a relatively simple way, especially in intensively farmed landscapes (Meichtry-Stier et al., 2018). More elaborate conservation measures are required when the target of AES is the protection of endangered species in extensively managed areas or the reintroduction of them into intensively managed landscapes (Kleijn et al., 2006).

The effectiveness of AES is also strongly related with landscape context and agricultural land-use intensity. In general, the effectiveness of AES should be higher in relatively simple landscapes than in complex ones (Tscharntke et al., 2005; Kleijn et al., 2011). For example, hedge length has a strong, positive influence on birds species richness in simple landscapes, however, in complex landscapes, this is not important as biodiversity in complex landscapes is high everywhere (Batáry et al., 2010). In addition, the effectiveness of AES may also depend on habitat type. Batáry et al. (2011) found that in cropland, species richness was significantly enhanced by AES in simple but not in complex landscapes, while in grasslands, AES effectively enhanced species richness regardless of landscape context. Nevertheless, even in structurally simple landscapes, some semi-natural habitats should be present – if the surrounding landscape has low biodiversity, then the habitat created by AES may be colonised poorly (Tscharntke et al., 2005). On the other hand, biodiversity is higher in extensively farmed rather than in intensively farmed agricultural areas (Tryjanowski et al., 2011). Therefore, increasing land-use intensity in extensively farmed areas should cause higher biodiversity loss than in intensive landscapes, since biodiversity on agricultural land declines exponentially with increasing land-use intensity (Kleijn et al., 2009). This suggests that AES should be more effective in extensive rather than intensively managed landscapes. In short – conserving what is left is more effective than getting back what was lost (Kleijn et al., 2011).

The great majority of studies evaluating the effectiveness of AES have been focused on intensively farmed landscapes, and AES activities lead up to decreasing the intensity of agriculture and therefore cause biodiversity improvement (Batáry et al., 2010). However, agricultural margin areas, which are characterised by high biodiversity (Tryjanowski et al., 2011), are under strong pressure from agricultural intensification, but may be abandoned and transformed into woodlands during the succession process (Batáry et al., 2010). Areas with unfavourable biophysical conditions (short vegetation season, frequent inundation, steep slopes, low soil quality, high soil moisture) are more likely to be abandoned by farmers, and as a consequence allow for the succession of shrubs and trees (Schmidt et al., 2000). Thus in the last case, AES should protect existing biodiversity and inhibit the succession process.

In our study we investigated the effectiveness of the agri-environmental measure implemented for the protection of the aquatic warbler (*Acrocephalus paludicola)* (henceforth AWM) in the extensively managed landscape of Biebrza Marshes (NE Poland). The aquatic warbler is a promiscuous, migratory and globally threatened songbird (Red List category: vulnerable, decreasing population trend; BirdLife International, 2018). The global population is highly fragmented and is estimated at 11,000–16,000 singing males, with Poland hosting 2700 – 3100 (ca. 20% of global population) (Flade et al., 2011; Kloskowski et al., 2015; BirdLife International, 2018). Aquatic warblers inhabit sedge fen mires and wetlands with similarly structured, low vegetation (Mitteilungen and Schulze-Hagen, 1989), and are considered to be a flagship species for those habitats (Kloskowski et al., 2015). Aquatic warbler-friendly management should be focused on late mowing, creating a mosaic of early and late patches, removing bushes and regulating water levels (Tanneberger et al., 2010). Such land use should be positive not only for aquatic warbler populations, but also for other threatened plant and animal species typical of fens and sedge meadows (Tanneberger et al., 2010). Wetlands occupied by aquatic warblers are unattractive for modern agriculture (high water level, vegetation structure with tussocks), therefore, they are usually abandoned or drained.

From many agri-environmental measures implemented in Poland in 2014–2020, four are focused on the protection of breeding habitats of rare and endangered birds in Natura 2000: (1) northern lapwing, black-tailed godwit, common snipe and common redshank; (2) Eurasian curlew and great snipe; (3) aquatic warbler, (4) corncrake. Due to the breeding distribution of the aquatic warbler being limited, the AWM is actually applied in 8 locations in Poland. Farmers applying the AWM are obligated to use agricultural areas with late mowing or low-intensity grazing. When an area is mowed (once a year, from 15 August to 15 February), 15–85% of the area is left unmown each year, or alternatively, the whole area is mowed each second year. In both cases the biomass is removed for two weeks after the mowing occurs and the mowing technique must not destroy the vegetation structure. Farmers must not undergo any agricultural activities until the 1 st April to the time of mowing. Any activities decreasing water levels are prohibited.

