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Habitats of the globally threatened Aquatic Warbler (*Acrocephalus paludicola*) in Pomerania — site conditions, flora, and vegetation characteristics

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With 3 figures, 4 tables and 1 appendix

Abstract

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The Aquatic Warbler is the only globally threatened passerine bird species in Europe. Around 1900, it was one of the most abundant birds in European fen mires. The population severely decreased as a consequence of extensive wetland drainage. In recent years, it has been rather stable in key breeding sites but has decreased sharply in its westernmost occurrence Pomerania. Conservation of the Pomeranian birds is of key importance for conserving the intraspecific diversity of the species.

Throughout 2004–2006 we studied all current breeding sites of the species in Pomerania. Two areas have been studied in more detail: Rozwarowo Marshes, the largest breeding site in Pomerania, and Lower Oder Valley National Park, the last breeding site in Germany. Data on vegetation composition and height, water level, site conditions, and land use were analysed.

The sites near the coast and in small river valleys are characterised by sparse and low *Phragmites australis* stands with a well-developed lower sedge and herb layer. The sites in the Lower Oder Valley are more nutrient-rich and dominated by *Carex acuta*, *Phalaris arundinacea*, and other meadow grasses. In Rozwarowo Marshes, the birds inhabit sparse, short *Phragmites australis* and *Thelypteris palustris* vegetation that is maintained by winter reed cutting. In the Lower Oder Valley National Park, Aquatic Warblers shifted from Caricetum gracilis to other plant communities that continued to be mown frequently. Similar to the Lithuanian Aquatic Warbler habitats in the Nemunas Delta and in contrast to the predominantly mesotrophic habitats of the core population, the Pomeranian habitats are eutrophic and more influenced by inundation. Various rare and threatened plant communities occur here. The Aquatic Warbler can be regarded as an umbrella species for mesotrophic and slightly eutrophic peatlands for which this bird is a specialist. Conservation activities should focus on a site-specific management and the prevention of further eutrophication.

Keywords: fen mires, vegetation structure, nutrients, habitat management.

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Introduction

The Aquatic Warbler (*Acrocephalus paludicola* Vieillot 1817) is a habitat specialist and the only globally threatened passerine bird species in Europe (BirdLife International 2008). In primeval landscapes it probably bred in mesotrophic or slightly eutrophic open fen mires in river valleys (Aquatic Warbler Conservation Team 1999). Around 1900 the species was still widespread in Central and Western European wetlands, and especially abundant in large fen mires (Hübner 1908, Hesse 1910, Schulze-Hagen 1991). In the course of the 20th century the world population decreased severely as a consequence of wetland drainage and agricultural intensification. The species became extinct in France, Belgium, Italy, and the Netherlands; in Northeast Germany the population probably shrank to 0.2% of its former size. Currently, the Aquatic Warbler breeds in less than 40 regular breeding sites in six countries. The world population is currently estimated between 10,000 and 13,800 singing males, with the biggest national populations (in 2009); in Belarus (4,000–7,600), Ukraine (4,000–4,700) and Poland (c. 3,200), making up 90–95 % of the world population (M. Flade pers. comm.). A Memorandum of Understanding under the Convention of Migrating Species (CMS) concerning conservation measures for the Aquatic Warbler was signed in 2003.

The Pomeranian Aquatic Warbler population is the smallest in Europe, but has a key function for the conservation of the species: Historical records suggest that the remaining birds in Pomerania are the last survivors of a large Western population (Aquatic Warbler Conservation Team 1999). As this population has decreased sharply in numbers in recent years (Tanneberger 2008, Flade et al. 2006) the Memorandum of Understanding pays special attention to the conservation and restoration of the Pomeranian habitats. Only recently the species' habitat requirements in Pomerania and possible differences to those in the well-studied core population (Dyrcz & Zdunek 1993, Kozulin & Flade 1999, Vergeichik & Kozulin 2006) have been studied (Tanneberger 2008). In this paper we describe vegetation and site characteristics of the last Pomeranian habitats, compare them to other habitats across the breeding range, and discuss management perspectives.

Study sites and methods

Study sites

The study was carried out in the nine current Aquatic Warbler breeding sites in Pomerania (Fig. 1, Table 1). They are located in a transitional climate region with both atlantic and continental influences (the latter being stronger in sites 5–9 located more inland, Fig. 1) and a mean annual precipitation of 450–600 mm (DWD 2007, Kondracki 1994). Already in the Tertiary, the Lower Oder Valley has been initially formed (Bülow 1934). Together with the basins of the surrounding mires, it has been further shaped by melting inland ice and was greatly influenced by the Litorina Transgression (7–3 ka BP; Dreyer 1914, Jasnowski 1962, Borówka 2007). The sites can be subdivided into sites near the coast and in small river valleys (1–5 in Fig. 1 and Table 1) and those in the Lower Oder Valley with strong influence of nutrient-rich inundation water (6–9 in Fig. 1, Tanneberger et al. 2010a).

Fig. 1. The last remaining Aquatic Warbler breeding sites in the Polish-German border region (Pomeranian population).

Table 1. Site characteristics of the Pomeranian Aquatic Warbler breeding sites. Soil data are from literature; water level data are given separately, if more than one vegetation type occurs within one site (see table 2 for abbreviations); land use types: WM = winter mowing; SM = summer mowing; GR = grazing; Aquatic Warbler data are from OTOP unpublished and own observations. Sites 4 and 8 are not included in the vegetation study, as Aquatic Warblers were recorded here only in 2007. NA = no data.

No.	Code	Breeding site	Location	Main soil type	Mean water levels in May/ June/July 2005 (cm) *	Trophic class (based on soil C/N ratio in 2005)	Acidity class (based on soil pH in 2005)	Main land use type	Aquatic Warblers (sm) 2004–2007
Coastal and small river valley sites									
1	RO	Rozwarowo Marshes	small river valley (partly dikes)	peat	VF13: 0/4/2 VF27: 17/15/7	eutrophic – mod. rich 18.8 (15.8-25.1)	subneutral 5.3 (3.8-6.0)	WM	22–37
2	WP	Wolin National Park	islands in Świna delta (no dikes)	peat	NA/0/NA	eutrophic – mod. rich 17.5 (16.3-19)	subneutral 5.4 (5.3-5.5)	WM, SM, GR	8–18
3	KK	Karsiborska Kępa	island in Świna delta (with dike)	peat	4/8/3	eutrophic – mod. rich 15.6 (13.4-18.4)	subneutral 5.3 (4.2-6.0)	WM, SM, GR	11–21
4	ZL	Zajęcze Łęgi	island in Świna delta (with dike)	peat	NA/5/NA 16.6 (15.6-17.5)	eutrophic – mod. rich 4.4 (4-4.7)	subneutral GR	WM, SM,	0–2
5	MI	Miedwie Lake	small river valley (no dike)	peat	32/26/6	eutrophic – mod. rich 15.3 (12.0-21.0)	alkaline 7.0 (6.7-7.1)	SM, GR	0–8
Lower Oder Valley sites									
6	GR	Gryfino	outer Odra polder (with dike)	peat	3/5/0	eutrophic – rich 12.7 (10.4-18.4)	subneutral 5.9 (4.7-6.9)	SM	5–7
7	CR	Lower Oder Valley National Park	inner Oder polder (with dike)	mineral soil	VF 30m: 0.5/0/0 VF 30u: 8/2/0	eutrophic – rich 11.5 (9.8-13.8)	subneutral 5.4 (4.6-7.2)	SM, GR	4–9
8	SR	Stara Rudnica	Odra floodplain (no dike)	mineral soil	30/15/NA	eutrophic – rich (10.4)	subneutral 5.5	no land use	0–1
9	SL	Warta Mouth National Park	Warta floodplain (no dike)	peat	0/0/0	eutrophic – rich 10.8 (10.3-12.5)	subneutral 6.0 (5.6-6.7)	SM, GR	2–10

* above soil surface

Sources:
Rozwarowo Marshes: Dreyer (1914), Tegetmeyer (2006), Jurzyk (2004a). Wolin National Park: Jasnowski (1962), Jurzyk (2004a), Karsiborska Kępa: Jasnowski (1962), Matkowska et al. (1977). Zajęcze Łęgi: Jasnowski (1962), Matkowska et al. (1977). Miedwie Lake: Jasnowski (1962), Borówka (2007). Gryfino: Dreyer (1914), Niedzwiecki (2002), Jasnowski (1962). Lower Oder Valley National Park: code refers to Criewen village; Dreyer (1914), IUS (1999). Stara Rudnica: belongs to the area Kostrzyneckie Rozlewisko; Krogulec (1998). Warta Mouth National Park: code refers to Słońsk town; Engel et al. 1998, Osiejuk et al. (1999).

