Spatial Variation in Long-Term Trends in a Metapopulation of the Globally Threatened Aquatic Warbler Acrocephalus paludicola in Poland

Authors: Żmihorski, Michał, Ławicki, Łukasz, Marchowski, Dominik, Wylegała, Przemysław, and Pärt, Tomas

Source: Acta Ornithologica, 51(2) : 245-256

Published By: Museum and Institute of Zoology, Polish Academy of Sciences

URL: https://doi.org/10.3161/00016454AO2016.51.2.010

ACTA ORNITHOLOGICA
Vol. 51 (2016) No. 2

Spatial variation in long-term trends in a metapopulation of the globally threatened Aquatic Warbler *Acrocephalus paludicola* in Poland

Michał ŻMIHORSKI[1,2]*, Łukasz ŁAWICKI[3], Dominik MARCHOWSKI[3], Przemysław WYLEGAŁA[4] & Tomas PÄRT[1]

[1]Department of Ecology, Swedish University of Agricultural Sciences, Box 7044, SE–75007 Uppsala, SWEDEN
[2]Institute of Nature Conservation, Polish Academy of Sciences, Mickiewicza 33, 31–120 Kraków, POLAND
[3]West-Pomeranian Nature Society, Wąska 13, 71–415 Szczecin, POLAND
[4]Polish Society for Nature Conservation Salamandra, Stolarska 7/3, 60–788 Poznań, POLAND
*Corresponding author, e-mail: michal.zmihorski@gmail.com

Żmihorski M., Ławicki Ł., Marchowski D., Wylegała P., Pärt T. 2016. Spatial variation in long-term trends in a metapopulation of the globally threatened Aquatic Warbler *Acrocephalus paludicola* in Poland. Acta Ornithol. 51: 245–256. DOI 10.3161/00016454AO2016.51.2.010

Abstract. The Polish breeding population (3,200–3,250 males) of the globally threatened Aquatic Warbler *Acrocephalus paludicola* represents almost 25% of the global population. Except for the relatively stable large population in the Biebrza valley in north-east Poland less is known about population trends of peripheral populations in western, central and south-eastern regions of the country and whether trends differ depending on region. We investigated the long-term population dynamics in 38 small populations between 1969–2013 in the four Polish regions. Summarizing the trends of all small populations of Aquatic Warblers showed a significant decline in total number of individuals and declining number of populations over time. However, population trends were distinctly different in the different regions, with stable dynamics in south-east, moderate decline in north-east and sharp decline in the central and western regions. During the study period 19 out of 38 populations became extinct (11 populations in the western region, two in central region, four in north-east region and none in the south-east region). Five of these populations were later recolonised thus suggesting a pattern of metapopulation dynamics. To mitigate the negative trends and increased risk of local and regional extinction in the western and central parts of Poland effort should be put to increasing dispersal among populations by increasing the number of stepping stone patches between the viable large eastern populations and the smaller central and western ones.

Key words: conservation, dynamics, extinction, metapopulation, threatened species, Aquatic Warbler, *Acrocephalus paludicola*, additive model

Received — Aug. 2016, accepted — Nov. 2016

INTRODUCTION

Populations of endangered species are often spatially subdivided between networks of separate habitat patches surrounded by unsuitable habitat matrix. Because such local populations are usually small they are prone to extinction due to demographic and environmental stochasticity and reduced genetic variability (Hanski 1989). However, when dispersal of individuals occurs among habitat patches local populations close to extinction may be rescued and patches with extinct populations may be recolonized, forming a network of local populations, i.e. a metapopulation displaying dynamics in local extinctions and recolonisations (Hanski 1989). Thus, in a metapopulation some suitable habitat patches will be unoccupied at any time step. In a metapopulation where habitat patches differ in quality and size, furthermore, one expects source-sink dynamics with a surplus from sources dispersing to sink patches (Pulliam 1988, Dias 1996). In such source-sink metapopulations, the dynamics of sink populations may reflect both local population demography and productivity of the neighboring source populations. The dynamics of small populations may be therefore an indicator of the overall status of the metapopulation (Dias 1996).

The Aquatic Warbler *Acrocephalus paludicola* is a wetland species breeding in a network of spatially separated patches in eastern Europe. It is a globally threatened passerine bird, listed as

"Vulnerable" in the IUCN Red List of Globally Threatened Species and recent European Red List of Birds, because of its rapid decline in the past and the limited present breeding distribution of < 1,500 km^2 (Flade & Lachman 2008, Hirschfeld et al. 2013, BirdLife International 2015a, b). Once widespread and numerous in fen mires and wet meadows throughout Europe, the Aquatic Warbler has disappeared from most of its former range. In Western Europe its range covered whole Germany, eastern France and north Italy (Flade & Lachman 2008) and the species was reported to be common in Italy, Switzerland, Germany and the Netherlands in the late 1800s (Flade et al. 1999). Since 1875 the species rapidly declined and became locally extinct in at least eight European countries (Dyrcz & Schulze-Hagen 1997, Flade & Lachman 2008). The species has also declined rapidly in the central parts of the breeding distribution (at a rate equal to 40% per ten years) during the last 30 years probably as a result of the destruction of its breeding habitat (BirdLife International 2015b). The total European population is estimated at 9,000–13,800 singing males in 2000–2012 (BirdLife International 2015a). Approximately 75% of the European populations breeds in the river systems of upper Pripyat, Yaselda (Belarus) and Biebrza and Narew (Poland) (BirdLife International 2015b).

Poland plays a key role for the survival of this endangered species, because almost 25% of the global population occur here. The species breeds mainly in two areas in eastern Poland (Biebrza valley and Polesie region), but it occurs also in a few isolated populations (i.e. relicts of the otherwise extinct Western European population) concentrated mainly in Western Pomerania (Dyrcz et al. 2007, Sikora et al. 2013). The Polish breeding population in 2009–2012 was estimated at 3,200–3,250 males, of which 80% occurs in the Biebrza valley (BirdLife International 2015a). Estimates concerning the population size in the Biebrza valley suggest that the population has been fairly stable since 1991, although some uncertainty exists thus potentially hiding small trends (Grzywaczewski et al. 2012, Oppel et al. 2014). Much less is known, however, about the long-term dynamics of the species at remaining sites in Poland although there are reports suggesting population declines at some of these localities (Tanneberger et al. 2010, 2013). Therefore the dynamics of these small populations could reflect the general dynamics of the metapopulation and especially the dynamics of large source populations producing dispersers (Howe et al. 1991, Dias 1996). Thus, for effective protection of the overall metapopulation knowledge concerning dynamics of populations occurring at small habitat patches is also of great importance.

Here we investigate population trends of the all known small populations of Aquatic Warblers in Poland, i.e. 38 sites located in Western, Central, North-east and South-east Poland. We investigate whether population trends differ geographically, bearing in mind that the largest known populations of the species are located in eastern Poland, Belarus and Ukraine. Given a general population decline, we expect populations located far from the large populations in the east to decline most in numbers and to suffer from a higher probability of local extinction.