In this study, we examined how AWM impacts the target species (aquatic warbler), selected groups of species and general bird biodiversity. The AWM should create habitats in a specific way, and so we compared habitat characteristics at AWM and control points as well as analysing which habitat features are beneficial and which are unfavourable for the most common bird species observed during our study period. We predicted that in an extensively managed landscape, strong secondary succession may limit the occurrence of typical meadow species and support forest or ecotone species. Therefore, AWM should stop the succession process, positively influencing meadow species and negatively influencing forest and ecotone species.

2. Methods

2.1. Study site

The study was conducted in the Natura 2000 site Ostoja Biebrzańska (PLB200006), located in north-eastern Poland. The Biebrza Wetlands cover an area of 116,000 ha and have unique natural values due to water and swamp ecosystems (Okruszko, 1990). About half of this area is protected in the Biebrza National Park, which is the largest national park in Poland (Budka et al., 2013). A large area of the Biebrza valley has been used for haymaking since the mid- 16th century (Bartoszuk and Kotowski, 2009). The old and extensive management of wet grasslands has shaped many valuable botanical habitats i.e. Biebrza NP contains over 10% of the EU's alkaline fens (Sefferova et al., 2008). A flagship bird species of the Biebrza fen mires is the aquatic warbler and this holds one of the largest population of this species in the world (Oppel et al., 2014).

Since the 1970's, the process of abandoning the use of Biebrza meadows has been intensifying, causing them to overgrow with common reed (*Phragmites australis*) and woody vegetation, including willows (*Salix sp.*) and birches (*Betula sp.*; Oświt, 1973). Nowadays, secondary plant succession on marsh and wet meadows is one of the main threats of Biebrza wetlands biodiversity (Dembek, 2002). Breeding habitats of aquatic warblers are threatened due to land abandonment (Oppel et al., 2014). The implementation of AES on a large scale, in the area of the Biebrza valley, contributed to the maintainance and restoration of the aquatic warbler habitats (Lachmann et al., 2010), but also created additional threats to other species (Kotowski et al., 2013).

2.2. Bird counting and habitat description

In 2015 ornithologists found aquatic warbler in 166 parcels in Ostoja Biebrzańska. These parcels were entered for the AWM and were managed by farmers according to the requirements of the AWM. In each parcel ornithologists surveyed birds by using the point-count method in at least one point. When the bird survey was conducted in more than one point per parcel, we selected the first point to conduct our monitoring. For each AWM point we selected a control point using orthophotomap. The control point was at a distance less than 10 km from AWM point (medium distance between AWM point and paired control point was 1529 m; minimum 302 m; maximum – 6 685 m). We took care to locate the control point in grasslands with similar physiographic conditions to the paired AWM points (i.e. similar distance to the forest and watercourses, shares of bushes, shrubs and watercourses in buffer around the point, similar structure of vegetation and similar altitude). In this way we tried to minimise the influence of factors other than meadow management on the birds. In contrast to AWM areas, control points were located in parcels in which farmers had no restriction to farming regimes, like the intensity of farming, time of mowing and leaving unmown areas or management of water level.

To avoid double counting of the same birds from different points, during the selection of points we rejected those points which were located closer than 300 m from already selected ones. Finally we randomly selected 70 AWM points and 70 control points. However, during the first field survey we found that access to some points was very difficult, or we met other technical problems to conduct four surveys during the study. Therefore, in the final analyses we only considered 120 points (60 AWM points and 60 control points) in which four surveys (two in 2017 and two in 2018) were successfully conducted.