The coastal and small river valley sites are located on islands consisting of glacial sands in the delta of the river Świna (2–4 in Fig. 1) and in glacial basins that have been shaped by melting inland ice (1 and 5 in Fig. 1), respectively. The relevant mires originated by terrestrialization and paludification with predominantly reed and sedge peat. Inundation can occur in autumn and winter, in some areas (2–4 and partly 1 in Fig. 1) with brackish water, and is in some areas mitigated by dikes (Table 1). The current prevailing land use types are winter reed cutting and (to a lesser extent) summer mowing and grazing. In the past, Aquatic Warblers have also bred on extensive pastures along the entire German Baltic Sea coast, the last remaining breeding sites being situated near Greifswald and Szczecin Lagoon (e. g. Schadefähre island until 1975 and Freesendorfer Wiesen 1973–1997; Sellin 1989 and 1990, Helmecke et al. 2003). There are also historical records from several other sites around Szczecin lagoon (e g. Rów peninsula, Struskie Bagna). Rozwarowo Marshes (1 in Fig. 1; 1,600 ha), located 15 km from the Baltic Sea shore between Kamień Pomorski and Wolin towns, is currently the largest breeding site of Aquatic Warbler in Pomerania (Tanneberger et al. 2009). This area is exemplary for this group of Pomeranian Aquatic Warbler habitats and has been studied with particular detail (case study 1). It is located on both sides of the small Grzybnica river and receives additional water from the Wołczenica river and during heavy northerly storms also brackish water from the Baltic Sea. The site is mainly used for reed cutting.

The Lower Oder Valley sites, located in polders in the former floodplains of the Oder (6–8 in Fig. 1) and in the mouth of Warta river (9 in Fig. 1), are more strongly influenced by water level fluctuations of the Oder river. Their soils largely consist of alluvial sediments such as loam and clay that were deposited in the floodplain over the glacial sands, gravels, and clays as a result of medieval clearings in the uplands. In a part of the Lower Oder Valley National Park, closer to the river scarp, and in the Warta river mouth, mostly organic material was deposited and peat soils were formed (Jasnowski 1962). In the 19th and early 20th century, Aquatic Warblers have been widespread on wet meadows in the Lower Oder Valley (Hübner 1908, Robien 1920). They have also bred on mown meadows in the Międzyodrze area (Lower Odra Valley Landscape Park) until 1997 (R. Czeraszkiewicz unpubl.). We have studied the last German breeding site of Aquatic Warbler in the Lower Oder Valley National Park (7 in Fig. 1; approx. 36 km²) as exemplary Lower Oder Valley site (case study 2). Its polder area is flooded from winter until mid-April, heavily drained afterwards and used for mowing and grazing (Dittberner & Dittberner 1976; Helmecke et al. 2003; Tanneberger et al. 2008). Since 1991 the intensity of land use has strongly declined and an increasing part of the meadows has been abandoned.

Sampling

The study was carried out on 25 m^2 plots in early June 2006. Plant species cover was estimated in the Londo scale (Londo 1984) and transformed to percent values as follows: 0.1 = 0.5; 0.2 = 2, 0.4 = 4, 1 = 10, 2 = 20, 3 = 30, 4 = 40, 5 = 50, 6 = 60, 7 = 70, 8 = 80, 9 = 90, 10 = 97.5 (slightly modified after Dierschke 1994). The nomenclature of angiosperm species follows Wisskirchen & Haeupler (1998); that of moss species Frahm & Frey (1992). Vegetation height was measured with a measuring stick with 5–10 replicates per plot.

Water level was measured with a measuring stick in spring and summer 2005 and 2006 with three replicates per plot. As a proxy for nutrient availability total organic carbon (C) and total nitrogen (N) were determined in mixed soil samples from a depth of approx. 5 cm (cf. Succow & Joosten 2001) from each plot in June 2006. The samples were stored for 1 week in polyethylene bags at 5°C, dried for 12 hours in an oven at 105°C, and after Dumas digestion measured with a C/N-analyser (Element vario EL). The pH was determined after Rowell (1997) in 0.01 M CaCl2 with a pH-electrode (pH 96 WTW, Weilheim) with automatic temperature correction. Dry samples were rewetted with distilled water to the estimated original water content. The electroconductivity of the surface water was measured in the field with three replications with an EC-meter (LF 91 WTW, Weilheim). Land use information was collected by interviews with Park authorities and local people.

Information on Aquatic Warbler occurrence was obtained by own observations in the years 2004–2007 (i.e. search for singing males, in particular shortly before and after sunset Krogulec & Kloskowski 2003) and from literature. Nesting sites were detected in some areas in June and July 2006 by observation of alarming or feeding females.

Data analysis

Ecological-sociological species groups were elaborated manually by table work (Mueller-Dombois & Ellenberg 1974), using information on bioindication (Koska et al. 2001), abiotic data (moisture, nutrient availability, pH), and indirect gradient analysis (see below). Relevés were ordered according to the major environmental gradients and non-hierarchical vegetation types were identified following Koska et al. (2001) and Koska (2007). These site-indicative vegetations types are termed "vegetation forms". They are differentiated by ecological species groups that are valid for the lowlands of Northeastern Germany. The vegetation types in our study are not strictly floristically defined but reflect habitat complexes for which minor deviations in species composition and site characteristics within one spatially connected and structurally homogenous Aquatic Warbler habitat were tolerated. In one area — the Lower Oder Valley National Park — the resulting vegetation type was further subdivided into a frequently mown and unmown variant. This was based on the occurrence and cover of species sensitive to summer mowing.

Indirect gradient analysis (Detrended Correspondence Analysis, DCA) was used to analyse differences in plant community composition caused by specific site conditions. The analysis was carried out with percentage cover data for each study plot separately using the software package PCORD 4.01. As data from a large variety of sites with a small number of plots are included, a downweighting of rare species has been performed. Correlations of species and site conditions with the ordination axes were assessed using Pearson's correlation coefficient (r^2; McCune & Mefford 1999).

In the two case studies, additional analyses were carried out: The vegetation forms occurring in Rozwarowo Marshes were subdivided into vegetation structure types, which additionally take vegetation structure features relevant to Aquatic Warbler habitat selection into account, i.e. cover and height of various vegetation layers (cf. Leisler 1981; Tanneberger et al. 2010a). For this area, also vegetation data from the years 1993, 1997, and 2003 (R. Czeraszkiewicz unpublished) were included. In the Lower Oder Valley National Park, Jehle & Pankoke (1995; 1999) undertook a detailed vegetation study in 1993. Based on their maps, the proportion of different vegetation types in an area of 100 m around positions of Aquatic Warbler records was calculated for all years with sufficient information on Aquatic Warbler occurrence (Tanneberger et al. 2010b) using a GIS (ArcView 3.2). The results were analysed using the electivity index after Jacobs (1974). The positive values between 0 and 1 indicate preference, the negative between 0 and-1 avoidance.

