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ORIGINAL PAPER

Commercially cut reed as a new and sustainable habitat for the globally threatened Aquatic Warbler

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Abstract The Aquatic Warbler (*Acrocephalus paludicola*) is a song bird breeding in fen mires and similarly structured other wetlands with a water depth of 1–10 cm. Widespread in central-European wetlands at the beginning of the 20th century, the species is now globally threatened. The westernmost and genetically distinct Pomeranian population is even on the verge of extinction. The major challenge in the conservation of remaining habitat is the cost-efficient removal of biomass. About 50% of the Pomeranian population survives in a valley fen near Rozwarowo in Northwest Poland, where between 1993 and 2007 a conspicuous change in breeding habitat has taken place from summer grazed sedge meadows to commercial winter cut reed beds. We compared vegetation structure, site conditions, and potential prey abundance with the distribution and abundance of Aquatic Warblers in Rozwarowo Marshes and studied temporal changes and the compatibility of conservation and reed cutting interests. Aquatic Warblers now occur almost exclusively in sparsely growing, low reed with abundant *Thelypteris palustris, Carex elata*, and *Lysimachia vulgaris*. This vegetation type provides more potential prey for Aquatic Warblers than the higher productive tall reed, whereas the patches of sedge vegetation have become too small following succession after abandonment. Currently, commercial reed cutting maintains suitable Aquatic Warbler breeding habitat. Considering the impending changes in the reed market, there is a need for flexible agri-environmental schemes (AES) to ensure that stripes are left uncut and to prevent eutrophication by high and long flooding of the site.

Keywords *Acrocephalus paludicola* · Agri-environmental programs · Biomass use · Commercial reed beds · Long-term management · Nutrient enrichment · Species conservation · Vegetation structure

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Introduction

Until the beginning of the 20th century the Aquatic Warbler (*Acrocephalus paludicola*) used to be a widespread bird in central-European wetlands (Schulze-Hagen 1991). The species bred in mesotrophic and slightly eutrophic river valley mires (Aquatic Warbler Conservation Team 1999) that remained treeless because of the stable high water levels and the low bearing capacity of the loose peat layers. Their vegetation dominated by sedges offered optimal conditions to the species that predominantly forages by climbing in the plants (Leisler 1981). In the course of the 20th century the global population decreased by >95% as a consequence of wetland drainage and agricultural intensification, and the species went extinct in France, Belgium, Italy, and The Netherlands. Currently, the Aquatic Warbler regularly breeds in only six countries in less than 50 sites (Fig. 1b) and is classified as vulnerable at a global level (BirdLife International 2000, 2007). Its world population comprises ~10,000–14,000 singing males, of which ~90% are concentrated in the nowadays stable core population in Belarus, Eastern Poland and Ukraine (Flade et al. 2006, data collected by BirdLife Aquatic Warbler Conservation Team).

The currently westernmost Aquatic Warbler breeding sites are located in Northeast Germany and Northwest Poland (Fig. 1a). This so-called Pomeranian population shows genetic (Giessing 2002) and possibly migrational (Pain et al. 2004) differences and its conservation is crucial for maintaining the intraspecific diversity of the species and for the re-colonization of restored breeding sites in Western Europe (Flade et al. 2006). The Pomeranian population has decreased sharply in numbers in recent years: the number of singing males fell from 230 in 1997 (Krogulec and Kloskowski 2003) to 80 in 2007. Aquatic Warblers breed in low and sparse vegetation (Aquatic Warbler Conservation Team 1999; Tanneberger et al. accepted). In contrast to the mainly sedge-dominated habitats of the core population, Pomeranian habitats have either a mixed vegetation of sedges and grasses (mainly *Carex acuta* and *Phalaris arundinacea*) or are dominated by reed