Bird surveys were conducted as a part of a larger, nationwide monitoring of the agri-environmental schemes effectiveness. We applied a fixed-radius point count method, similar to a previous study examining the effectiveness of AES in Poland (Zmihorski et al., 2016). Each point was visited twice a year: between 19th April and 19th May (early survey), and between 26th May and 29th June (late survey). The average interval between early and late surveys at the same point was 39 days (from 24 to 54 days). All bird species seen and heard within a 100 m radius around the point were counted (except for nestlings and those that moved at high altitude) during the 10-minutes of the survey. Fieldwork was conducted by three experienced observers who counted birds in the morning – from 04:18 to 09:54 during the early survey or from 03:11 to 8:59 during the late survey (local time). Observers also collected basic data on the structure of land use, grassland management and habitat characteristics. Habitat characteristics were assessed as proportions of different land use forms (grassland, arable land, forests and shrubs, waters, buildings) in a buffer 100 m from the point. Additional criteria were adopted for grasslands. We evaluated: share of each form of management (mowing meadows; grazed meadows; no used meadows), share of individual sward height classes (low meadows – covered by vegetation lower than 30 cm; high meadows – covered by vegetation higher than 30 cm) and moisture classes (wet meadows – water appears after pressing the ground or remains above the ground; dry meadows – water is not found).

2.3. Statistical analysis

We conducted two sets of models to evaluate how AWM impacts bird species richness and how it effects the most common single species. We used Generalized Estimating Equations (GEE), which enabled us to analyse repeated measurement data (in our case – surveys in the same point). We compared: (1) number of all bird species, (2) number of Polish AES species, (3) number of meadow species, and (4) number of farmland species between points located on AEM areas and control areas (see Appendix A for the list of the species included into each category). In all cases we used the number of species detected within 100 m around a point during early and late survey conducted in the same year for the dependent variable. Data were fitted by a Poisson distribution and loglinear link function. We used (1) year (2017 or 2018), (2) AWM (present or absent), and (3) interactions between them (year x AWM) as factors. Visibility was used as an offset variable to eliminate differences in visibility between points. In each model we defined point as a subject and year as a repeated measure. Additionally, in the same way we tested how AWM impacted the occurrence (data fitted by binary distribution and logistic link function) of 20 of the most commonly observed species in our study (recorded in more than 20% points), including the target species – the aquatic warbler.

To examine the impact of AWM on habitat characteristics we compared (1) covering by successional vegetation (area covered by shrubs and forests), (2) covering by wet meadows (percent of wet meadows from whole meadows within 100 m radius around the point) and (3) covering by unmown meadows (percent of unmown meadows from whole meadows within 100 m radius around the point) between AWM and control points. We chose these characteristics because they should strongly depend on the management of agricultural areas. We applied separate GEEs for each dependent variable. In each model we defined point as a subject and year and survey as repeated measurements. As predictors we used (1) year (2017 or 2018), (2) AWM (present or absent), (3) survey (early or late) and interaction between these three predictors. Data were fitted by negative binomial distribution and log link function.

Habitat preferences of the 20 most common bird species were analysed using GEE. Initially, we described habitat using nine variables: (1) covering by successional vegetation, (2) covering by meadows, (3) covering by water, (4) percentage of meadows with high vegetation (> 30 cm), (5) percentage of meadows with short vegetation (< 30 cm), (6) percentage of dry meadows, (7) percentage of wet meadows, (8) percentage of unmown meadows, (9) percentage of mown meadows. In the analysis we excluded three variables which were only observed occasionally during our study: covering by crops (observed in 2 points), presence of farm buildings (observed in 5 points), covering by pastures (observed in 1 point). Habitat characteristics were significantly and highly correlated with each other (variable 1 and 2: $r = -0.980$, $p < 0.01$; variable 4 and 5: $r = -0.668$, $p < 0.001$; variable 6 and 7: $r = -0.747$, $p < 0.01$; variable 8 and 9: $r = -0.330$, $p < 0.01$). Therefore, for each pair of variables we conducted a separate principal component analysis (PCA) to reduce the number of variables from two to one and eliminate collinearity. In this way we get four new variables (PCA regression scores) which we named as a gradient of: (1) succession, (2) vegetation height, (3) moisture, (4) agricultural use. Then, we extracted four gradients and original variables of water level as factors. Habitat preferences of birds may change across the breeding season. Therefore in our models we specified point as a subject and year and survey as repeated measurements. As the dependent variable we used occurrence of the species (present vs absent) during a single survey. Data were fitted by binary distribution and logistic link function. Visibility in point was set as an offset value. Statistical analyses were run in IBM SPSS Statistics 25. All p-values are two-tailed.