Results

Site conditions of the Pomeranian habitats

The habitats are mostly eutrophic according to the mire typology in Succow & Joosten (2001; Tables 1 and 2). The habitats in the coastal and small river valley sites show medium to moderately rich conditions (with the most nutrient-poor conditions in the Rozwarowo Marshes: mesotrophic-higher medium (m-hm) to eutrophic-moderately rich (e-mr)), whereas Lower Oder Valley habitats have rich conditions (e-r, with few exceptions tending to moderately rich). Except the more alkaline (alk) Miedwie Lake area, all habitats are subneutral (sub, Tables 1 and 2). The ordination graph (Fig. 2) shows that the plots are primarily clustered according to their location (i.e. sharp separation of sites), with the riverine areas as well as the coastal sites (see Table 1 for site codes) grouped together. The main gradients separating the groups are nutrient availability (C/N ratio) and electroconductivity (Fig. 2 and Table 3), with higher C/N values (i.e. more nutrient-poor conditions according to Succow & Joosten 2001) at the small river valley and the coastal sites and higher electroconductivity values at the coastal sites.

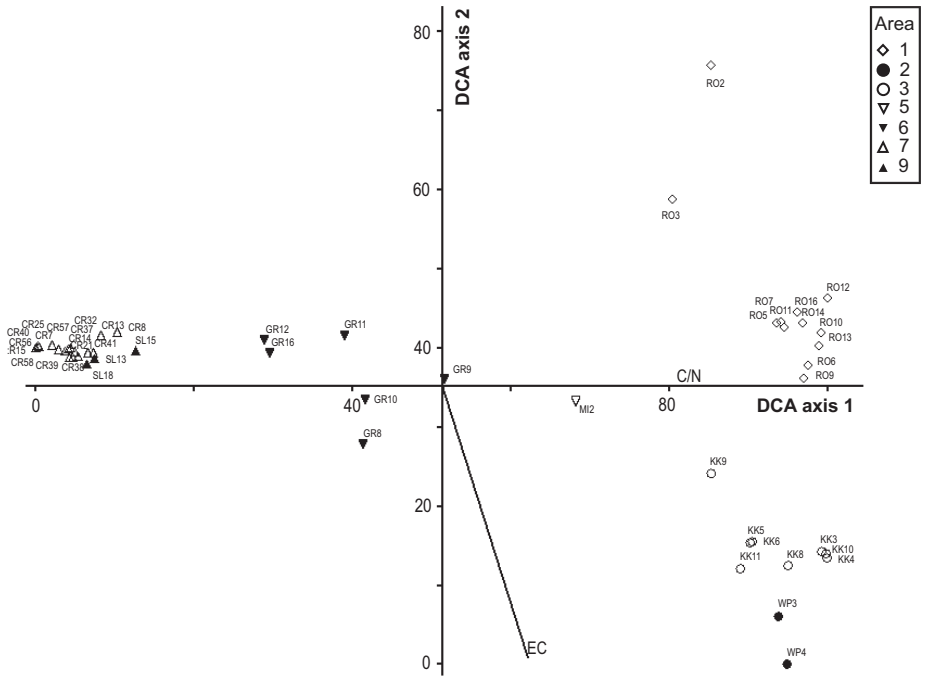

Fig. 2. Ordination diagram of all Pomeranian Aquatic Warbler sites (48 plots). The ordination (DCA) is based on plant species cover values and is presented as a joint plot with site condition values (C/N ratio and EC [µS/cm]; r2>0.285). Total number of plant species: 77. Eigenvalues axis 1/axis 2: 0.918/0.368. Length of gradient axis 1/axis 2: 5.295/3.982. Total variance of the species data: 4.834. Numbers in the legend and abbreviations of the plot names refer to Table 1. See also correlations in Table 3.

Flora and vegetation of the Pomeranian habitats

In total, 101 vascular plant and moss species were recorded (see Annex). They belong to five vegetation forms (VFs; Table 2) after Koska et al. (2001): *Calliergonella cuspidata-Carex elata* reed (13, Table 2), *Ranunculus lingua-Carex elata* reed (27, with transitions to 13), *Aster tripolium-Phragmites australis* reed (42), *Poa palustris-Phalaris arundinacea* reed (30, subdivided into the mown variant 30m and the unmown variant 30u), and *Caltha palustris-Filipendula ulmaria* tall herb vegetation (47). All vegetation forms indicate wet conditions (5+ according to Koska et al. 2001: most of the year inundated) except VF 47 (Gryfino), which indicates very moist conditions (4+: most of the year water slightly below surface), and VF 42, which shows transitions between very moist and wet conditions. Aquatic Warbler nesting sites have been recorded in all vegetation forms except VF 27. Singing males have been recorded only in VF 27 and VF 30u when adjacently regularly mown or grazed VF 13 and VF 30m occurred, respectively.

VFs 13 and 27 (Rozwarowo Marshes, Miedwie Lake) have a topogenous water

Table 2. Vegetation forms (number after Koska et al. 2001) of the Pomeranian Aquatic Warbler breeding sites. A selection of characteristic species and information on bioindication (water regime type, moisture class, sensitivity to summer mowing, trophic class) is given. Codes represent constancy class (I = species present in 1–20% of all relevés, II = 21–40%, III = 41–60%, IV = 61–80%, V = 81–100% (modified after Dierschke 1994) and mean cover (Londo scale). Other abbreviations: See text.

Vegetation form					27	13	42	30m	30u	47
Breeding sites (see Table 1)					MI / RO	RO	KK / WP	CR / SL	CR	GR
Number of plots					3	13	11	18	6	7
Water regime type (WRT)					T	T	C / T	U / D	U / D	T / U / D
Moisture class (MC)					5+	5+	4+..5+	5+ (..4+)	5+	4+
Main land use type (see Table 1)					no land use	WM	WM / SM / no	SM	no land use	SM
Trophic class (TC)					m-hm	e-mr..m-hm	e-r..mr	e-r (..e-mr)	e-r	e-r (..e-mr)
Acidity class					sub..alk	sub	sub	sub	sub	sub
	Indicative for:									
Species name	WRT	MC	Sens	TC						
Carex disticha	T				IV/4	II/4	II/4	I/4	-	II/2
Carex acutiformis					IV/10	-	II/4	-	-	II/2
Carex elata		5+	SM		V/10	V/4	-	-	-	-
Carex lasiocarpa				hm	V/4	I/4	-	-	-	-
Calamagrostis stricta					IV/4	II/2	-	-	-	-
Potentilla palustris					IV/4	V/2	-	-	-	-
Menyanthes trifoliata					IV/2	-	-	-	-	-
Rumex hydrolapathum			SM		IV/2	-	-	-	-	-
Ranunculus lingua				mr	II/2	-	-	-	-	-
Leptodictyum riparium					III/3	I/2	-	-	-	-
Calliergonella cuspidata		4+..5+			I/4	III/10	-	-	-	-
Carex appropinquata				mr	IV/10	I/4	-	-	-	-
Peucedanum palustre			SM		IV/2	IV/2	-	-	-	-
Thelypteris palustris					-	V/20	-	-	-	-
Lysimachia thyrsiflora					IV/2	-	-	-	-	-
Equisetum fluviatile					IV/10	-	-	-	-	I/2
Juncus gerardii	C				-	-	II/2	-	-	-
Bolboschoenus maritimus		4+..5+			-	-	I/2	-	-	-
Schoenoplectus tabernaemontani	local		SM		-	-	I/2	-	-	-
Festuca rubra agg.		drier 5+			-	-	II/4	-	-	-