METHODS

Aquatic Warbler data

In this study we focused on all known small populations of Aquatic Warblers in Poland (see Appendix 1 for details). Data from the Biebrza valley, which is the largest Polish population possibly acting as a source (together with large populations in Belarus and Ukraine), were not included, partly because full inventories of this large population, implemented until 2010, cannot detect fine-tuned dynamics (Grzywaczewski et al. 2012, Oppel et al. 2014). However, as this population is expected to act as a source to neighbouring small populations, the dynamics of these populations may potentially reveal finer trends in the large Biebrza population. We compiled all available data concerning the number of males at local breeding sites of the Aquatic Warbler in Poland from 1930 to 2013 (Appendix 1). When population size in a given site and year was reported as a range we used average values. In general, at most of these sites regular counts of singing males were performed, which is known to reflect the number of breeding females (Dyrcz & Zdunek 1993, Kubacka et al. 2014). Singing males were counted twice per season, during their highest activity periods in their first and second breeding attempt (20 May–10 June and 20 June–10 July). Surveys were started about 1.5 hours before sunset and were finished ca. 1 hour after the sunset. Surveys were usually performed by several observers walking simultaneously along the predefined transects and all singing males were mapped (Krogulec & Kloskowski 2004). Some of the sites, however, especially those surveyed before 1990, were inventoried with the help of less specific methods, aimed at surveying the full list of wetland species by territory mapping performed during several repeated visits in a breeding season, thus allowing for a reliable population size assessment (detailed information is available in original works listed in Appendix 1).

In total we analysed available population data (including all known scientific studies and inventories conducted by NGOs, but also our own field inventories; see Appendix 1) from 38 sites in Poland, divided into four regions: (i) western (15 sites up to 25 km from Odra river valley and sea coast), (ii) central (8 sites in Wielkopolska lakeland and Wielkopolska lowland, i.e. the region of relatively high agriculture intensity), (iii) north-east (8 sites in areas of less intensive agriculture belonging to Mazowsze and Podlasie lowlands and Mazurian lakeland) and (iv) south-east (7 sites in Polesie, Fig. 1). For single sites, the average number of years with population estimates was 8.2 (SD = 7.4, range 1–34). The full list of sites with basic count characteristics is given in Appendix 1.

The model allowing for spatial variation in time trends

We investigate long-term changes in the abundance of the Aquatic Warbler in 38 small populations using generalized additive mixed model (GAMM) with Poisson error distribution and logarithmic link. The abundance of a given population in a given year was used as a response variable but we excluded two counts made before 1969 (1930 and 1960) as during this period counts were separated too much in time and thus provided no information on local population dynamics. In total 310 local abundance estimates were used in the models.

We assumed that the numbers of birds may change continuously over time but the change may be different in different parts of species distribution range. This might be the case if different regions show different population changes. In such a case fitting single trend curve for the whole distribution range may be inappropriate and a more flexible statistical method is needed. On the other hand, it is reasonable to assume that adjacent populations show more similar trend than spatially separated populations (i.e. trend is spatially autocorrelated). To take these assumptions into account, we applied a modeling approach (Harrison et al. 2014) where number of the Aquatic Warbler is a function of 3-way interaction of penalized thin plate regression splines between longitude, latitude (controlling for spatial autocorrelation) and time (i.e. year). We set the upper limit at 30 for the effective degrees of freedom in the interaction to control the complexity of the model. Splines allow for possible non-linear fit (i.e. non-linear time trend reflecting declines and increases in population size) and appropriate smoothness is chosen by generalized cross-validation criterion as a trade-off between the percentage of variance explained and the amount of wiggliness of the smoother. The geographical location of each population is included in the fitting of temporal dynamics and nonlinear temporal trends are allowed to vary across space. Consequently, populations placed close to each other have more similar trends as compared to more distant populations, which is not taken into account when population identity is introduced as fixed effect. The area of each site (log-transformed) was used as an offset and site ID was used as a random factor in the models. Moreover, we also performed an alternative model with random year effect and fixed effective degrees of freedom, but due to little difference we used the former one. All analyses were conducted in "*mgcv*" package (Wood 2006) in R (R Core Team 2015).

RESULTS

Several relatively large populations of the Aquatic Warbler were known from the South-east region (e.g. up to 340 males at site 37 in 1986) but in the Western and Central region some of the populations were also large, but mainly in the past (at site 11: 150 males in 1930, site 17: 300 males in 1972, Appendix 1). Populations never exceeding 10 singing males were observed in all studied regions (15 populations in total, Fig. 1, Appendix 1).

Several populations displayed a steep decline as e.g. at sites 16, 17 in central and at sites 1, 2, 11, 15 in western region (Appendix 1). Among the studied populations 19 (50%) became extinct during the study period: 12 in western region (80%), two in central region (25%), five in north-east region (63%) but none in the south-east region. Many of these populations were initially small (10 never exceeded 10 individuals), but four initially larger populations (≥ 50 individuals) also went extinct after a period of population decline (sites 1, 2, 16, 17, Appendix 1). However, five of the sites with populations going extinct were again recolonized (sites 2, 4, 7, 15 in western region and site 33