Table 1
Results of four Generalized Estimating Equations examining the influence of AWM and year on all bird species richness, Polish AES bird species richness, meadow bird species richness and farmland bird species richness. See Appendix A for the list of bird species included in each category. Significant effects are in bold.

	B	SE	Wald χ^2	df	p
	Overall bird species richness				
Intercept	**1.396**	**0.0645**	**467.870**	**1**	**< 0.001**
AWM = present	**−0.291**	**0.0891**	**10.708**	**1**	**< 0.001**
Year = 2017	0.035	0.0471	0.537	1	0.464
AWM [present] x Year [2017]	0.038	0.0715	0.287	1	0.592
	Polish AES bird species richness				
Intercept	**−0.991**	**0.1283**	**59.688**	**1**	**< 0.001**
AWM = present	**0.507**	**0.1621**	**9.764**	**1**	**0.002**
Year = 2017	0.065	0.1473	0.192	1	0.661
AWM [present] x Year [2017]	0.064	0.1798	0.125	1	0.723
	Meadow bird species richness				
Intercept	−0.004	0.1024	0.002	1	0.968
AWM = present	**0.320**	**0.1216**	**6.942**	**1**	**0.008**
Year = 2017	0.033	0.0954	0.121	1	0.728
AWM [present] x Year [2017]	−0.038	0.1205	0.098	1	0.755
	Farmland bird species richness				
Intercept	−0.032	0.1038	0.094	1	0.760
AWM = present	−0.230	0.1406	2.667	1	0.102
Year = 2017	−0.047	0.1194	0.157	1	0.692
AWM [present] x Year [2017]	0.257	0.1597	2.596	1	0.107

3. Results

During this study we recorded 89 bird species within a 100 m radius around counting points. A single survey enabled us to detect on average of 4.7 species (from 0 to 12 species). Cumulatively, during two surveys conducted in the same year observers detected on average 7.6 species (from 0 to 16 species), and during four surveys conducted in 2017 and 2018 – 11.4 species per point (from 2 to 22 species). Four species were recorded in more than 50% of points during the two year study (Appendix B). Detailed data are available in supplementary materials (Appendix C).

3.1. Bird biodiversity at AWM and control points

We found significant differences in the overall bird species richness, meadow and Polish AES bird species richness, but not in the farmland bird species richness between points located in AWM and control areas (Table 1). The overall bird species richness was significantly higher at control points, while the Polish AES and meadow bird species richness were significantly higher at AWM points (Table 1, Fig. 1). In all four models we did not observe significant effects of year and interaction between year and presence of AWM.

3.2. Effect of AWM on target species and the most common species

The target species (aquatic warbler), was recorded in 43% of AWM points and in 3% of control points. We found that the probability of aquatic warbler occurrence was significantly higher in AWM points than in control points (Table 2). Presence of AWM positively affected seven bird species, but negatively affected three bird species and was neutral for ten bird species (Table 3).

3.3. Impact of AWM on habitat characteristics

We found that the proportion of area covered by various succession stages (from shrubs to forest) around control points was significantly higher than around AWM points (on average 43% at control points vs 8% at AWM points; Table 4). AWM points were wetter than control points (higher percent of wet meadows within 100 m around the point).