Carex vulpina	U				-	-	-	III/4	-	-
Achillea salicifolia					-	-	-	II/3	-	-
Cnidium dubium					-	-	-	I/3	-	-
Oenanthe fistulosa				mr	-	-	-	I/2	-	-
Thalictrum flavum			SM		-	-	-	I/2	-	III/2
Ranunculus repens	local				-	-	-	V/4	-	-
Lysimachia nummularia					-	-	-	III/2	-	-
Poa palustris					-	-	-	III/2	-	-
Alopecurus geniculatus					-	-	-	III/2	-	-
Carex acuta					-	-	-	V/50	V/60	V/20
Phalaris arundinacea					-	-	-	IV/30	IV/20	II/4
Polygonum amphibium					-	-	-	III/4	II/4	I/2
Symphytum officinale					-	-	-	-	I/1	V/4
Iris pseudacorus			SM		-	-	-	-	III/2	-
Sium latifolium		5+			-	-	-	III/2	II/2	-
Rorippa amphibia					-	-	-	II/2	III/2	-
Carex vesicaria					-	-	-	II/2	-	II/10
Stellaria palustris		4+..5+		mr	-	-	-	II/10	-	-
Glyceria maxima					-	-	-	III/4	V/10	-
Caltha palustris					-	-	-	III/2	-	II/2
Calamagrostis epigejos		drier 5+	SM		-	-	I/2	-	-	V/30
Alopecurus pratensis					-	-	-	I/4	-	I/4
Lythrum salicaria	ubiq.				II/2	I/2	II/2	I/1	I/1	II/2
Mentha arvensis					-	II/2	-	II/10	-	-
Carex riparia					II/10	-	V/10	-	-	III/10
Epilobium palustre		4+..5+			IV/2	II/1	-	I/1	-	I/2
Galium palustre					IV/2	V/2	I/2	IV/4	II/2	I/1
Myosotis palustris					II/1	I/1	-	II/2	-	-
Lathyrus palustris				mr	IV/2	II/2	-	I/1	-	I/2
Agrostis stolonifera					-	-	II/20	II/10	I/4	-
Lysimachia vulgaris			SM		IV/4	V/4	II/2	I/1	I/2	I/1
Solanum dulcamara					II/4	-	-	-	II/2	-
Calamagrostis canescens					II/4	II/2	-	-	I/4	II/4
Phragmites australis					-	V/40	V/50	-	-	-

regime (T, permanent or periodically inundated but with moderate amplitude) with typical species such as *Carex disticha, Carex acutiformis*, and *Carex elata*. VF 27 is mostly nutrient-poor (mesotrophic — higher medium, m-hm), has the highest water levels during the breeding season and is not mown or grazed. Here, more species indicative for wet conditions (5+) and sensitive to mowing, e.g. *Rumex hydrolapathum, Ranunculus lingua, Equisetum fluviatile*, and *Lysimachia thyrsiflora* occur. In contrast to the winter mown VF 13, *Phragmites australis* is absent. VF 42 (Karsiborska Kępa, Wolin National Park) is characterised by a small share of species indicating a coastal storm flooding water regime with some salt water influence (C), i.e. *Juncus gerardii* and *Bolboschoenus maritimus* as well as by the dominance of *Phragmites australis*. Still, also species typical for a topogenous water regime and fresh water conditions (*Carex disticha, C. riparia, Lysimachia vulgaris*: low salt-tolerance) occur and indicate transitional conditions to fresh water habitats. The presence of *Calamagrostis epigeios* indicates a transition to drier habitats. VF 30 (Lower Oder Valley National Park, Warta Mouth National Park) is characterised by the absence of some typical species of topogenous water regimes which are sensitive to high water level amplitudes and high inundation. On the other hand species indicating a fluvial flooding water regime (U) occur, the most characteristic indicators being *Carex vulpina, Achillea salicifolia*, and *Cnidium dubium*. The latter only occur in the summer mown variant of this vegetation form and not at high constancy. The water regime type has also a tendency to a periodically inundated water regime of compacted soils (D). Local indicators of fluvial flooding are *Carex acuta* and *Phalaris arundinacea*. The variant without mowing or grazing (VF 30u, in the Lower Oder Valley National Park only) is additionally characterised by the occurrence of species sensitive to mowing (e.g. *Iris pseudacorus, Solanum dulcamara*) and a lower number of (local) indicators for the fluvial flooding water regime. VF 47 shows similarities to VF 30 but is characterised by species indicating drier conditions (e. g. *Calamagrostis epigejos, Caltha palustris*) as well as some species indicating a transition to a topogenous water regime (*C. disticha, C. acutiformis*). Located in an outer polder, this area (Gryfino) is — in contrast to Lower Oder Valley and Warta Mouth National Park area — not completely flooded in winter.

Table 3. Correlation matrix (Pearson and Kendall r2 with ordination axes) of all Pomeranian sites (N = 48). Relate to Fig. 2.

Parameter	Axis 1	Axis 2	Axis 3
C/N ratio	0.596	0.000	0.048
pH	0.000	0.006	0.054
EC [µS/cm]	0.216	0.689	0.054
Water level (cm)	0.139	0.019	0.001

According to a phytosociological classification after Rennwald (2000), the vegetation forms belong to five associations from three alliances: VF 13 to the Sphagno-Caricetum appropinquatae (Caricion lasiocarpae) and the Caricetum elatae (Magnocaricion elatae); VF 27 and 42 to the Schoenoplecto-Phragmitetum australis (Phragmition australis) with VF 42 showing tendencies to the Scirpion maritimi (according to the classification of Polte 2004, VF 42 is a transition to the Scirpetum

maritimi, *Galium palustre*-subunit); VF 30m and VF 30u to the Caricetum gracilis and the Phalaridetum arundinaceae (Magnocaricion elatae), and VF 47 to a drier version of the Caricetum gracilis with transitions to the Caricetum ripariae (Magnocaricion elatae).

Case study 1: Rozwarowo Marshes, Poland

In this area, Aquatic Warblers favour vegetation that consists of moderately high (< 2 m) and sparsely growing Common Reed (*Phragmites australis*) under which the broad leafs of Marsh Fern (*Thelypteris palustris*) form an additional plant layer (VF 13). Soil conditions are moderately rich or mesotrophic and the water level during the breeding season is permanently at or up to 5 cm above the soil surface (Table 2) and falls deeply in July/August. Typical additional plant species include *Peucedanum palustre, Lysimachia vulgaris*, *Lythrum salicaria*, and *Myrica gale.* This type of vegetation mainly occurs in the western and northeastern parts of the area. Here, three nesting sites of Aquatic Warblers were found in July 2006. In some years, birds also occur in adjacent moderately high (< 2 m) *Phragmites australis* stands with a dense herb layer dominated by sedges, typically *Carex acuta*, *Carex elata*, and also *Potentilla palustris* and the moss *Leptodictium riparium*.

Very few observations of singing males have been made in recent years in sedge vegetation (VF 27) without *Phragmites australis*. Here, soil conditions are mesotrophic, sometimes slightly eutrophic, and the water level lies permanently high above the soil surface (Table 2). Typical plant species include *Carex elata, C. disticha, Equisetum fluviatile, Rumex hydrolapathum*, *Typha latifolia*, and *C. pulicaris*. The area of this vegetation type has decreased strongly in recent years and reed vegetation has increased. Whereas in the 1990s, only about 50% of the Aquatic Warblers occurred in reed-dominated vegetation (R. Czeraszkiewicz unpubl. data), this figure was 90–100% in recent years.

Case study 2: Lower Oder Valley National Park, Germany

In this area, the most striking result is the abandonment of sedge-dominated vegetation by Aquatic Warblers after 1990. Areas classified as Caricetum gracilis in 1993 were preferred by the birds in 1982 and 1986 (forming roughly half of the area occupied), but less so after 1995, and were nearly completely avoided since 2000 (Fig. 3). At the same time, Aquatic Warblers shifted to other meadows dominated by Phalaridetum arundinaceae and the *Galium album-Alopecurus pratensis* community (nomenclature after Rennwald 2000). This change can largely be attributed to changes in land use. The meadows occupied prior to 1995 were usually mown twice each year until 1989 leading to the development of a mosaic of sedges, grasses and herbs. Since 1992, many of these meadows were only mown once or completely set aside which caused succession to denser and taller *Carex acuta* stands.