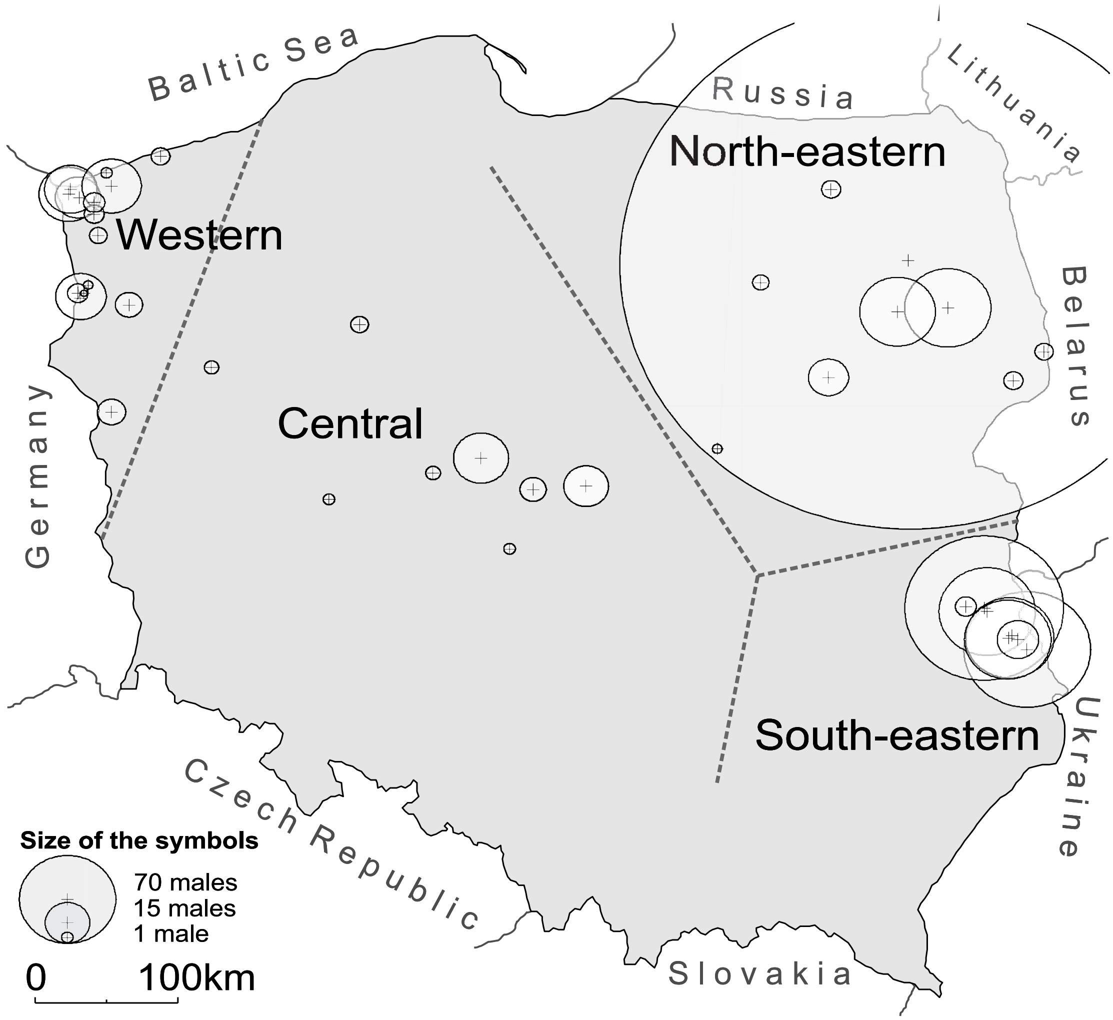

Fig. 1. Location of 38 sites of the Aquatic Warbler in Poland analysed in this study and the Biebrza valley (the largest circle, not included in the modeling, see methods). Area of the symbols is a linear function of mean population size of the species at the site. Four regions were distinguished.

in north-east region) but three of them again became extinct (Appendix 1).

The population trends differed between the four regions of Poland (GAMM, intercept: -0.94, SE = 0.26, t = 3.64, $p < 0.001$; longitude, latitude and time interaction: estimated degrees of freedom = 28.3, F = 74.9, $p < 0.001$). The model explained 24.9% of the variance in the response variable. The numbers of the Aquatic Warbler declined distinctly in the western region (at least since 1990) and possibly also in the central region (although the population shows a slight possible recovery with a peak year in 2008; Fig. 2). Also in the north-east region the trend was negative although less distinctly so due to a great variability in numbers among years (Fig. 2, 3). In this region estimates from the Biebrza valley (population not included in our model) between 1995 and 2012 suggest a fairly stable population size (e.g. Grzywaczewski et al. 2012). In contrast, the population trend in the South-east region was either stable or even slightly increasing across years (Fig. 2, 3).

DISCUSSION

Our use of additive models with time-space interaction made it possible to investigate whether patterns of non-linear population trends of the Aquatic Warbler population differed between geographical locations (Fig. 1). In general we believe

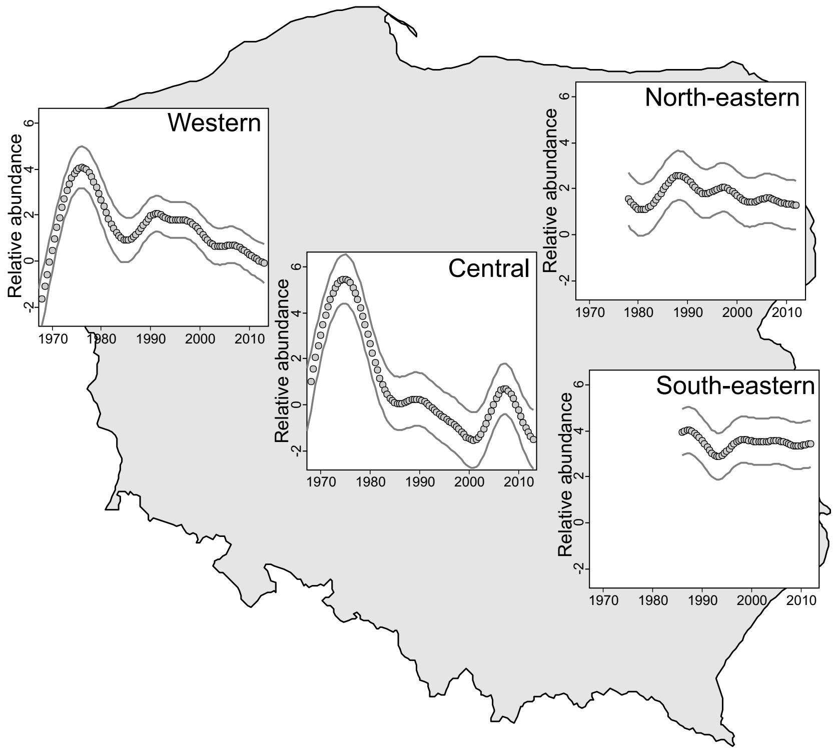

Fig. 2. Population trends (accompanied with 95% CI) of the Aquatic Warbler in Poland in 1969–2013, predicted for centroids of the four regions by the single additive mixed model fitting 3-way spline interaction of longitude, latitude and time. Note that y-axes are of the same scale on the four subplots and thus trend estimates are directly comparable.

this type of modelling to be useful when analyzing long-term dynamics of metapopulations. It should be mentioned however, that this model has some constraints as well, since nonparametric spline fit is very flexible and can be relatively easily adapted to outliers or noise (Wood 2006). Thus, the final patterns should be interpreted with caution and in some cases fixing the degrees of freedom and including random year effect may produce more accurate estimates of population trends (Knape 2016).

The general decline of the Aquatic Warbler with local extinctions at 19 out of 38 sites and the observation of the greatest declines and the highest probability of local extinction in populations in the most peripheral parts of the species distribution (western and central) is in line with the predictions set in the introduction. Similarly, populations close to large core populations in Belarus and Ukraine in eastern Poland also showed less negative or stable population trends. Below, we discuss possible explanations to the regional differences in trends observed, environmental threats and future conservation strategies to increase the long-term viability of the species in Poland and within the whole species distribution.

Habitat preferences and threats to the Aquatic Warbler in Poland

The Aquatic Warbler occurs in very specific habitats and thus is prone to habitat changes. It settles in fen mires in the valleys and deltas of lowland rivers in sparsely vegetated open areas with low density of shrubs and trees (Schulze-Hagen 1991, Grzywaczewski et al. 2014b). It occurs mainly on the sedge-dominated fen mires, covered with mosses, mid-tall grasses and tussocks. In the Biebrza valley the Aquatic Warbler nests mainly in non-flooded open marshlands covered by shallow water pools, sedge of an average vegetation height of 70–80 cm with high amount of mosses, old dead sedge and small patches of reed and single small (1–1.5 m) willows (Dyrcz & Zdunek 1993). Aquatic Warblers may also breed in wet meadows with tall grasses and patches of sedge (Dyrcz & Zdunek 1993). In South-east Poland the species breeds in calcareous marshes dominated by the *Cladium mariscus* with low share of