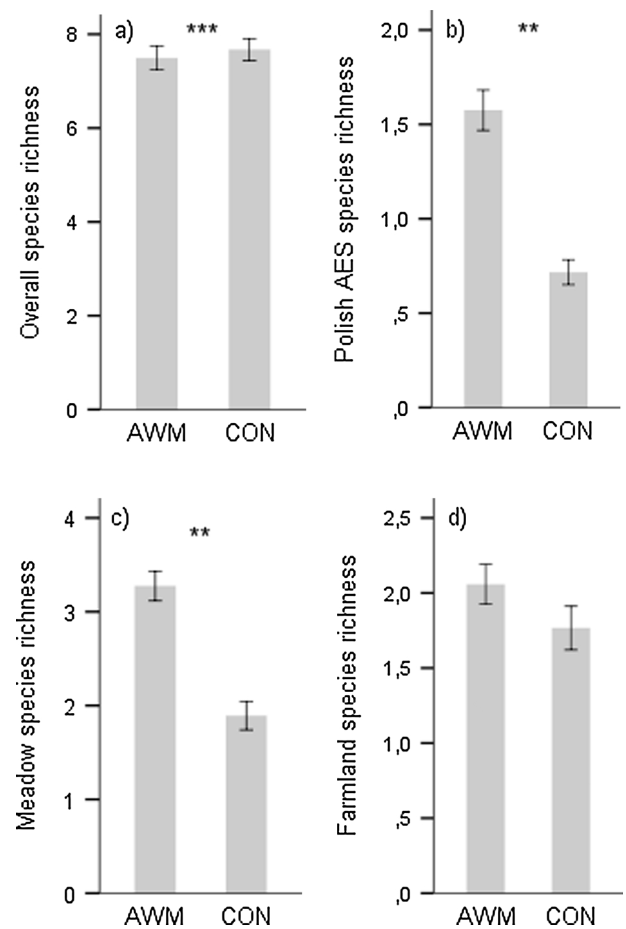

Fig. 1. Differences in average (a) overall bird species richness, (b) Polish AES bird species richness, (c) meadow bird species richness and (d) farmland bird species richness between AWM points and control (CON) points. During the study we observed 89 bird species, 8 Polish AES bird species, 20 meadow bird species and 13 farmland bird species. Mean number of species (+/- standard errors of mean) detected at point are given. Graphs based on 120 points surveyed in two breeding seasons. *** - $p < 0.001$, ** - $p < 0.01$. See Table 1 for model details.

Table 2
Results of Generalized Estimating Equation examining the effect of AWM and year on the occurrence of the target species- aquatic warbler. Significant effects are in bold.

	B	SE	Wald χ^2	df	p
Intercept	**2.878**	**0.7322**	**15.445**	**1**	**< 0.001**
AWM = present	**−2.864**	**0.7911**	**13.101**	**1**	**< 0.001**
Year = 2017	0.664	0.7197	0.852	1	0.356
AWM [present] x Year [2017]	−1.200	0.7510	2.552	1	0.110

The moisture was significantly higher during the early rather than the late survey, and in 2017 than in 2018. We observed a significantly higher decrease in cover by wet meadows between surveys (decrease in late survey) in 2018 than in 2017 (Table 4; Fig. 2a). However, we did not find significant differences in interaction of AWM and year or AWM and survey, meaning that seasonal and yearly changes in moisture were not dependent on presence of AWM. We also found that meadows around AWM points were unmown during both surveys, while around the control points we only observed mowing during the late survey (Table 4; Fig. 2b).

Table 3
Results of Generalized Estimating Equations examining effect of the AWM and year on occurrence of the 20 the most common species. ↑ - positive effect of AWM / widely distributed in 2018; ↓ - negative effect of AWM / widely distributed in 2017; * - $p < 0.05$; ** - $p < 0.01$; *** - $p < 0.001$; NS – no significant. The occurrence is defined as a percentage of points at which a particular species was detected during two-years study.

Species	Occurrence (%)	AWM	Year	AWM x Year
Savi's warbler	28.3	NS	NS	↑*
Common whitethroat	48.3	↓*	NS	NS
Northern lapwing	24.2	↑***	NS	NS
Common rosefinch	25.0	↓*	↑**	NS
Red-backed shrike	20.0	NS	NS	NS
Barred warbler	29.2	NS	↓*	NS
Eurasian blackcap	20.8	NS	↓*	NS
Mallard	24.2	NS	NS	NS
Common snipe	77.5	↑***	↓*	NS
Willow warbler	50.0	↓***	↓*	NS
Bluethroat	21.7	NS	NS	NS
Whinchat	29.2	NS	NS	NS
Reed bunting	79.2	↑*	NS	NS
Sedge warbler	69.2	↑*	NS	NS
Skylark	31.7	NS	↓*	↓*
European starling	27.5	NS	↓*	↓*
Meadow pipit	41.7	↑***	NS	NS
Aquatic warbler	23.3	↑***	NS	NS
Grasshopper warbler	37.5	↑***	NS	NS
Water rail	22.5	NS	NS	NS

Table 4
Results of three Generalized Estimating Equations examining the impact of AWM on habitat characteristics. Significant effects are in bold.