On the margins of the meadows at higher elevations we usually find either the *Ga-*

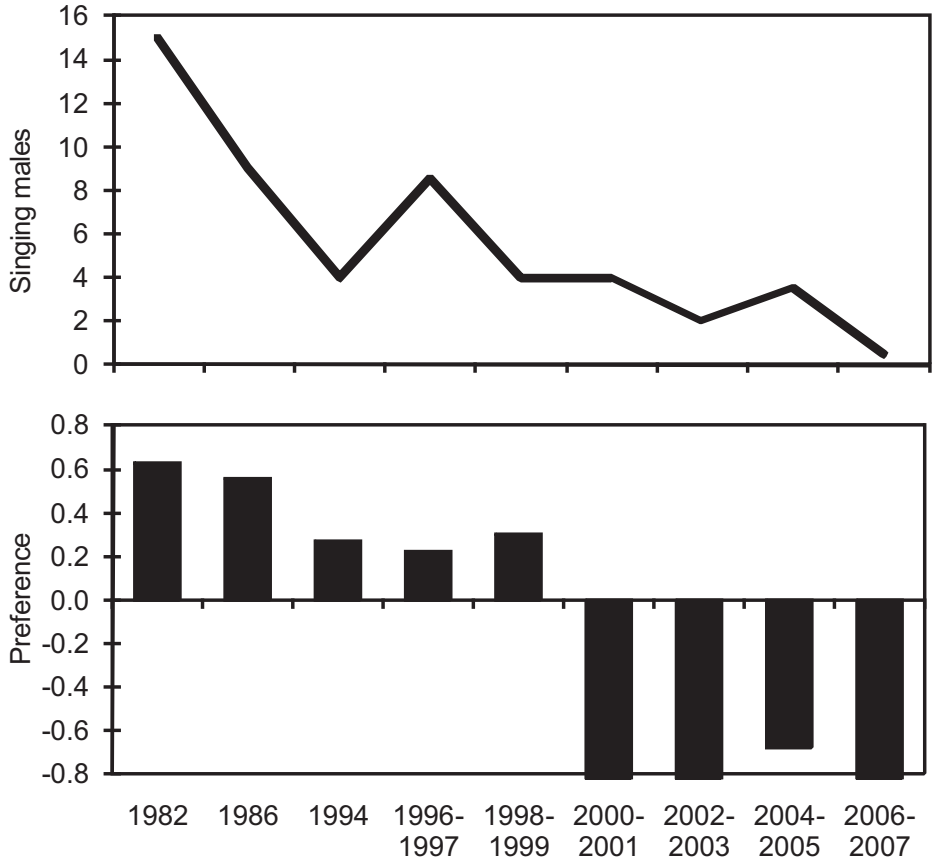

Fig. 3. Changes in the numbers of Aquatic Warblers (upper panel) and their preference for Caricetum gracilis (lower panel) in the Lower Oder Valley National Park on the study plots of Jehle & Pankoke (1995). For the period 1996–2007, two-year means are presented. Modified after Tanneberger et al. (2010b).

lium album-Alopecurus pratensis community with *Cnidium dubium* or true Cnidion dubii meadows (Konczak 1999). Although not preferred by Aquatic Warblers, they form a contiguous mosaic with Aquatic Warbler habitats at lower elevations that is currently maintained by haymaking. The dominating species of the Cnidion meadows are *Achillea salicifolia*, *Alopecurus pratensis*, *Cnidium dubium*, *Elymus repens*, *Phalaris arundinacea*, *Poa palustris*, *Potentilla reptans,* and *Vicia cracca*.

Discussion

Comparison of the Pomeranian habitats and other habitats across the breeding range

Although having a common vegetation structure that makes them suitable for Aquatic Warbler occurrence, the Pomeranian habitats vary with respect to plant composition. The five vegetation forms differ mainly with respect to their water regime. Because of the dikes in the sites with vegetation forms VF 42, 30, and 47, the coastal flooding and river inundation effects are mitigated and the water regime is transitional. The occurrence of plant species characteristic for certain water regime types is also influenced by land use: Whereas typical, less competitive fluvial inundation species such as *Carex vulpina, Cnidium dubium,* and *Oenanthe fistulosa* occur in the regularly mown variant VF 30m, they are absent in the unmown variant VF 30u due to the strong competition of tall and dense growing species (e.g. *Carex acuta, Glyceria maxima*).

On a very small area, the Pomeranian habitats reflect the overall variety of Aquatic Warbler breeding habitats. Rozwarowo Marshes and Miedwie Lake (VF 13 and 27) are rather similar to Eastern Polish and Belarusian mesotrophic groundwater-fed percolation mire habitats. Whereas VF 13 resembles sedge fen habitats with a sparse reed cover (e.g. „Trzcina Ławki" in Eastern Poland, H. Bartoszk unpubl. data; Zvanets mire in Belarus, Kozulin and Flade 1999), VF 27 is most similar to the more widespread sedge-brownmoss habitats without reed. In the Biebrza Marshes (Eastern Poland), *Carex appropinquata, C. elata, C. rostrata, Calliergonella cuspidata, Drepanocladus intermedius,* and *Bryum ventricosus* are the dominant species (Dyrcz & Zdunek 1993). In the Belarusian habitats, the main associations are the Caricetum elatae (most dominant in the more nutrient-rich mires), Caricetum rostratae, Caricetum diandrae, Caricetum appropinquatae, and Caricetum lasiocarpae (most dominant in the more nutrient-poor mires; Kozulin & Flade 1999). The most common moss species are *Hypnum* mosses, *Calliergon giganteum, Calliergonella cuspidata*, and *Bryum ventricosum*. In the Ukrainian habitats, *Carex rostrata, C. omskiana,* and *C. appropinquata* prevail (Poluda 2006). Typical co-occurring herbs in all percolation mire habitats are *Menyanthes trifoliata, Lysimachia vulgaris, Potentilla palustris*, and *Equisetum fluviatile*.

The Pomeranian coastal habitats on Karsiborska Kępa and in Wolin National Park are most similar to the Lithuanian habitats at the Curonian lagoon. These sites are described as Caricetum distichae with small areas dominated by *Phragmites australis* and *Glyceria maxima*. Other typical species are *Triglochin maritimum, Schoenoplectus tabernaemontani, Bolboschoenus maritimus, Carex acuta, Rumex hydrolapathum, Phalaris arundinacea,* and *Agrostis stolonifera* (Lithuanian Ornithological Society 2000).

The Lower Oder Valley sites with VF 30 and 47 have key features in common with the Lithuanian Nemunas Delta habitats (Table 4, Tanneberger et al. 2010a). The eutrophic conditions are in both areas mainly caused by inundation with nutrient-rich river water. In the Nemunas Delta, vegetation formed by *Carex disticha*, *Carex acuta*, and *Phalaris arundinacea* prevails (F. Tanneberger unpubl.). Other characteristic species are *Lysimachia nummularia, Lysimachia vulgaris, Agrostis stolonifera, Galium palus-*

tre, Ranunculus repens, Cardamine pratensis, and *Carex vulpina*. These habitats also resemble some floodplain habitats in Belarus, Ukraine, and Eastern Poland (Narew valley) where a small proportion of the core population breeds and *C. riparia* and *C. acuta* communities prevail (Flade & Kozulin 1999, Poluda 2006).

Table 4. Main Aquatic Warbler habitats across the breeding range.

Area	Dominant vascular plants	Moss layer developed	Main water regime type	Nutrient availability
Pomerania [a]	sedges (*C. acuta*), *Phalaris arundinacea, Phragmites australis*	no	inundation	eutrophic
Lithuania [a]	sedges (*C. disticha, C. acuta*), *Phalaris arundinacea*	no	inundation	eutrophic
Biebrza / E Poland [b]	sedges (*C. appropinquata*)	yes	percolation	mainly mesotrophic
Pripyat / S Belarus[c]	sedges (*Carex elata, C. rostrata, C. lasiocarpa, C. appropinquata*)	yes	percolation	mainly mesotrophic
Pripyat / N Ukraine [d]	sedges (*C. rostrata, C. omskiana, C. appropinquata*)	yes	percolation	mainly mesotrophic

[a] F. Tanneberger unpubl., Pomerania: range of soil C/N 10-28, Lithuania: range 11-18.
[b] Dyrcz & Zdunek (1993), Wassen & Joosten (1996) for soil C/N ratio in Biebrza Upper Basin (21.45 ±2.2).
[c] Kozulin & Flade (1999), N. Bambalov pers. comm. for soil C/N ratio (mean 20.2).
[d] Poluda (2006).