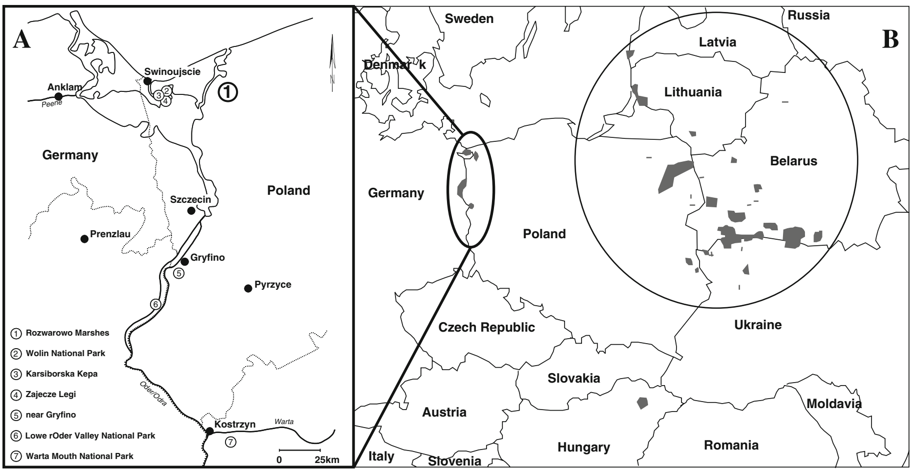

Fig. 1 **a** Location of the seven current Aquatic Warbler breeding sites in Pomerania, including (1) Rozwarowo Marshes. **b** Global distribution of current Aquatic Warbler breeding sites, with Pomeranian population (*small oval*) and core population (*large oval*). The West-Siberian breeding sites (no permanent breeding) are not depicted. Data: members of Aquatic Warbler Conservation Team pers. comm.

Phragmites australis (Tanneberger et al. 2005, accepted). The frequently cut reed is currently a unique habitat type across the breeding range (Aquatic Warbler Conservation Team 1999), where many sedge-dominated habitats loose their suitability due to overgrowth by reed (Kozulin and Flade 1999; Krogulec and Kloskowski 2003). Winter cutting may become a new and important management tool in such overgrown habitats, in Belarus, Poland, and Lithuania.

In this paper we compare the floristic composition, structure, site conditions, management, prey resources, and Aquatic Warbler occurrence of the vegetation types of the Rozwarowo Marshes, where ~50% of the Pomeranian Aquatic Warbler population survives. Based on this analysis, we give recommendations on vegetation management that integrates conservation and socio-economic interests.

Methods

Study area

Rozwarowo Marshes (1,100 ha) are located 15 km from the Baltic Sea in Northwest Poland (Fig. 1a). The Grzybnica river (Fig. 2) divides the peatland into an eastern and a western part. The area receives additional water from the Wołczenica river in the east and during heavy northerly storms also brackish water from the Baltic Sea. The peatland occupies a glacial basin that was shaped by melting inland ice. Lake sediments upto 3.5 m