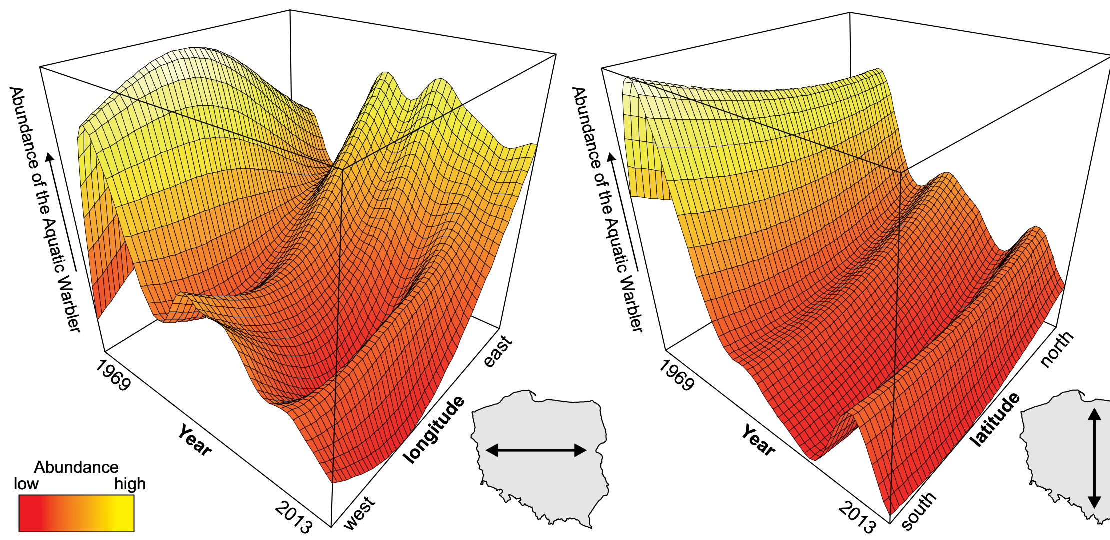

Fig. 3. Visualisation of the effect of 3-way interaction of longitude, latitude and time on the abundance of the Aquatic Warbler in Poland. Fitted trend was changing along the longitude (left-hand panel: declining in the west and stable in the east) but was fairly stable along the latitude (right-hand panel). Note that the surfaces are presented to aid interpretation of the model and thus are extrapolated to grid points far from data.

reeds and tall sedge (Kloskowski & Krogulec 1999) while in Western Poland it breeds in coastal halophilous marshes, seasonally flooded, with sparse patches of reeds (Dyrcz & Czeraszkiewicz 1993, Tanneberger et al. 2009). The species occurs also on the eutrophic marshes along the river valleys, dominated by the large sedge tussocks forming tufts as well as on wet meadows, mowed once or twice a year. On the most important site in Western Poland (Rozwarowo Marshes, site no. 6) the Aquatic Warbler breeds mainly in harvested reedbeds or sedge-dominated areas with shallow water pools (Tanneberger et al. 2010). Some of these habitats are disturbance-driven early succession stages, originally driven by flooding thus remaining open due to natural water conditions, whereas others are dependent on extensive management, mainly reed-cutting and mowing, to halt the natural succession of tall vegetation (Kubacka et al. 2014). Also burning as a management to control vegetation succession may be beneficial for the Aquatic Warbler (Grzywaczewski et al. 2014a).

Habitat change in breeding areas driven by changed agricultural practices is probably the main reason for many of the observed declines in Polish populations (Dyrcz & Schulze-Hagen 1997, Flade et al. 1999) although habitat quality along migration routes and in wintering grounds should not be neglected (e.g. Musseau et al. 2014). The known environmental key drivers of the observed historical decline of the Aquatic Warbler in Poland are: eutrophication, drainage and water table changes, land abandonment and agriculture intensification (Kloskowski & Krogulec 1999, Flade & Lachmann 2008, Kloskowski et al. 2015) and all have led to a change in vegetation structure and loss of the main habitat of the Aquatic Warbler. Eutrophication may be a major problem in western Poland and adjacent German populations, where agriculture has been intensified with increased use of fertilizers (Tanneberger et al. 2010, 2013). Similar changes in the vegetation of fens and mires of the Aquatic Warbler may also be caused by increased drainage lowering the water table (Kozulin et al. 2004). In Belarus the population decreased by more than 90% over the last 30 years possibly due to habitat loss caused by drainage and exploitation of peat (Kozulin & Flade 1999). On the Kramskie marshes (site 17) a large population (300 males in 1972) disappeared within 20 years due to drainage of the main nesting area (Winiecki 2000). At some other sites natural succession (encroachment of reed, birches, willows and other tall vegetation) accelerated by land abandonment and decline of water table may constitute an important threat for specific stage of plant succession preferred by the Aquatic Warbler (Tanneberger et al. 2009, see also Kozulin et al. 2004). In the Biebrza valley this process started a few decades ago, when many owners of the sedge meadows gave up the mowing due to economic reasons (Dyrcz & Zdunek 1993, Kubacka et al. 2014). In Międzyodrze in Western Poland (ca. 30 km-long island between two parallel routes of Odra river, site 10) secondary succession caused a nearly complete overgrowth of over 4,000 ha of suitable habitat (Ławicki et al. 2007, Marchowski & Ławicki 2014) possibly causing the population number to drop from 10–15 to 0 during 1995–2009. In Świna river estuary (sites 1, 2, 3) the abandonment of grazing resulted in the expansion of reed, which resulted in a large decline of the population – from over 220 males in 1991 (the three sites pooled) to only four males in 2012 (Dyrcz & Czeraszkiewicz 1993, Sikora et al. 2013).

Differences in trends between east and west: habitat change and demography

The higher population numbers of Aquatic Warblers in the east as compared to the west have been observed for more than 130 years (Taczanowski 1882) and the differences in population trends between regions can be attributed to two main factors; namely (i) habitat change and (ii) effects of fragmentation and small population size.

Agriculture in western Poland has always been relatively more intensive as compared to the east, with more complex drainage systems, larger field sizes and more use of fertilizers as was evident already at the start of World War I (i.e. 1914; Gorzelak 2010). For example, the share of farms exceeding > 15 ha in the most western parts of Poland (i.e. western region in Fig. 1) increased from 3% in 1960 to 27% in 1997 whereas the corresponding figures in the east were 3% to 6%, respectively (Kociszewski 1999). Nowadays the share of large farms (> 50 ha) is still about 10-times higher in the west as compared to the south-east of Poland (Central Statistical Office in Poland 2010). Thus, changes in important breeding wetlands have been more dramatic in the north-western and central parts as compared to the eastern parts of the country. In general, more intense agriculture have led to stronger bird declines in western than in eastern Europe, so the trends for the Aquatic Warbler match this pattern (Donald et al. 2001, Tryjanowski et al. 2011).

The strong decline observed in the western region may also be exacerbated by effects of small local population sizes and spatial isolation from the three large populations of Eastern Poland (ca. 3,000 singing males), Ukraine (2,600–3,400 males) and Belarus (3,100–7,000 males, BirdLife International 2015a). The observed recolonizations following local extinction clearly show that Aquatic Warblers disperse between local populations at least within regions. However, scattered ringing data suggest some degree of isolation between eastern and western regions (i.e. no birds have been detected moving between these regions; Ławicki et al. in prep.). Moreover, observed differences in male song (repertoire size, contents, song time organization, syntax and spectral parameters) between males inhabiting western region and the Biebrza valley probably has a genetic basis (Glapan 2013) and also suggest a present restricted gene flow between eastern and western populations. Finally, analyses of six micorsatellite markers confirm that the population in northwest Poland is to some extent isolated from eastern populations (Giessing et al. 2006). It is therefore possible that the central and western regional populations are isolated remnants of the western part of the historical Eurasian population and that these populations today suffer from the classical demographic problems of small fragmented populations (Caughley 1994, Hanski 1998).