The Pomeranian Aquatic Warbler as an umbrella species

Our study shows that Aquatic Warbler habitats in Pomerania are not only important for birds, but also for plant conservation. In total, four strictly protected and four protected species listed in the Polish Red Data Book occur in our study areas.

The Rozwarowo Marshes belong to the botanically most valuable peatlands in Northwest Poland with a mosaic of rare and threatened plant communities. The site holds the largest population of *Myrica gale* (Myrico-Salicetum auritae) in Northwest Poland (Jurzyk 2004a and 2004b). This community is closely intertwined with the Aquatic Warbler breeding habitat. In some parts of the Myrico-Salicetum auritae, *Carex pulicaris* grows on *Molinia caerulea* tussocks. This species is threatened with extinction in Poland (Jurzyk & Wróbel 2003, Wróbel & Jurzyk 2004). Seasonal groundwater fluctuations and soil drainage in summer provoke soil aeration and support the development of *Myrica gale* and *Molinia caerulea*. Even in summer, however, the *Carex pulicaris* microhabitats remain moist as a result of capillary rise inside the *Molinia* tussocks. This habitat type is listed under Annex I of the Habitats Directive (Code 6410; European Commission 1992). In the eastern part of the peatland, halophytes of the Triglochino-Glaucetum maritimae with abundant *Triglochin maritima, Glaux maritima, Juncus gerardi, Aster tripolium*, and *Plantago maritima* occur (Ciaciura &

Stępień 1998, Tegetmeyer 2006). This area has been maintained by summer mowing in the last few years.

At Miedwie Lake, the only alkaline Aquatic Warbler breeding site in Pomerania, the calcareous Caricion davallianae (Habitats Directive Annex I, Code 7210) occurs with threatened species such as *Cladium mariscus, Schoenus nigricans,* and *C. buxbaumii* (Wołejko et al. 2007). The Habitats Directive Annex II species *Liparis loeselii* has grown here until 1995. The sites used to be mown, grazed, and occasionally burnt. In recent years, large parts became abandoned and many threatened plant species disappeared.

The Oder Valley is one of the strongholds of Cnidion meadows in Germany (Burkart et al. 2004), a habitat type listed in Annex I of the Habitats Directive (Code 6440). The Cnidion meadows of the Oder Valley are species-rich plant communities. River corridor plants (German: "Stromtalpflanzen") such as *Achillea salicifolia*, *Carex vulpina*, *Cnidium dubium*, *Inula britannica*, *Lathyrus palustris*, *Scutellaria hastifolia, Thalictrum flavum,* and *Veronica longifolia* are characteristic for these regularly mown meadows.

Because of its particular breeding system of multiple paternity and uniparental (female) brood care (Giessing 2002), Aquatic Warbler conservation requires areas large enough to support a sufficient number of males (and probably females) at each breeding site (Heise 1974), i. e. usually an area of more than 200 ha of suitable habitat (Tanneberger et al. 2010b). In Pomerania it can therefore be regarded as an umbrella species (sensu Simberloff 1998 and Roberge & Angelstam 2004), enveloping the needs of plant and animal species of mesotrophic and slightly eutrophic peatlands for which this bird is a specialist. Their importance for other animals than Aquatic Warbler is illustrated by the occurrence of Habitats Directive Annex II species such as the arthropod species *Lycaena dispar* and *Carabus menetriesi* as well as the amphibians *Triturus cristatus* and *Bombina bombina*. Among EU Birds Directive Annex I species, 16 species often occur together with Aquatic Warblers, with Spotted Crake (*Porzana porzana*), Corncrake (*Crex crex*), and Great Snipe (*Gallinago media*) regularly breeding in the same localities.

Management perspectives

As causes for Aquatic Warbler habitat deterioration in Pomerania, the cessation of land use (Krogulec & Kloskowski 2003, Tanneberger et al. 2010a), continuously late land use in eutrophic sites (Tanneberger et al. 2008), and further eutrophication (Tanneberger et al. 2009) have been identified. In the anthropogenically eutrophicated Pomeranian sites, the removal of biomass by mowing or grazing 'mimics' naturally nutrient-poor conditions and vegetation structure and the species thus 'relies' on management. All factors negatively affecting Aquatic Warbler habitats are similarly detrimental for the associated threatened plant communities.

According to our current knowledge, management favourable for Aquatic Warblers can be described as follows. Reed-dominated coastal sites: annual winter cutting of current breeding sites and summer mowing with biomass removal or grazing in sites

currently unsuitable for breeding because of dense and high reed. Lower Oder Valley sites: summer mowing, at least in some years at early dates (before end of July; Tanneberger et al. 2008). Because early mowing of currently occupied meadows puts Aquatic Warbler broods at risk, any static management with fixed mowing dates is impractical or even detrimental. Instead, flexible management decisions have to be taken each year according to the occurrence of the target species. Such a management would also approach the form of land use that originally led to the development of these habitats: before the areas were ameliorated, the extent and timing of mowing was mainly dependent on the strongly variable spring water tables. Despite the fact that we now have a sound basis to improve the management of Pomeranian Aquatic Warbler breeding sites in the near future, perhaps the most important long-term problem is still unsolved. The biomass harvested has a low forage quality for cattle and is thus unattractive for farmers. An economic alternative for the use of biomass is therefore needed. Hopefully, ongoing research on its use for energy and biogas production will soon lead to practical solutions.

Today Aquatic Warbler conservation in Pomerania benefits from species conservation projects and improved agri-environmental schemes (AES). Their main focus is to implement the recommended management by facilitating and financially supporting low-intensity mowing, preferably with sustainable use of the mown biomass, and grazing schemes.

The EU Life Nature project 'Conserving *Acrocephalus paludicola* in Poland and Germany' (LIFE05NAT/PL/000101, 2005–2011) is one of the largest and most comprehensive species conservation projects ever implemented in Poland and includes six project sites in Pomerania (Rozwarowo Marshes, Wolin National Park, Karsiborska Kępa, Zajęcze Łęgi, Krajnik, Lower Peene Valley/Germany) as well as the Biebrza National Park and its buffer zone. Management plans for the species in the project sites are set up for c. 42,000 ha, and about 3,000 ha are effectively managed. As the project sites differ strongly in vegetation and site conditions (Table 1), planning and management address them individually. In the Lower Oder Valley NP, another project is currently aiming at creation of > 200 ha of new fen mire habitat for Aquatic Warblers and at specifically targeted incentives for farmers managing sedge as well as Cnidion meadows.

Agri-environmental schemes play an important role beyond the Life and other projects. In Poland, new AES have been implemented starting in 2007 (Brzezińska et al. 2007) which include two attractive packages of major importance for Aquatic Warbler habitats: Package 3.2 (Protection of breeding birds) and 4.2 (Tall sedge vegetation). The 'bird package' addresses in particular Aquatic Warbler habitats and prescribes annual mowing after 1.8., 30–50% at varying places set aside, height of mowing 5–15 cm, removal of the biomass at the latest 2 weeks after mowing or grazing.

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References

Aquatic Warbler Conservation Team 1999: World population, trends and conservation status of the Aquatic Warbler *Acrocephalus paludicola*. — Vogelwelt **120**: 65–89.

BirdLife International 2008: Acrocephalus paludicola. — In: IUCN 2010. IUCN Red List of Threatened Species. Version 2010.4. — www.iucnredlist.org, downloaded on 26 January 2011.

Borówka, R.K. 2007: Jak kształtowała się geologiczna rzezba Niziny Pyrzyckiej. — In: Borówka, R.K. (ed.), Jezioro Miedwie i Nizina Pyrzycka. 6–21. — Szczecin: Oficyna.