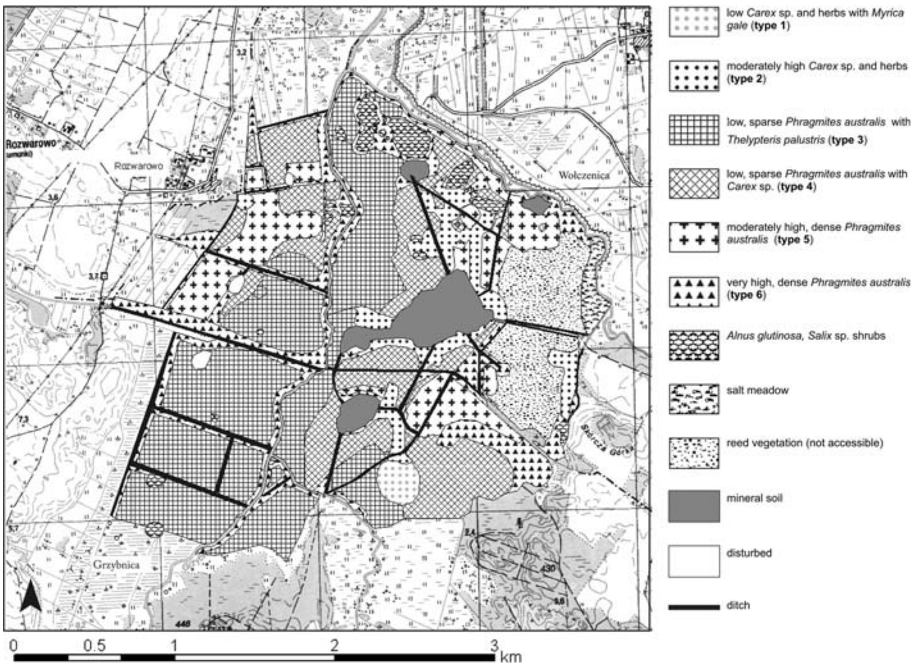

Fig. 2 Vegetation of Rozwarowo Marshes as in July 2005 (ditches as in summer 2007). Aquatic Warblers occur only in vegetation type 3 throughout the peatland and partly in adjacent patches of type 4

thick underlay a 1–2 m thick reed peat that was deposited in subneutral conditions (Tegetmeyer et al. 2007). Ditches and a settlement on maps from the 19th to 20th century indicate that the area was used for grazing, mowing and peat extraction. Rozwarowo Marshes have never been intensively drained, despite of plans to do so (Dreyer 1913). After more than 40 years without land use, winter reed cutting for thatching started in 1989 and the area became managed as a single wale cutting commercial reedbed (reed cut every winter, Hawke and José 1996). In 2004, along with the enlargement of the European Union, the peatland was designated as a special protection area (SPA) under the Birds Directive (79/409/EEC) for the European network of protected areas Natura 2000. It is one of the floristically most valuable peatlands in Northwest Poland, with the largest population of *Myrica gale* in this region (Jurzyk 2004), *Carex pulicaris* that is threatened with extinction in Poland (Jurzyk and Wróbel 2003), and halophytes of the Triglochino-Glaucetum maritimae (Jurzyk unpublished data).

Sampling

Plots (25 m^2) representative for larger areas to allow for later mapping of the whole area were sampled throughout July 2005 ($N = 82$) and in early June 2006 ($N = 16$). Plant species cover was estimated in 2005 in a modified Braun–Blanquet scale (Dierschke 1994) and in 2006 in the Londo scale (Londo 1984). These ordinal scales were transformed into single percentage values following Dierschke (1994): Braun–Blanquet scale: $r = 0.1\%$; $+ = 0.5\%$; 1a = 2%; 1b = 4%; 2a = 8.8%; 2b = 20.0%; 3 = 37.5%; 4 = 62.5%; 5 = 87.5%; Londo scale: 0.1 = 1%; 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%. The nomenclature of angiosperm species follows Wisskirchen and Haeupler (1998); that of bryophytes Frahm and Frey (1992). Height of the upper and of the ground vegetation layer was measured with three replicates per plot. Thickness of the litter layer was measured with three replicates per plot in 2006 and the geometric mean of minimum and maximum litter height per plot was calculated.

Water height (three replicates per plot) was measured during vegetation sampling with a measuring stick and expressed in centimeter above soil surface. As a proxy for productivity C:N ratios were determined in soil samples ($N = 35$) from a depth of 5–10 cm (cf. Succow and Joosten 2001) with a C:N-analyzer (Element vario EL) with Dumas digestion.

Singing Aquatic Warbler males (sm) were counted annually 2004–2007 in late May and late June shortly before and after sunset (Südbeck et al. 2005). Density was estimated for the total area with Aquatic Warbler occurrence (310 ha) and additionally for a core area in the southwestern part of the peatland south of the main channel with a particularly high Aquatic Warbler density during the study period (90 ha).