Conservation implications

All in all, the observed declines of western and central populations are likely to be a combination of both environmental and demographic factors. The main challenge now is to halt the present population trend of this iconic endemic species by keeping and developing the present metapopulation structure of the species. This should be possible by increasing the connectivity between eastern and western populations e.g. by increasing the number of stepping stone habitat patches and improving the breeding habitat in the central and western parts e.g. by increasing the areas of suitable habitat (Flade & Lachmann 2008). As empty patches may be recolonized it is important to manage and protect also these patches as they may promote larger overall metapopulation size and stabilize the metapopulation dynamics by increased rescue effects (Howe et al. 1991, Semlitsch & Bodie 1998). Evidence from habitat conservation actions undertaken in the Biebrza valley suggest the Aquatic Warbler may respond positively and quickly to such a careful habitat management (Oppel et al. 2014). Moreover, new patches of available habitat can emerge as a result of agriculture extensification causing a water table increase. It is highly recommended therefore that such new populations are covered with appropriate management improving the suitability of the breeding habitat.

ACKNOWLEDGEMENTS

Our analysis would have not been possible without the field effort of many volunteers who counted Aquatic Warblers in Poland, mainly as a part of two LIFE projects (LIFE05 NAT/PL/000101 and LIFE09 NAT/PL/000260). They were mostly members and supporters of the Polish Society for the Protection of Birds — BirdLife Poland and the West-Pomeranian Nature Society. We would like to thank all of them. Steffen Oppel and Justyna Kubacka provided useful comments to former version of this manuscript. TP had funding from FORMAS (215-2014-1425), Swedish EPA (13/361) and VR (621-2011-5608).

REFERENCES

BirdLife International 2015a. European red list of birds. Luxembourg, Office for Official Publications of the European Communities.

BirdLife International 2015b. Species factsheet: *Acrocephalus paludicola*. Available at: http://www.birdlife.org on 25/06/2015.

Caughley G. 1994. Directions in conservation biology. J. Anim. Ecol. 63: 215–244.

Central Statistical Office 2010. Statistical yearbook of agriculture in Poland. Zakład Wydawnictw Statystycznych, Warszawa.

Dias P. C. 1996. Sources and sinks in population biology. Trends Ecol. Evol. 11: 326–330.

Donald P. F., Gree R. E., Heath M. F. 2001. Agricultural intensification and the collapse of Europe's farmland bird populations. Proc. R. Soc. Lond. B 268: 25–29.

Dyrcz A., Czeraszkiewicz R. 1993. [The abundance, threats and means of protection of the breeding population of the Aquatic Warbler (*Acrocephalus paludicola*) in Poland]. Not. Orn. 34: 231–246.

Dyrcz A., Krogulec J., Wójciak J. 2007. [The Aquatic Warbler *Acrocephalus paludicola*.] In: Sikora A., Rodhe Z., Gromadzki M., Neubauer G., Chylarecki P. (eds). The atlas of breeding birds in Poland 1985–2004. Bogucki Wydawnictwo Naukowe, Poznań, pp. 388–389.

Dyrcz A., Schulze-Hagen K. 1997. *Acrocephalus paludicola* Aquatic Warbler. In: Hagemeijer W. J. M., Blair M. J. (eds). The EBCC Atlas of European breeding birds: Their distribution and abundance. T & A D Poyser, London, pp. 664–665.

Dyrcz A., Zdunek W. 1993. Breeding ecology of the Aquatic Warbler *Acrocephalus paludicola* on the Biebrza Marshes, northeast Poland. Ibis 135: 181–189.

Flade M., Giessing B., Gorban I., Kalyakin M., et al. 1999. World population, trends and conservation status of the Aquatic Warbler *Acrocephalus paludicola*. Vogelwelt 120: 65–85.

Flade M., Lachman L. 2008. International species action plan for the Aquatic Warbler *Acrocephalus paludicola*. BirdLife International on behalf of the European Commission.

Giessing B., Moosmayer P., Segelbacher G., Wink M., Leisler B. 2006. Phylogeography of the Aquatic Warbler: a habitat specialist. J. Ornithol. 147 (Suppl): 172.

Glapan J. 2013. [Geographic variability of the Aquatic Warblers' song]. PhD Thesis, Adam Mickiewicz University, Poznań, Poland.

Gorzelak E. 2010. [Polish agriculture in XX century. Productivity and population]. Prace i Materiały Instytutu Rozwoju Gospodarczego SGH 84: 1–244.

Grzywaczewski G., Cios S., Sparks T. H., Buczek A., Tryjanowski P. 2014a. Effect of habitat burning on the number of singing males of the Aquatic Warbler *Acrocephalus paludicola*. Acta Ornithol. 49: 175–182.

Grzywaczewski G., Krogulec J., Marczakiewicz P., Piasecka M., Wołczuk B., Zadrąg M. 2012. [Inventory of the Aquatic Warbler in Poland in 2012]. Polish Society for the Protection of Birds, Marki.

Grzywaczewski G., Osiejuk T., Cios S. Marczakiewicz P. 2014b. Song post selection in the aquatic warbler *Acrocephalus paludicola*. Ann. Zool. Fenn. 51: 495–500.

Hanski I. 1998. Metapopulation dynamics. Nature 396: 41–49.

Harrison P. J., Buckland S. T., Yuan Y., Elston D. A., Brewer M. J., Johnston A., Pearce-Higgins J. W. 2014. Assessing trends in biodiversity over space and time using the example of British breeding birds. J. Appl. Ecol. 51: 1650–1660.

Hirschfeld E., Swash A., Still R. 2013. The World's rarest birds. Princeton University Press, Princeton.

Howe R. W., Davis G. J., Mosca V. 1991. The demographic significance of "sink" populations. Biol. Conserv. 57: 239–255.

Kloskowski J., Krogulec J. 1999. Habitat selection of Aquatic Warbler *Acrocephalus paludicola* in Poland: consequences for conservation of the breeding areas. Vogelwelt 120: 113–120.

Kloskowski J., Tanneberger F., Marczakiewicz P., Wiśniewska A., Choynowska A. 2015. Optimal habitat conditions for the globally threatened Aquatic Warbler *Acrocephalus paludicola* in eastern Poland and their implications for fen management. Ibis 157: 406–412.

Knape J. 2016. Decomposing trends in Swedish bird populations using generalized additive mixed models. J. Appl. Ecol. 53: 1852–1861.

Kociszewski J. 1999. [Distinctive features and effects of restructurisation of the bi-polar Polish agriculture under recent system transformation]. Ruch prawniczy, ekonomiczny i socjologiczny 61: 231–243.

Kozulin A., Flade M. 1999. Breeding habitat, abundance and conservation status of the Aquatic Warbler *Acrocephalus paludicola* in Belarus. Vogelwelt 120: 97–111.

Kozulin A., Vergeichik L., Stepanovich Y. 2004. Factors affecting fluctuations of the Aquatic Warbler *Acrocephalus paludicola* population of Byelarussian mires. Acta Ornithol. 39: 35–44.

Krogulec J., Kloskowski J. 2004. Monitoring of Aquatic Warbler *Acrocephalus paludicola* in Poland. Ornis Hungarica 12–13: 191–196.

Kubacka J., Oppel S., Dyrcz A., Lachmann L., Da Costa J. P. D. B., Kail U., Zdunek W. 2014. Effect of mowing on productivity in the endangered Aquatic Warbler *Acrocephalus paludicola*. Bird Conserv. Int. 24: 45–58.

Ławicki Ł., Marchowski D., Mrugowski W., Niedźwiecki S., Kaliciuk J., Śmietana P., Wysocki D. 2007. [Avifauna of the Międzyodrze region in 1994–2006]. Not. Orn. 48: 37–53.