Brzezińska, K., Kotowski, W., Dzierża, P. & Jobda, M. 2007: Pakiety przyrodnicze projektu Programu Rolnośrodowiskowego na lata 2007–2013. Chrońmy Mokradła, IMUZ, Towarzystwo Przyrodnicze „Bocian" i OTOP, Warszawa. Unpublished draft.

Bülow, K. v. 1934: Zum Problem der „Eberswalder Pforte". Jb. Preuß. Geol. Landesanst. **55**: 28–43.

Burkart, M., Dierschke, H., Hölzel, N., Nowak, B. & Fartmann, T. 2004: Molinio-Arrhenatheretea (E1) — Futter- und Streuwiesen feucht-nasser Standorte und Klassenübersicht Molinio-Arrhenatheretea. — Synopsis der Pflanzengesellschaften Deutschlands **9**: 1–103.

Ciaciura, M. & Stępień, E. 1998: O ochronę stanowisk woskownicy europejskiej Myrica gale L. na Bagnach Rozwarowskich. Chrońmy Przyrodę Ojczystą 4 (54). — Kraków: IOPPAN.

DWD (Deutscher Wetterdienst) 2007: Klimadaten von den Wetterstationen Angermünde und Schwedt.

Dierschke, H. 1994: Pflanzensoziologie. Grundlagen und Methoden. — Stuttgart: Ulmer.

Dittberner, H. & Dittberner, W. 1976: Der Seggenrohrsänger im Bezirk Frankfurt/Oder. — Falke **23**: 78–81.

Dreyer, J. 1914: Die Moore Pommerns, ihre geographische Bedingtheit und wirtschaftsgeographische Bedeutung. XIV. Jahresbericht der Geographischen Gesellschaft zu Greifswald 1913–1914. — Greifswald: Abel.

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

Engel, J., Jackowiak, B., Kuczyński, L. & Osiejuk, T.S. 1998: Plan Ochrony Rezerwatu Przyrody Słońsk. Część ogólna. Poznań — Słońsk.

European Commission 1992: Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora. L206, 22.07.1992.

Flade, M., Giessing, B., Pain, D. & Kozulin, A. 2006: Partial extinction: The case of the globally threatened Aquatic Warbler. — J Ornithol **147** suppl: 79.

Frahm, J.P. & Frey, W. 1992: Moosflora. — Stuttgart: Ulmer.

Giessing, B. 2002: Viele Väter für eine Brut — vorteilhaft oder unausweichlich für das Weibchen? Zum Paarungssystem und zur Populationsgenetik des Seggenrohrsängers (*Acrocephalus paludicola*). — PhD thesis, Köln University.

Heise, G. 1974: Der Seggenrohrsänger — eine vom Aussterben bedrohte Art. — Falke **21**: 6–10.

Helmecke, A., Sellin, D., Fischer, S., Sadlik, J. & Bellebaum, J. 2003: Die aktuelle Situation des Seggenrohrsängers *Acrocephalus paludicola* in Deutschland. — Ber Vogelschutz **40**: 81–89.

Hesse, E. 1910: Beobachtungen und Aufzeichnungen während des Jahres 1909. — J. Ornithol. **58**: 489–519.

Hübner E. 1908: Avifauna von Vorpommern und Rügen. — Leipzig: Weigel.

IUS (Institut für Umweltstudien Weisser & Ness GmbH) 1999: Pflege- und Entwicklungsplan „Unteres Odertal". — Heidelberg. Unpublished report.

Jacobs, J. 1974: Quantitative measurement of food selection. — Oecologia **14**: 413–417.
Jasnowski, M. 1962: Budowa i roślinność torfowisk Pomorza Szczecińskiego. Szczecińskie Towarzystwo Nauk, Wydzial Nauk Przyrodniczo-rolniczych. Tom X.
Jehle, P. & Pankoke, K. 1995: Vegetationskundliche Untersuchungen an Auenstandorten im Nationalpark Unteres Odertal. — Diploma thesis, Technische Universität Berlin.
Jehle, P. & Pankoke, K. 1999: Die Pflanzengesellschaften ausgewählter Totalreservatsflächen im Nationalpark Unteres Odertal. — Limnol. aktuell **9**: 123–146.
Jurzyk, S. 2004a: Znaczenie warunków siedliskowych w kształtowaniu struktury populacji woskownicy europejskiej *Myrica gale* L. i jej ochrona na Pomorzu Zachodnim. — PhD thesis. Akademia Rolnicza. Szczecin.
Jurzyk, S. 2004b: Protection of *Myrica gale* L. brushwood in a peatbog under agricultural management. — In: Wołejko, L. & Jasnowska J. (eds.), The future of Polish mires. 263–270. — Szczecin: Agricultural University of Szczecin.
Jurzyk, S. & Wróbel, M. 2003: Co-occurrence of two species *Molinia caerulea* L. and "red-list" species *Carex pulicaris* L. in Western Pomerania (Poland). — Polish J. Ecol. **51**: 363–367.
Konczak, P. 1999: Überblick über die Vegetationsverhältnisse der märkischen Oderaue im Bereich des Nationalparks "Unteres Odertal". — Limnol. aktuell **9**: 99–121.
Kondracki, J. 1994: Geografia Polski — mezoregiony fizyczno-geograficzne. –Waszawa: PWN.
Koska, I., Succow, M., Clausnitzer, U., Timmermann, T. & Roth, S. 2001: Vegetationskundliche Kennzeichnung von Mooren (topische Betrachtung). — In: Succow, M. & Joosten, H. (eds.), Landschaftsökologische Moorkunde. 112–184. — Stuttgart: E. Schweizerbart'sche Verlagsbuchhandlung.
Koska, I. 2007: Weiterentwicklung des Vegetationsformenkonzeptes. Ausbau einer Methode für die vegetationskundliche und bioindikative Landschaftsanalyse, dargestellt am Beispiel der Feuchtgebietsvegetation Nordostdeutschlands. — PhD thesis, Greifswald University.
Kozulin, A. & Flade, M. 1999: Breeding habitat, abundance and conservation status of the Aquatic Warbler *Acrocephalus paludicola* in Belarus. — Vogelwelt **120**: 97–112.
Krogulec, J. (ed.) 1998: Ptaki łąk i mokradeł Polski. Stan populacji, zagrożenia i perspektywy ochrony. — Warszawa: IUCN Poland.
Krogulec, J. & Kloskowski, J. 2003: Monitoring Aquatic Warbler *Acrocephalus paludicola* in Poland. — Ornis Hungarica **12–13**: 191–196.
Lithuanian Ornithological Society 2000: National Aquatic Warbler Acrocephalus paludicola survey and development of the habitat management plan. — Vilnius. Unpublished report.
Londo, G. 1984: The decimal scale for relevés permanent quadrats. — In: Knapp, R. (ed.), Sampling methods and taxon analysis in vegetation science. Handbook of Vegetation Science 4. 45–49. — The Hague: Junk.
Matkowska, Z., Ruszala, M. & Wdowiak, M. 1977: Objasnienia do szczegolowej mapy geologicznej Polski. Arkusz Swinoujscie i arkusz Międzyzdroje 1:50 000. — Warszawa: Wydawnictwo Geologiczne.
McCune, B. & Mefford, M.J. 1999: PC-ORD. Multivariate Analysis of Ecological Data, Version 4.01. MjM Software Design, Gleneden Beach, Oregon, USA.
Mueller-Dombois, D. & Ellenberg, H. 1974: Aims and Methods of Vegetation Ecology. — New York: Wiley.
Niedzwiecki, E. 2002: Klimat i gleby Doliny Dolnej Odry na tle stratygrafii. — In: Jasnowska, J. (ed.), Dolina Dolnej Odry. Monografia przyrodnicza Parku Krajobrazowego. 53–66. — Szczecin: Wydawnictwo ZAPOL.
Osiejuk, T.S., Kuczynski, L., Jermaczek, A. & Tryjanowski, P. 1999: The effect of water conditions on breeding bird communities of pastures, meadows and shrub habitats in the Słońsk reserve, NW Poland. — Biologia **54**: 207–214.
Polte, T. 2004: Juncetea maritime — Salzwiesen und Brackwasserröhrichte. — In: Berg, C., Dengler, J., Abdank, A. & Isermann, M. (eds), Die Pflanzengesellschaften Mecklenburg-Vorpommerns und ihre Gefährdung. 225–245. — Jena: Weissdorn, Jena.
Poluda, A. 2006: Survey of New Potential Sites and Monitoring of Key Breeding Sites of Aquatic Warbler in Ukraine 2006. — Unpublished project report, Kyiv.