To assess food resources for Aquatic Warbler samples were collected in early June 2006 by sweeping a net with 30 cm diameter, 80 cm handle and fine mesh along transects of 100 sweeps (cf. Mühlenberg 1993; Robel et al. 1995). Because the vertical distribution of invertebrates varies diurnally and with weather condition (Southwood 1978), sampling was restricted to between 10 a.m. and 5 p.m., and to not or only partly clouded days with no or little wind and dry vegetation. Samples were stored immediately in an ether bar, subsequently (after a few hours) in acetic acid water, and after identification in ethanol. Identification (mostly to family level) followed Schaefer (2006). The length of the invertebrates was measured and their biomass was calculated using length–weight reference curves derived from invertebrate sampling in Aquatic Warbler breeding sites in

Pomerania in 2005 (Tanneberger et al. accepted). Information on timing and methods of land use was collected in interviews with the landowners.

Data analysis

As vegetation structure is more important in Aquatic Warbler habitat selection than plant species composition (Leisler 1981; Tanneberger et al. accepted), we integrated vegetation structure variables in our analysis. We included cover values of the upper vegetation layer (≥1 m height), of the ground vegetation layer (vascular plants <1.0 m height), of small and medium-sized least competitive species (CSR species according to Grime 1974; Grime et al. 1988; Hodgson et al. 1999; Klotz et al. 2002, including e.g., *Carex disticha, Thelypteris palustris, Potentilla palustris*, and *Galium palustre*), and of mosses, respectively. For each plant species the Ellenberg nutrient indicator value *N* (Ellenberg et al. 1992; Hill et al. 2000) was multiplied by its coverage in a plot and the sum of these values for all species was used as a proxy for the productivity of that site (Wagner et al. 2007).

On the basis of the vegetation relevés, ecological–sociological species groups were elaborated manually by table work (Mueller-Dombois and Ellenberg 1974), using the bioindication data of Ellenberg et al. (1992) and Koska et al. (2001) and own water level data. To assess the main floristic and ecological gradients an indirect gradient analysis (detrended correspondence analysis (DCA) using the program package PC-ORD 4.01) was carried out with the percentage cover data. Correlations of site and vegetation structure variables with the ordination axes were assessed using Pearson's correlation coefficient (r^2) (McCune and Mefford 1999). The relevés were ordered according to the environmental and vegetation structure gradients most important in the DCA and classified to non-hierarchical vegetation units following Koska et al. (2001).

To identify differences between vegetation types with and without Aquatic Warbler, we used multiple (ANOVA with Scheffé test and Kruskal–Wallis *H*-test) and pairwise (with Mann–Whitney *U*-test) tests. Significance levels were Holm corrected (Quinn and Keough 2002) where appropriate. One vegetation type was excluded from the analysis as it occurs only along ditches and does not meet the minimum Aquatic Warbler home range size and shape (Schaefer et al. 2000). For statistical analyses, the software package R 2.5.1 (R Development Core Team 2007) was used.

Results

Vegetation types

Six vegetation types were distinguished: two sedge-dominated (types 1 and 2) and four reed-dominated ones (types 3–6; Table 1; Fig. 2). Type 1 belongs to the *Typha latifolia–Carex rostrata* reed, types 2–4 to the *Calliergonella cuspidata–Carex elata* reed, type 5 to the *Ranunculus lingua–Carex elata* reed, and type 6 to the *Solanum dulcamara–Phragmites australis* tall herb vegetation according to the regional vegetation form classification of Koska et al. (2001). According to phytosociological classification (Pott 1995), type 1 belongs to the *Caricetum lasiocarpae* association of the *Caricion lasiocarpae* alliance, type 2 to the *Caricetum elatae* (*Magnocaricion elatae*), and types 3–6 to the Scirpo-Phragmitetum australis (Phragmition australis).