Marchowski D., Ławicki Ł. 2014. Changes in the numbers of breeding birds in the Lower Odra Valley Landscape Park (NW Poland) between 1995 and 2013. Vogelwelt 135: 51–66.

Musseau R., Herrmann V., Benard S., Kerbiriou C., Herault T., Jiguet F. 2014. Ecology of Aquatic Warblers *Acrocephalus paludicola* in a fall stopover area of the Atlantic coast of France. Acta Ornithol. 49: 93–104.

Oppel S., Marczakiewicz P., Lachmann L., Grzywaczewski G. 2014. Improving aquatic warbler population assessments by accounting for imperfect detection. PLoS ONE 9(4), e94406.

Pulliam H. R. 1988. Sources, sinks, and population regulation. Am. Nat. 132: 652–661.

R Core Team 2015. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Available at: http://www.R-project.org/.

Schulze-Hagen K. 1991. *Acrocephalus paludicola* — Seggenrohrsänger. In: Glutz von Blotzheim U. N., Bauer K. M. (eds). Handbuch der Vögel Mitteleuropas. Vol. 12, Aula-Verlag, Wiesbaden, pp. 252–291.

Semlitsch R. D., Bodie J. R. 1998. Are small, isolated wetlands expendable? Conserv. Biol. 12: 1129–1133.

Sikora A., Ławicki Ł., Kajzer Z., Antczak J., Kotlarz B. 2013. [Rare birds breeding in Pomerania in 2000–2012]. Ptaki Pomorza 4: 5–82.

Taczanowski W. 1882. [National birds]. Wyd. Akademii Umiejętności, Kraków.

Tanneberger F., Bellebaum J., Helmecke A., Minets M. 2013. Nesting and foraging characteristics of Aquatic Warblers *Acrocephalus paludicola* in the fast declining Pomeranian population (NE Germany/NW Poland). Acta Ornithol. 48: 109–118.

Tanneberger F., Flade M., Preiksa Z., Schröder B. 2010. Habitat selection of the globally threatened Aquatic Warbler *Acrocephalus paludicola* at the western margin of its breeding range and implications for management. Ibis 152: 347–358.

Tanneberger F., Tegetmeyer C., Dylawerski M., Flade M., Joosten H. 2009. Commercially cut reed as a new and sustainable habitat for the globally threatened Aquatic Warbler. Biodiv. Conserv. 18: 1475–1489.

Tryjanowski P., Hartel T., Baldi A., Szymanski P., et al. 2011. Conservation of farmland birds faces different challenges in Western and Central-Eastern Europe. Acta Ornithol. 46: 1–12.

Winiecki A. 2000. [Aquatic Warbler *Acrocephalus paludicola*]. In: Bednorz J., Kupczyk M., Kuźniak, S., Winiecki A. (eds). [Birds of the Wielkopolska]. Bogucki Wydawnictwo Naukowe, Poznań, pp. 422–423.

Wood S. N. 2006. Generalized Additive Models: An Introduction with R. Chapman and Hall/CRC, Boca Raton.

STRESZCZENIE

[Przestrzenna zmienność trendów czasowych metapopulacji globalnie zagrożonej wodniczki w Polsce]

W Polsce gniazduje 3200–3250 par wodniczki, gatunku globalnie zagrożonego, co stanowi ok. 25% światowej populacji. Stosunkowo najwięcej wiadomo o trendach liczebności największej polskiej populacji w dolinie Biebrzy, natomiast bardzo słabo poznane są zmiany liczebności mniejszych i rozdrobnionych populacji w zachodniej, centralnej i południowo-wschodniej części kraju. W niniejszej pracy badano trendy liczebności wodniczki w latach 1969–2013 w 38 małych populacjach zlokalizowanych w czterech regionach Polski (Fig. 1, Appendix 1). Ogólna liczebność wodniczki w badanym okresie wyraźnie spadła, jednak dynamika liczebności różniła się wyraźnie między regionami: stwierdzono stabilne populacje w południowo-wschodniej części kraju, umiarkowany spadek w północno-wschodniej części oraz silny spadek na zachodzie i w centrum (Fig. 2, 3). W okresie objętym badaniami 19 z 38 populacji wymarło (11 na zachodzie, dwie w centrum i cztery w północno-wschodniej Polsce), jednak pięć z tych lokalizacji zostało zrekolonizowanych w późniejszych latach, co wskazuje na dynamikę o charakterze metapopulacji. By złagodzić negatywne trendy i zminimalizować wymieranie lokalnych populacji w zachodniej i centralnej części kraju, konieczne jest poprawienie dyspersji między dużymi populacjami na wschodzie a małymi w centralnej i zachodniej Polsce.

Appendix 1. Characteristics of 38 sites occupied by the Aquatic Warbler populations in Poland, used in the modelling.

Site	Region	Ycoord, Xcoord	N counts	Years	Abund. min, max	Dynamics	Source
1. Karsiborska Kępa	W	53.867; 14.333	14	1991–2012	0, 100	Extinct	6, 7, 9, 12, 13, 14, 16, 18,19, 20, 21,22, 26, 27, 28, 34, 35, 37, 38, 39, 40, 43, 44, 45
2. Zajęcze Łęgi, Karsibór	W	53.850; 14.417	14	1991–2012	0, 100	Extinct, recolonized, extinct	6, 7, 9, 12, 13, 14, 16, 18, 19, 20, 21, 22, 26, 27, 28,34, 35, 37, 38, 39, 40,43, 44, 45
3. Woliński Park Narodowy	W	53.900; 14.350	14	1989–2013	0, 83	-	6, 7, 9, 12, 13, 14, 16, 18, 19, 20, 21, 22, 26, 27, 28, 34, 35, 37, 38, 39, 40, 43, 44, 45
4. Łąki Skoszewskie	W	53.750; 14.583	4	1991–2000	0, 10	Extinct, recolonized	6, 7, 9, 13, 19, 20, 21, 26, 38, 44
5. Półwysep Rów	W	53.817; 14.583	7	1989–2009	0, 20	Extinct	6, 7, 9, 13, 19, 20, 21, 26, 27, 28, 38, 44
6. Bagna Rozwarowskie	W	53.917; 14.750		1991–2013	4, 60	-	6, 7, 8, 9, 12, 13, 14, 16, 18, 19, 20, 22, 26, 27, 28, 29, 35, 38, 39, 40, 41, 43, 44, 45
7. Bagna Struskie	W	53.617; 14.617	5	1991–1999	0, 7	Extinct, recolonized, extinct	6, 7, 9, 13, 14, 19, 20, 21, 26, 43, 44, 53
8. Łubnica, k. Daleszewa	W	53.317; 14.517	3	1991–1997	0, 2	Extinct	6, 7, 9, 13, 20, 23, 25, 26, 42
9. Żabnica	W	53.267; 14.483	3	1991–1997	0, 1	Extinct	6, 7, 9, 13, 20, 23, 25, 26, 42
10. Międzyodrze k. Gryfina	W	53.267; 14.417	13	1991–2009	0, 15	Extinct	6, 7, 9, 13, 20, 24, 25, 26, 30, 44
11. Krajnik	W	53.250; 14.450	15	1930–2013	0, 150	-	6, 7, 9, 13, 20, 24, 25, 26, 30, 44
12. Jez. Miedwie, Turze	W	53.200; 14.917	15	1969–2012	0, 17	Extinct	6, 7, 9, 13, 14, 15, 16, 18, 20, 21, 26, 27, 28, 35, 38, 40, 42, 43, 44, 45
13. Dol. Regi k. Włodarki	W	54.100; 15.233	5	1991–2004	0, 6	Extinct	6, 7, 9, 13, 20, 44
14. Międzywodzie	W	54.000; 14.700	4	1990–1997	0, 3	Extinct	6, 7, 9, 13, 20, 44
15. Ujście Warty	W	52.550; 14.750	26	1969–2013	0, 45	Extinct, recolonized, extinct	1, 9, 13, 16, 17, 20, 21, 26, 27, 28, 33, 35, 38, 39, 42, 43, 45
16. Dol. Środkowej Warty	C	52.183; 17.900	34	1960–2013	0, 50	Extinct	3, 26, 47
17. Bagna Kramskie	C	52.267; 18.367	27	1972–-2013	0, 300	Extinct	3, 26, 46
18. Dol. Noteci k. Krostkowa	C	53.083; 17.183	3	2010–2013	1, 6	-	26, 50
19. Dol. Noteci k. Trzebicza	C	52.817; 15.733	2	1982–2011	1, 2	-	3, 26, 51
20. Dol. Rowu Wyskoć	C	52.017; 16.883	1	1988	1	-	3
21. Zbiornik Jeziorsko-cofka	C	51.717; 18.650	1	1990	1	-	3
22. Dol. Neru	C	52.083; 18.883	8	1996–2009	1, 18	-	31
23. Dol. Bzury	C	52.100; 19.400	1	1975	15	-	48