	B	SE	Wald χ^2	df	p
	Sucession				
Intercept	**3.731**	**0.1277**	**853.641**	**1**	**< 0.001**
AWM = present	**−1.592**	**0.2650**	**36.099**	**1**	**< 0.001**
Year = 2017	0.062	0.0617	1.005	1	0.316
Survey = early	0.009	0.0588	0.022	1	0.883
AWM [present] x Year [2017]	0.070	0.1252	0.317	1	0.574
AWM [present] x Survey [early]	−0.154	0.1131	1.858	1	0.173
Year [2017] x Survey [early]	−0.006	0.1115	0.003	1	0.957
	Wet meadows				
Intercept	**2.677**	**0.2755**	**94.361**	**1**	**< 0.001**
AWM = present	**0.834**	**0.2879**	**8.390**	**1**	**0.004**
Year = 2017	**0.926**	**0.2142**	**18.687**	**1**	**< 0.001**
Survey = early	**1.539**	**0.2445**	**39.633**	**1**	**< 0.001**
AWM [present] x Year [2017]	−0.204	0.1656	1.512	1	0.219
AWM [present] x Survey [early]	−0.413	0.2226	3.443	1	0.064
Year [2017] x Survey [early]	**−0.800**	**0.1629**	**24.142**	**1**	**< 0.001**
	Unmowed meadows				
Intercept	**4.203**	**0.0868**	**2346.869**	**1**	**< 0.001**
AWM = present	**0.404**	**0.0880**	**21.015**	**1**	**< 0.001**
Year = 2017	0.014	0.0486	0.078	1	0.779
Survey = early	**0.138**	**0.0532**	**6.732**	**1**	**0.009**
AWM [present] x Year [2017]	−0.016	0.0441	0.133	1	0.715
AWM [present] x Survey [early]	**−0.140**	**0.0537**	**6.845**	**1**	**0.009**
Year [2017] x Survey [early]	0.005	0.0375	0.019	1	0.889

3.4. Habitat preferences of the most common birds

Four separate PCAs enabled us to reduce the number of variables from eight to four principal components: (1) succession, which was correlated positively (0.995) with coverage by successional vegetation, negatively (-0.995) with coverage by meadows and explained 99.0% of total variance; (2) vegetation high, which was correlated positively (0.913) with coverage by meadows with high vegetation, negatively (-0.913) with coverage by meadows with short vegetation and explained 83.4% of total variance; (3) moisture, which was correlated positively (0.934) with coverage by wet meadows, negatively (-0.934)

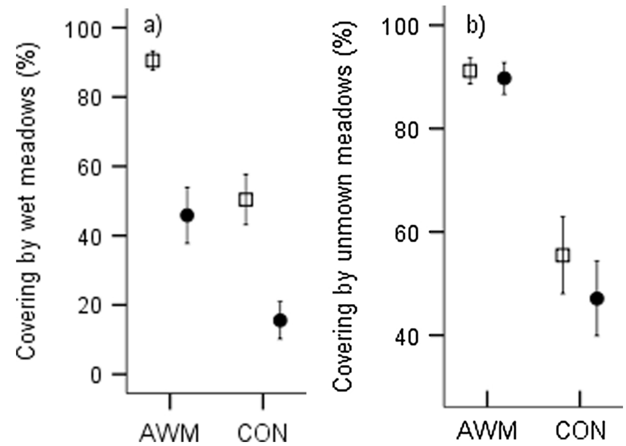

Fig. 2. Differences in average covering by (a) wet and (b) unmown meadows between AWM and control (CON) points during early (squares) and late (circles) survey. Mean values and 95% confidence interval for mean are given.

with coverage by dry meadows and explained 87.3% of total variance; (4) agricultural use, which was correlated positively (0.815) with coverage by mown meadows, negatively (-0.815) with coverage by unmown meadows and explained 66.5% of total variance. In all four PCAs the Kaiser-Meyer-Olkin measure of sampling adequacy was equal 0.5 and the Barlett's test of sphericity was significant ($p < 0.001$).

We found that increasing the areas covered by successional vegetation positively affected the occurrence of five species, and negatively affected nine species (Table 5). Increasing areas covered by wet meadows positively affected the occurrence of six species and was negative for five other species. Increasing areas that were mowed positively affected the occurrence of two species and negatively affected one species. Increasing areas with high vegetation positively affected the occurrence of six species and negatively of five species. Areas covered by water was avoided by one species.