Cover and height of the upper vegetation layer increase from type 1 to type 6, whereas the cover of the ground vegetation layer and those of CSR species decrease (Table 1). The

Table 1 Vegetation types of Rozwarowo Marshes in July 2005

Vegetation type			1	2	3	4	5	6
Number of plots			3	13	35	8	16	7
Total area of this type (ha)			6	37	204	106	64	77
Cover of upper vegetation layer (%)			4 ±1.4	20.8 ±29.2	58.7 ±17.3	74.4 ±12.1	93.1 ±14.1	94 ±10.4
Cover of ground vegetation layer (%)			86.7 ±4.7	78.8 ±31.1	68 ±17	50.6 ±27.7	25.8 ±23.6	23.1 ±24.6
Cover of CSR species (%)			64.7 ±20.3	69.8 ±24.8	27.4 ±14.3	16.2 ±10.6	8.2 ±6.4	5.7 ±3.9
Cover of mosses (%)			0	0.1 ±0.2	20.2 ±25.2	31.5 ±21.1	10.6 ±20.7	0
Height of upper vegetation layer (m)			1 ±0.6	1.2 ±0.4	1.4 ±0.2	1.6 ±0.2	2 ±0.3	2.1 ±0.3
Height of ground vegetation layer (m)			0.6 ±0.1	0.8 ±0.1	0.8 ±0.1	0.5 ±0.2	0.4 ±0.3	0.8 ±0.3
Thickness of the litter layer (m)			0.03 ±0.01	0.03 ±0.01	0.06 ±0.02	0.04 ±0.03	0.02 ±0.01	0.04 ±0.02
Mowing			no	no	winter	winter	winter	no
Water level above soil surface (cm)			15 ±4.1	15.4 ±9.9	1.5 ±2.6	5 ±2.7	10.4 ±9.3	6.7 ±7.7
Productivity proxy based on Ellenberg (1992) nutrient indicator values N			3.4 ±0.1	4.4 ±0.3	5.6 ±0.8	5.9 ±0.7	6.8 ±0.3	7.1 ±0.1
Soil C:N ratio			24.2 ±8	21.6 ±5.4	20.1 ±2.9	20.7 ±2.1	18 ±1.8	18.2 ±4.1
	soil C/N	moisture class						
Myrica gale	>20		V/9		I/7			
Eriophorum angustifolium		5	IV/2					
Menyanthes trifoliata			V/36	III/16				
Carex rostrata			V/2	III/15				
Carex lasiocarpa			II/3	III/10	I/4			
Potentilla palustris			IV/14	II/4	III/12	III/5		
Calamagrostis stricta			II/2	V//2	II/8	I/9		
Ranunculus lingua	>13-20			II/1		I/1		
Carex appropinquata		4	II/4	IV/9	II/8			
Lathyrus palustris			II/1	IV/2	III/2			
Peucedanum palustre			IV/5	V/5	II/5	II/1		I/2
Stellaria palustris				I/1	I/1	IV/3	I/3	
Thelypteris palustris					V/7	I/9		
Carex elata	>10-13		IV/3	V/I7	IV/11	IV/26		
Carex disticha			II/2	V/26	II/11	I/9		
Calliergonella cuspidata				I/2	III/19			
Symphytum officinale					I/2			III1/1
Urtica dioica	≤10				I/4			IV/6
Calystegia sepium					I1/			III/3
Leptodictyum riparium		5			II/6	III/3	II/11	
Spirodela polyrhiza				I/3			II/35	
Lemna trisulca							I/12	
Equisetum fluviatile	ubiq.		IV/12	V/24				
Calamagrostis canescens			V/11	I/4	IV/3			
Lysimachia vulgaris			IV/3	IV/11	V/11	II/2		I/2
Lythrum salicaria			IV/1	III/2	III/2	IV/1		
Epilobium palustre			IV/1	IV/2	II/1	III/3		
Mentha arvensis					III/7	III/8	I/3	III/12
Cardamine pratensis					I/1	I/3	IV/4	I/1
Typha latifolia		5		III/6			I/1	
Rumex hydrolapathum				III/2	I/1		I/2	
Carex pseudocyperus					II/1	IV/4	II/2	
Sium latifolium						I/4	I/1	
Phragmites australis				I/2	V/30	V/49	V/79	V/85

A selection of species is presented with their general soil C:N (2nd column) and moisture (3rd column, 5 = wet; 4 = very moist) indication after Koska et al. (2001), and their constancy (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 percentage cover in the vegetation types. Site and vegetation structure parameters are presented as mean ± SD

types are also well separated with regard to site conditions: the sedge-dominated types 1 and 2 differ from all other types by their higher water level and their generally higher soil C:N values (Fig. 3; Table 2). Within the four reed-dominated types, types 3 and 4 have higher soil C:N values than types 5 and 6. The Ellenberg nutrient indicator values increase from type 1 to 6.