Continued the next page....

Site	Region	Ycoord, Xcoord	N counts	Years	Abund. min, max	Dynamics	Source
24. Nietlickie Bagno	NE	53.897; 21.801	7	1991–2012	0, 10	Extinct	9, 12, 13, 16, 20, 21, 27, 28, 35, 39, 43, 45
25. Dolna Narew	NE	52.760; 21.774	7	1978–2012	2, 35	-	5, 9, 11, 12, 13, 14, 16, 20, 21, 22, 27, 28, 32, 35, 38, 39, 43, 45
26. Górna Narew	NE	53.181; 22.943	7	1988–2012	17, 126	-	9, 11, 12, 13, 14, 16, 20, 21, 22, 27, 28, 35, 36, 38, 39, 43, 45
27. Siemianówka	NE	52.916; 23.887	5	1978–2012	0, 11	Extinct	9, 11, 12, 13, 14, 16, 20, 21, 22, 27, 28, 35, 38, 39, 43, 45
28. Hajnówka	NE	52.740; 23.586	8	1978–2012	0, 8.5	Extinct	9, 11, 12, 13, 14, 16, 20, 21, 22, 27, 28, 35, 38, 39, 43, 45
29. Bagno Wizna	NE	53.158; 22.451	6	1989–2012	7, 79	-	4, 9, 11, 12, 13, 14, 16, 20, 21, 22, 27, 28, 35, 38, 39, 43, 45
30. Kampinos	NE	52.326; 20.684	4	1996–2012	0, 3	Extinct	9, 12, 13, 16, 20, 21, 27, 28, 35, 39, 43, 45
31. Dol. Szkwy i Omulwi	NE	53.335; 21.111	6	1995–2012	0, 8.5	Extinct, recolonized	9, 12, 13, 16, 20, 21, 27, 28, 35, 39, 43, 45
32. Ciesacin	SE	51.366; 23.119	3	1997–2012	1, 7	-	9, 12, 13, 16, 20, 27, 28, 35, 39, 43, 45, 49
33. Gotówka	SE	51.180; 23.548	4	1986–2012	21, 96	-	9, 12, 13, 16, 20, 27, 28, 35, 39, 43, 45, 49
34. Błota Serybryskie	SE	51.172; 23.529	3	1986–2012	38, 70	-	9, 12, 13, 16, 20, 21, 27, 28, 35, 39, 43, 45, 49
35. Brzeźno	SE	51.165; 23.630	4	1986–	3, 22	-	9, 12, 13, 16, 20, 21, 27, 28, 35, 39, 43, 45, 49
36. Roskosz	SE	51.107; 23.716	4	1986–2012	53, 178	-	9, 12, 13, 16, 20, 27, 28, 35, 39, 43, 45, 49
37. Bubnów	SE	51.359; 23.298	6	1986–2012	38, 340	-	9, 12, 13, 16, 20, 27, 28, 35, 39, 43, 45, 49
38. Staw	SE	51.343; 23.329	6	1986–2012	12, 131	-	9, 12, 13, 16, 20, 27, 28, 35, 39, 43, 45, 49

(1) Bartoszewicz M., Wypychowski, K., Engel, J. 2000. Numbers of some birds species in the Słońsk Nature Reserve in years 1994–1997. Biol. Bull. Poznań 37: 235–256.
(2) Bednorz J., Kupczyk M. 1995. Birds of the Noteć River valley. Prace Zakł. Biol. i Ekol. Ptaków UAM 3: 3–94.
(3) Bednorz J., Kupczyk M., Kuźniak, S., Winiecki, A. 2000. The birds of Wielkopolska region. Bogucki Wyd. Nauk. Poznań.
(4) Chmielewski S., Stelmach R. (eds.) 2009. Ostoje ptaków w Polsce — wyniki inwentaryzacji, cz. 1. Bogucki Wyd. Nauk., Poznań.
(5) Chyl A., Górski A. 1993. Birds of the Narew River Valley between Rakowo and Łomża. Not. Orn. 34: 277–286.
(6) Czeraszkiewicz R. 1993. Liczenie wodniczki *Acrocephalus paludicola* na Pomorzu Zachodnim w sezonie lęgowym 1993. Maszynopis. OTOP, Gdańsk.
(7) Czeraszkiewicz R. 1997. Występowanie, liczebność i wybiórczość siedliskowa wodniczki (*Acrocephalus paludicola*) w Polsce w 1997 r. Pomorze Zachodnie. Maszynopis. OTOP, Gdańsk.
(8) Dylawerski M., Lachmann L. 2011. Plan zarządzania dla Bagien Rozwarowskich — obszaru występowania wodniczki *Acrocephalus paludicola*. Maszynopis. OTOP, Marki.
(9) Dyrcz A., Czeraszkiewicz R. 1993. The abundance, threats and means of protection of the breeding population of the Aquatic Warbler (*Acrocephalus paludicola*) in Poland. Not. Orn. 34: 231-246. (In Polish with English abstract).
(10) Dyrcz A., Okulewicz J., Wiatr B. 1973. Ptaki pojezierza Łęczyńsko-Włodawskiego w okresie lęgowym (z uwzględnieniem badań ilościowych na torfowiskach niskich). Acta zoologica cracoviensia 18: 399–473.
(11) Dyrcz A., Okulewicz J., Tomiałojć L., Witkowski J. 1972. Breeding avifauna of the Biebrza Marshes and adjacent territories. Acta Ornithol. 13: 343–422.
(12) Dyrcz A., Maniakowski M. 2004. *Acrocephalus paludicola* (Vieill., 1817) — wodniczka. W: Gromadzki M. (red.). Ptaki (część II). Poradnik ochrony siedlisk i gatunków Natura 2000. Podręcznik metodyczny. 8: 325–329. Ministerstwo Środowiska, Warszawa.
(13) Głowaciński Z. (ed.). 2001. Polish Red Data Book of Animals. PWRiL. Warszawa.
(14) Gromadzki M., Dyrcz A., Głowaciński Z., Wieloch M. 1994. Important Bird Areas in Poland. Biblioteka Monitoringu Środowiska, Gdańsk.
(15) Guentzel S., Wysocki D. 2004. Breeding avifauna of the meadows at Lake Miedwie (Western Pomerania). Not. Orn. 45: 91–99.
(16) Grzywaczewski G., Krogulec J., Marczakiewicz P., Piasecka M., Wołczuk B., Zadrąg M. 2012. Inventory of the Aquatic Warbler in Poland in 2012. OTOP. Marki.