4. Discussion

The results of our study showed positive, neutral and negative effects of AWM on bird biodiversity, the occurrence of particular species or their groups (Tables 1–3). In our case, the effectiveness of AWM depended on the measure used for evaluation. In AES, and any other protection schemes dedicated to a particular species, the changes in abundance or distribution of the target of protection should be the measure used for evaluation (Bellebaum and Koffijberg, 2018). Using this criteria, AWM was successful, as the aquatic warbler occurred significantly more often at AWM than control points (Table 2). Also, Polish AES bird species richness, as well as meadow bird species richness, were greater in AWM than control points. Similar to other studies, AWM was beneficial not only to the target of protection but also to other species (Wood et al., 2015; Fischer and Wagner, 2016; Ouvrard and Jacquemart, 2018). This result is consistent with the conception of umbrella species (in our case the aquatic warbler) whose protection automatically protects other organisms living in the same habitat (Simberloff, 1998). However, we also found an opposite pattern when we considered the overall bird species richness. We found lower overall bird species richness in AWM than in control points, however, when considering farmland bird species richness, AWM did not affect them negatively (Table 1). Similarly, when the effect of AWM was considered separately for each species, we found a positive response for some meadow species (e.g. northern lapwing, grasshopper warbler, meadow pipit), no response in certain species (e.g. whinchat, mallard, red-backed shrike) and negative responses for three of the 20 analysed species (common whitethroat, common rosefinch, willow warbler) (Table 3). These results show the challenges associated with project

Table 5
Results of Generalized Estimating Equations examining habitat preferences of the 20 the most common bird species. In the models we specified point as a subject, year and survey as repeated measurements. As a dependent variable we used occurrence of the species (present vs absent) during a single survey. Data were fitted by binary distribution and logistic link function. ↑ - probability of species occurrence significantly increases when value of habitat characteristic increase; ↓ - probability of species detection significantly decreases when value of habitat characteristic increase; * - p < 0.05; ** - p < 0.01; *** - p < 0.001; NS – no significant effect. Interpretation of habitat characteristics see subsection 3.4. Number of detections indicates in how many surveys (from 480 conducted) a particular species was detected.

Species	Number of detections	Agricultural use	Moisture	Succession	Vegetation high	Water
Savi's warbler	75	NS	↑**	NS	NS	NS
Common whitethroat	104	NS	NS	NS	NS	NS
Northern lapwing	35	NS	NS	↓*	↓**	NS
Common rosefinch	35	↑**	↓**	↑*	↑**	NS
Red-backed shrike	32	↑*	NS	NS	NS	NS
Barred warbler	50	NS	NS	↑**	↑*	NS
Eurasian blackcap	49	NS	NS	↑***	NS	NS
Mallard	36	NS	↑*	↓**	NS	NS
Common snipe	172	↓*	↑***	↓***	NS	NS
Willow warbler	141	NS	NS	↑***	↓*	NS
Bluethroat	37	NS	NS	↑***	NS	NS
Whinchat	65	NS	NS	↓***	↓*	NS
Reed bunting	233	NS	NS	↓*	↑***	NS
Sedge warbler	221	NS	↑**	NS	↑***	NS
Skylark	81	NS	↓***	↓***	↓***	NS
European starling	48	NS	↓**	↓***	NS	NS
Meadow pipit	100	NS	NS	↓***	↓***	↓*
Aquatic warbler	59	NS	↑*	↓*	↑**	NS
Grasshopper warbler	65	NS	NS	NS	NS	NS
Water rail	40	NS	↑**	NS	↑*	NS

management units when choosing the target of protection and planning conservation activities. One strategy is that creation of habitats on a micro scale which strongly supports some species but also eliminates others. In our study regular, extensive farming prevented succession and supported meadow species, but simultaneously, had a negative influence on early-succession stage species (Table 3). On a micro scale, AWM created homogenous patches of land which are strongly preferred by some species but also strongly avoided by others. Species richness tends to peak in ecotone areas where species typical in various habitats, as well as only for the ecotone are observed (Kark, 2007). Thus, when the effect of AES is considered on a micro scale (in our case – 100 m around the counting point) all of the bird biodiversity does not seem to be an appropriate measure for evaluation. We suggest that in such cases it is better to use biodiversity of a specific group of species: biodiversity of farmland species in arable land (Colhoun et al., 2017; Daskalova et al., 2019) or biodiversity of meadow species in meadows and pastures (Breeuwer et al., 2009; Ottvall and Smith, 2006). In this way the evaluation of AES would be more appropriate to the targets of protection.