Types 1 and 2 are both dominated by sedges and have no or hardly *Phragmites australis* (Table 1). Soil C:N values are >20 and Ellenberg nutrient indicator values <5. The water level lies high above the soil surface, and the vegetation is about 1 m high. Typical plant species include *C. elata*, *C. disticha*, *Equisetum fluviatile*, and *Menyanthes trifoliata*, in

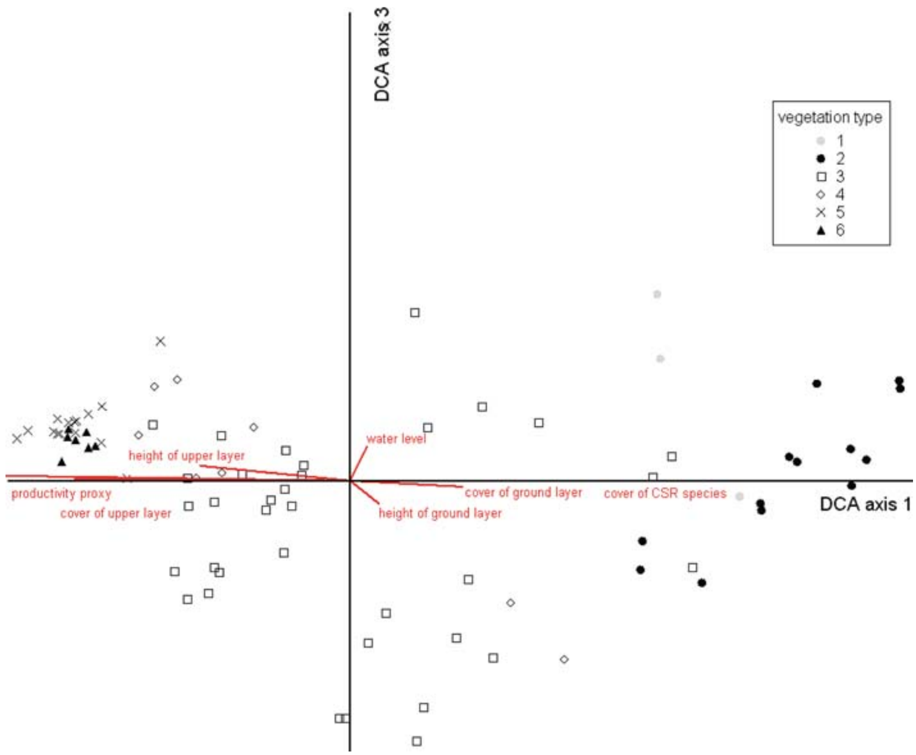

Fig. 3 Detrended correspondence analysis ordination diagram of vegetation types at Rozwarowo Marshes, based on plant species cover values and presented as a joint plot with productivity proxy based on Ellenberg (1992) nutrient indicator values *N*, water level and vegetation structure parameters of Table 1; $r^2 > 0.047$, $N = 82$ plots. Total number of plant species: 69. Eigenvalues: axis 1 = 0.694, axis 2 = 0.273, axis 3 = 0.212; gradient lengths: axis 1 = 3.752, axis 2 = 2.891, axis 3 = 3.040. Total variance of the species data: 4.147. Axes 1 and 3 are depicted as they have the strongest correlation with site parameters (Table 2)

Table 2 Pearson and Kendall correlations (r^2) of selected environmental and vegetation structure variables with DCA axes 1–3

Parameter	Axis 1	Axis 2	Axis 3
Productivity proxy	0.781	0.000	0.011
Water level	0.039	0.016	0.076
Height of upper layer	0.338	0.005	0.034
Cover of upper layer	0.624	0.005	0.005
Height of ground layer	0.066	0.008	0.052
Cover of ground layer	0.254	0.018	0.013
Cover of CSR species	0.622	0.093	0.001

Relate to Fig. 3

type 1 also *M. gale* occurs. Type 1 (1% of the area) has the highest C:N values and a lower height than type 2 (8% of the area). Both types have not been mown for at least 10 years.