(17) Jermaczek A., Czwałga T., Jermaczek D., Krzyśków T., Rudawski W., Stańko R. 1995. Birds of the Lubusian Region. LKP. Świebodzin.
(18) Kajzer Z., Guentzel S., Jasiński M., Ławicki Ł. 2011. Rare and scarce birds observed in Western Pomerania in 2004–2008. Ptaki Pomorza 2: 93–125.
(19) Kaliciuk J., Staszewski A. 1997. Bird refuges in the Polish part of Szczecin Lagoon. West-Pomeranian Ornithological Society, Szczecin.
(20) Krogulec J., Kloskowski J. 1997. Występowanie, liczebność i wybiórczość siedliskowa wodniczki (*Acrocephalus paludicola*) w Polsce w 1997 roku. OTOP.
(21) Krogulec J. (red.). 1998. Birds of Polish wetlands and grasslands (Population, threats, protection). Fundacja IUCN Poland, Warszawa.
(22) Krogulec J., Kloskowski J. 2004. Monitoring of Aquatic Warbler *Acrocephalus paludicola* in Poland. Ornis Hungarica 12–13: 191–196.
(23) Lewartowski Z., Walankiewicz W., Wesołowski T. 1972. Occurrence of the Aquatic Warbler (*Acrocephalus paludicola*) near Konin. Not. Przyr. 6: 34-36.
(24) Ławicki Ł., Guentzel S., Jasiński M., Kajzer Z., Żmihorski M. 2009. Breeding avifauna of the Lower Odra River Valley. Not. Orn. 50: 268–281.
(25) Ławicki Ł., Marchowski D., Mrugowski W., Niedźwiecki S., Kaliciuk J., Śmietana P., Wysocki D. 2007. Avifauna of the Międzyodrze region in 1994–2006. Not. Orn. 48: 37–53.
(26) Ławicki Ł., Marchowski D., Wylegała P., Wypychowaki K. (unpublished data).
(27) Maniakowski M. 2003. Sprawozdanie z ogólnopolskiej akcji liczenia wodniczki. Maszynopis. OTOP, Gdańsk.
(28) Maniakowski M. 2010. Full country Aquatic Warbler count in Poland 2009. Aquatic Warbler LIFE Newsletter 2: 2.
(29) Marchowski D., Ławicki Ł., Guentzel S. 2012. Breeding birds of the Rozwarowo Marshes. Ptaki Pomorza 3: 49–59.
(30) Marchowski D., Ławicki Ł. 2014. Changes in the numbers of breeding birds in the Lower Odra Valley Landscape Park (NW Poland) between 1995 and 2013. Vogelwelt 135: 51–66.
(31) Mielczarek S., Grzybek J., Janiszewski T., Michalak P., Włodarczyk R., Wojciechowski Z. 2006. Avifauna of the Ner River valley in 1984–2005. Not. Orn. 47: 159–174.
(32) Nowakowski J.J., Górski A. 2009. Breeding avifauna of the Narew River National Park — state and changes. Not. Orn. 50: 97–110.
(33) Nowysz W., Wesołowski T. 1972. The birds of Kostrzyn retention reservoir and its environs in the breeding season. Not. Przyr. 6: 3-31.
(34) Osiejuk T.S., Cenian Z., Czeraszkiewicz R., Kalisiński M., Włodarczak A. 1993. The avifauna of islands in the Świna River Delta in 1990/91. Przegl. Przyr. 4, 1: 17–38.
(35) OTOP. 2011. Conserving Aquatic Warblers (*Acrocephalus paludicola*) in Poland and Germany. After-LIFE Conservation Plan. Polish Society for the Protection of Birds. Marki.
(36) Pugacewicz E. 2012. Changes in avifauna of Upper Narew Valley in 1986–2007. Dubelt 4: 1–41.
(37) Sellin D. 1991. Zum aktuellen Vorkommen des Seggenrohrsängers *Acrocephalus paludicola* im Oderdelta zwischen Peenestrom und Dziwna. Vogelwelt 111: 181–189.
(38) Sidło P.O., Błaszkowska B., Chylarecki P. (red.). 2004. Ostoje ptaków o randze europejskiej w Polsce. OTOP, Warszawa.
(39) Sikora A., Rohde Z., Gromadzki M., Neubauer G., Chylarecki P. (eds.) 2007. The atlas of breeding birds in Poland 1985–2004. Bogucki Wyd. Nauk. Poznań.
(40) Sikora A., Ławicki Ł., Kajzer Z., Antczak J., Kotlarz B. 2013. Rare birds breeding in Pomerania in 2000–2012. Ptaki Pomorza 4: 5–81.
(41) Staszewski A., Kaliciuk J. 1995. Awifauna Zalewu Kamieńskiego i okolic w latach 1979–1992. Not. Orn. 36: 75–97.
(42) Tomiałojć L. 1990. The Birds of Poland. Their distribution and abundance. PWN. Warszawa.
(43) Tomiałojć L., Stawarczyk T. 2003. The Avifauna of Poland: distribution, numbers and trends. PTPP proNatura. Wrocław.
(44) West-Pomeranian Nature Society (unpublished data).
(45) Wilk T., Jujka M., Krogulec J., Chylarecki P. (eds.) 2010. Important Bird Areas of international importance in Poland. OTOP. Marki.
(46) Winiecki A. 1992. Zmiany awifauny lęgowej Bagien Kramskich w wyniku ich osuszenia. Prace Zakł. Biol. i Ekol. Ptaków UAM 1: 83–91.
(47) Winiecki A., Grzybek J., Krupa A., Mielczarek S. 1997. Breeding avifauna of the Middle Warta River — present condition and trends of changes. Not. Orn. 38: 87–120.
(48) Wojciechowski Z., Janiszewski T. 2003. Changes in the breeding avifauna of the Warsaw-Berlin proglacial stream valley between Łęczyca and Łowicz in 1970–2001. Not. Orn. 44: 249–262.
(49) Wójciak J., Biaduń W., Buczek T., Piotrowska M. 2005. The atlas of breeding birds of the Lublin Region. LTO. Lublin.
(50) Wylegała P. 2013. Breeding avifauna of the ice-marginal section of the Noteć River valley — current state and changes in abundance. Ptaki Wielkopolski 2: 3–17.
(51) Wylegała P., Batycki A., Kasprzak A. 2012. The avifauna of the Lower Noteć River Valley — current state and changes in numbers. Ornis Pol. 53: 39–49.
(52) Wylegała P., Batycki A., Rudzionek B., Drab K., Blank M., Blank T., Barteczka J., Bagiński W., Konopka A. 2010. Avifauna of the Middle Noteć River Valley and Bydgoszcz Canal — current state and changes in abundance. Ornis Pol. 51: 43–55.
(53) Wysocki D. 1996. Ptaki wodno-błotne zbiorników wód pościekowych Zakładów Chemicznych „Police". Not. Orn. 37: 55–70.