Biodiversity could be an appropriate measure when the effect of AES is considered for a landscape context (Batáry et al., 2010). In general more complex landscapes, where different habitats and various regimes of agriculture occur, are characterised by higher biodiversity than a simple landscape (Concepción et al., 2012). Therefore, in a simple landscape with low crop diversity and only a few semi-natural habitats, creating heterogeneous habitats, such as small fallows, increases landscape complexity and as a consequence, increases biodiversity or the population size of some species (Meichtry-Stier et al., 2018). Similarly, in lowland meadows, the delay of grass harvesting may increase the population size of early-nesting species such as the Eurasian curlew, whinchat or yellow wagtail (Broyer et al., 2014). However, late mowing could be unfavourable for populations of birds which need short vegetation for foraging, like the white stork (Johst et al., 2001). In addition, some bird species establish large territories and need broad patches of homogeneous land, or alternatively, strongly avoid the proximity to a forest (Bertholdt et al., 2017). Thus, the same area that is covered by AES but that is distributed in space (e.g. a lot of small parcels vs a few large parcels) may deliver significantly different effects of AES on bird abundance and species richness (Whittingham, 2007). Our analyses of habitat preferences of the most common bird species (Table 5) clearly showed that it is not possible to protect various species in the same area when we consider protection activities on a micro scale. For example, the meadow pipit and bluethroat require completely different habitats (open meadows vs shrub vegetation) and so agricultural use will support the meadow pipit rather than the bluethroat, ultimately eliminating the bluethroat from the area. Another example can be seen with the common snipe and common rosefinch, whereby increasing the water level will positively affect populations of common snipe but cause a decrease of common rosefinch populations. A final example shows the presence of patches with short vegetation are preferred by skylarks, but this is unfavourable for sedge warblers. Therefore, habitat management on a landscape scale seems to be the better option than local activities, as this enables us to create optimal habitats for different species and increase biodiversity on a landscape scale (Whittingham, 2007). Thus, we suggest that the project management units should create management plans on the landscape scale, by stating areas in which different species or group of species have priority before others. For example, protection of northern lapwing will be more effective far away from the forest and buffers strips, since this species strongly avoids trees and shrubs (Bertholdt et al., 2017) whereas bluethroats may also be protected near to the forest, since proximity of the forest is neutral for this species. What is more, activities should be adapted to the local landscape characteristics in order to be effective (Tscharntke et al., 2005; Sefferova et al., 2018). Simply put, protection of the same species but in various landscapes (simple vs complex or intensive farming vs extensive farming) needs various and sometimes a completely different approach.

In our study area, we met high bird biodiversity (89 species in 120 points), high pressure of natural succession and extremely unfavourable conditions for agriculture (peat substratum, high water level, low productivity of meadows) (Table 4). Therefore, in contrast to most of the AES which are aimed at extensive farming (Ouvrard and Jacquemart, 2018; O'Brien and Wilson, 2011; Kleijn et al., 2011), our AWM was focused on the constraint of succession and encouraging farmers to conduct regular, late mowing. This regular mowing in AWM points compared to irregular mowing (depend on water level) in control points, seems to be only difference between these two kinds of points. When we compared AES and control points we found that control points had significantly more coverage of successional vegetation, were wetter and occasionally mowed during the second survey (mowing observed during 16 surveys in control points and during one survey in AES point). A decrease in moisture was similar in both the AES and control points. Thus, regular mowing successfully prevented succession and was sufficient to have a positive effect on meadow species, but not on the entire bird species richness. These positive effects probably occur across a high percentage of land under AES in our study area. However, in our study we did not evaluate the effect of AWM on animals other than birds, plants or fungi. We suppose that similar to birds, such analyses would show both, positive as well as negative influences.

Declaration of Competing Interest

The founding source did not influence on the study design.

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Appendix A

List of meadow bird species, farmland bird species and Polish AES bird species.

Appendix B

Species occurrence during a two-year study. Data shows percentage of: AES points, CON points and all points together at which particular species were detected in at least one survey.

Appendix C

Number of all bird species, number of meadow bird species, number of farmland bird species and number of Polish AES bird species recorded during each survey point.

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