Type 3 consists of moderately high (<2 m) and loosely growing *Phragmites australis* under which the broad leafs of *Thelypteris palustris* form a well-developed ground vegetation layer. Soil C:N values are about 20, Ellenberg nutrient indicator values >5, and in large parts the water level is permanently at or below the soil surface. Typical additional plant species include *Peucedanum palustre, Lysimachia vulgaris*, and *Lythrum salicaria*. This type mainly occurs in the western and north-eastern part on 41% of the area. Type 4 comprises moderately high (<2 m) *Phragmites australis* stands with a dense herb layer dominated by sedges. It occurs on 21% of the area, the water level is permanently at or below the soil surface, and soil C:N values are similar to those of type 3. Typical plant species include *Carex elata*, *Potentilla palustris*, and the moss *Leptodictyum riparium*. Type 5 comprises pure stands of in average 2 m high reed. The type covers 13% of the area. In contrast to type 6, also sedges (*Carex pseudocyperus*) and mosses occur. Here and in type 6, soil C:N values are <20 and Ellenberg nutrient indicator values are at about 7. Type 6 represents upto 2.5 m high, dense stands of reed with a water level that is generally above the soil surface. It occurs mainly along ditches and channels on 16% of the studied area. Typical additional plant species include *Urtica dioica* and *Calystegia sepium*. All four reed-dominated types are annually cut in winter.

Aquatic Warbler number and density

The total number of Aquatic Warbler singing males in Rozwarowo Marshes varied between 22 and 37 (Table 3). The density varied between 0.71 males/10 ha in 2004 and 1.19 males/10 ha in 2006 (for the full area of 310 ha) and reached a maximum of 2.8 males/10 ha in 2007 (for the core area of 90 ha).

Aquatic Warbler habitat characteristics

Since 2004, Aquatic Warblers occurred exclusively in reed vegetation, except during the second count in 2007 (97% in reed vegetation; Table 3). Comparison with the vegetation map of 2005 (Fig. 2) showed that during 2005–2007 the species mainly used vegetation type 3. A few times the species was observed in vegetation type 4 in areas close to type 3 and in one year (2007) one bird was seen in type 2.

Table 4 compares reed vegetation with Aquatic Warbler (types 3 and 4), reed vegetation without Aquatic Warbler (type 5), and sedge vegetation (types 1 and 2). Type 6 is not included as it mainly occurs along ditches and does not meet the required area of Aquatic Warbler habitat of several hectares. In contrast to reed vegetation without Aquatic Warblers, reed vegetation with Aquatic Warbler has a lower height of the upper vegetation layer, a lower cover of reed, and a higher cover of small, least competitive plant (CSR)

Table 3 Number of Aquatic Warbler singing males and their occurrence in reed vegetation (in %) in Rozwarowo Marshes 1993–2007

Year	First count		Second count	
	Total number	Reed (%)	Total number	Reed (%)
1993	37	55	Not counted	–
1997	28	60	22	Not known
2003	4	75	Not counted	–
2004	0	–	22	100
2005	18–21	100	21–23	100
2006	*6–7*	100	37	100
2007	19–21	100	35	97

Data are from R. Czeraszkiewicz, unpublished data (1993–2003) and own observations (since 2004). Italics indicate a possible underestimate (very bad counting conditions)

Table 4 Characteristics of reed vegetation with Aquatic Warbler (types 3 and 4), reed vegetation without Aquatic Warbler (type 5), and sedge vegetation (types 1 and 2) in Rozwarowo Marshes in July 2005