Rennwald, E. 2000: Verzeichnis und Rote Liste der Pflanzengesellschaften Deutschlands. — Schriftenreihe für Vegetationskunde 35. Bonn-Bad Godesberg.

Roberge, J.-M. & Angelstam, P. 2004: Usefulness of the Umbrella Species Concept as a Conservation Tool. — Conserv. Biol. **18**: 76–85.

Robien, P. 1920: Die Vogelwelt des Bezirks Stettin. Teil 1. L. — Stettin: Saunier.

Rowell D.L. 1997: Bodenkunde — Untersuchungsmethoden und ihre Anwendungen. — Berlin: Springer.

Schulze-Hagen K. 1991: *Acrocephalus paludicola* (Vieillot 1817) — Seggenrohrsänger. — In: Glutz von Blotzheim, U.N. (ed.), Handbuch der Vögel Mitteleuropas. 252–291. — Wiesbaden: Aula.

Sellin, D. 1989: Vergleichende Untersuchungen zur Habitatstruktur des Seggenrohrsängers *Acrocephalus paludicola*. — Vogelwelt **110**: 198–208.

Sellin, D. 1990: Zum aktuellen Vorkommen des Seggenrohrsängers *Acrocephalus paludicola* im Oderdelta zwischen Peenestrom und Dziwna. — Vogelwelt **111**: 181–189.

Simberloff, D. 1998: Flagships, umbrellas, keystones: is single-species managament passé in the landscape era? — Biol. Conserv. **81**: 247–257.

Succow, M. & Joosten, H. (eds.) 2001: Landschaftsökologische Moorkunde. — Stuttgart: Schweizerbart'sche Verlagsbuchhandlung.

Tanneberger, F. 2008: The Pomeranian population of the Aquatic Warbler (*Acrocephalus paludicola*) — habitat selection and management. — PhD thesis, Greifswald University.

Tanneberger, F., Bellebaum, J., Helmecke, A., Fartmann, T., Just, P., Jehle, P. & Sadlik, J. 2008: Rapid deterioration of aquatic warbler *Acrocephalus paludicola* habitats at the western margin of its breeding range. — J. Ornithol. **149**:105–115.

Tanneberger, F., Tegetmeyer, C., Dylawerski, M., Flade, M. & Joosten, H. 2009: Slender, sparse, species-rich — winter cut reed as a new and alternative breeding habitat for the globally threatened Aquatic Warbler. — Biodiv. Conserv. **18**: 1475–1489.

Tanneberger, F., Schröder, B., Flade, M. & Preiksa, Z. 2010a: Conserving the last remnants of a formerly common species: Modelling habitat selection of the globally threatened Aquatic Warbler (*Acrocephalus paludicola*) at the western margin of its breeding range. — Ibis **152**: 347–358.

Tanneberger, F., Bellebaum, J., Frick, A., Haag, L., Steffenhagen, P., Kaffke, A. & Giessing, B. 2010b: NATURA 2000 Species Management Plan for the Aquatic Warbler in Brandenburg. — Unpublished report. 223 p.

Vergeichik, L. & Kozulin, A. 2006: Changing nesting dates and nest placement as adaptations of Aquatic Warbler *Acrocephalus paludicola* to unstable nesting conditions on fen mires in Belarus. — Vogelwelt **127**: 145–155.

Wisskirchen, R. & Haeupler, H. 1998: Standardlisten der Farn- und Blütenpflanzen Deutschlands — Mit Chromosomenatlas von Focke Albers. — Stuttgart (Hohenheim): Ulmer.

Wołejko, L., Bacieczko, W., Prajs, B., Kowalski W.W. & Ziarnek, K. 2007: Szata roślinna. — In: Borówka, R.K. (ed.), Jezioro Miedwie i Nizina Pyrzycka. 110–137. — Szczecin: Oficyna.

Wróbel, M. & Jurzyk, S. 2004: Habitat conditions of *Carex pulicaris* L. in the Rozwarowo wetlands (Western Pomerania). — In: Wołejko, L. & Jasnowska J. (eds.), The future of Polish mires. 85–89. — Szczecin: Agricultural University of Szczecin.

Żukowski, W. & Jackowiak, B. 1995: Ginące i zagrożone rośliny naczyniowe Pomorza Zachodniego i Wielkopolski. Prace Zakładu Taksonomii Roślin UAM w Poznaniu 3. — Poznan: Bogucki Wyd. Nauk.

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Appendix

List of plant species (N = 101) recorded in Aquatic Warbler breeding sites in Pomerania in the years 2004–2007. **=strictly protected in Poland, *=protected in Poland, after Żukowski & Jackowiak (1995) and Rozporządzenie Ministra Środowiska z dnia 9 lipca 2004 r. w sprawie gatunków dziko występujących roślin objętych ochroną

Achillea salicifolia
Agrostis stolonifera
Alisma plantago-aquatica
Alopecurus geniculatus
Alopecurus pratensis
Bolboschoenus maritimus
Calamagrostis cansecens
Calamagrostis epigejos
Calamagrostis stricta
*Calliergonella cuspidata**
Caltha palustris
Calystegia sepium
Cardamine pratensis
Carex acuta
Carex acutiformis
Carex appropinquata
Carex disticha
Carex elata
Carex lasiocarpa
Carex nigra
Carex pseudocyperus
Carex riparia
Carex rostrata
Carex vesicaria
Cirsium palustre
Cnidium dubium
*Cladium mariscus***
Eleocharis palustris
Eleocharis uniglumis
Elymus repens
Epilobium palustre
Equisetum fluviatile
Eriophorum angustifolium
Festuca rubra agg.
Filipendula ulmaria
Galium aparine
Galium palustre
Galium uliginosum
Glechoma hederacea
Glyceria fluitans
Glyceria maxima
*Hierochloe odorata**
Holcus lanatus
Inula britannica
Iris pseudacorus
Juncus conglomeratus
Juncus gerardii
Lathyrus palustris
Lathyrus pratensis
Leptodictyum riparium
Lotus uliginosus
Lycopus europaeus
Lysimachia nummularia
Lysimachia thyrsiflora
Lysimachia vulgaris
Lythrum salicaria
Mentha aquatica
Mentha arvensis
*Menyanthes trifoliata**
Myosotis arvensis
Myosotis scorpioides
*Myrica gale***
Oenanthe fistulosa
*Orchis mascula***
Peucedanum palustre
Phalaris arundinacea
Phragmites australis
Plagiomnium ellipticum
Plantago lanceolata
Plantago major
*Pleurozium schreberi**
Poa palustris
Poa pratensis
Poa trivialis
Polygonum amphibium
Potentilla anserina
Potentilla palustris
Ranunculus acris
Ranunculus auricomus
Ranunculus flammula
Ranunculus lingua
Ranunculus repens
Rorippa amphibia
Rumex crispus
Rumex hydrolapathum
Schoenoplectus tabernaemontani
*Schoenus nigricans***
Silene flos-cuculi
Sium latifolium
Solanum dulcamara
Stachys palustris
Stellaria palustris
Symphytum officinale
Thalictrum flavum
Thelypteris palustris
Trifolium repens
Typha latifolia
Urtica dioica
Veronica anagallis-aquatica
Veronica anagalloides
Vicia angustifolia
Vicia cracca