Dominant plant species	Reed	Reed	Sedge	Test value	*P*
Aquatic Warbler Occurence	Yes	No	No		
Vegetation type	3 and 4	5	1 and 2		
Number of plots	21	10	9		
Water level above soil surface (cm)	3.21 ± 5.4^{a}	10.9 ± 11.4^{ab}	17.5 ± 10^{b}	$F_{2,37} = 10.061$	0.007
Height of the upper vegetation layer (m)	1.44 ± 0.23^{a}	1.97 ± 0.43^{b}	1.29 ± 0.19^{a}	$\chi_2^{2} = 15.931$	0.007
Cover of CSR species (%)	27.19 ± 13.48^{a}	9 ± 6.5^{b}	58.56 ± 17.51^{c}	$\chi_2^{2} = 23.774$	0.007
Cover of reed (%)	59.9 ± 21.3^{a}	95 ± 7.1^{b}	3.33 ± 10^{c}	$\chi_2^{2} = 30.28$	0.007
Cover of mosses (%)	17.88 ± 20.6^{b}	3.2 ± 6.68^{a}	0.06 ± 0.17^{a}	$\chi_2^{2} = 10.747$	0.01
Productivity proxy based on Ellenberg *N* values	5.7 ± 0.8^{a}	6.8 ± 0.2^{b}	4.2 ± 0.5^{c}	$F_{2,37} = 36.985$	0.007
Potential prey (mg/transect)[1]	683.6 ± 677.4^{a}	147.3 ± 57.3^{b}	434.8 ± 266.8^{a}	$Z = 8.554$	0.014

Type 6 is excluded as it does not meet the required area of Aquatic Warbler habitat of several hectares. Means ± SD and test results for parameters relevant for Aquatic Warbler are given. Values followed by the same letter do not differ significantly from one another (at $P < 0.05$, Scheffé test for ANOVA and multiple Mann–Whitney *U*-tests with Holm correction for Kruskal–Wallis *H*-test, respectively)

[1] For early June 2006 and $N = 9/5/5$

species and mosses. The productivity proxy value is lower and there is more potential prey biomass. The reed vegetation without Aquatic Warblers has the highest vegetation and the smallest biomass of potential Aquatic Warbler prey of all three categories. The sedge vegetation (without Aquatic Warbler) has a higher cover of CSR species, a lower cover of reed, and a lower productivity proxy value than both reed-dominated types. Height of the upper vegetation layer and potential prey biomass do not differ from reed vegetation with Aquatic Warbler records. Proportions of dominant arthropod groups are similar in all three categories: 35.4–47.1% of the total arthropod biomass are Coleoptera, 17.2–22.8% Diptera, 10.3–17.6% Arachnida, 7.3–11.3% Homoptera, and 2.5–9.9% Orthoptera.

Discussion

Changes between 1993 and 2007

Aquatic Warbler distribution maps and vegetation descriptions from 1993, 1997, and 2003 (Table 3; R. Czeraszkiewicz, unpublished data) reveal a gradual shift of the birds from sedge to reed vegetation. Simultaneously the reed covered area expanded as a result of reed favoring management by the land owners since the mid-1990s. In 1993, half of the Aquatic Warbler males occurred in sedge vegetation without reed, which was more abundant at that time especially in the eastern part of the area. Here, about 50 ha of sedge vegetation were still grazed. In 1997, the total number was smaller and 60% occurred in winter cut reed vegetation. The area with sedge vegetation had decreased especially in the south-eastern part and grazing had completely stopped.

Extraordinarily low numbers of Aquatic Warbler were observed in May 2003 and May 2004, probably due to very high water levels dammed up by heavy spring storms over the Baltic Sea. Subsequently the birds almost completely abandoned the sedge vegetation, probably because the remaining sedge patches had become so small and fragmented due to overgrowth with bushes (Fig. 2) that the necessary home range size (upto 8 ha, Schaefer et al. 2000) was no longer reached. Apparently the birds could find a similar vegetation structure and prey abundance (Table 4) in the annually cut, sparse reed vegetation. An additional reason for the shift might be the diminishing habitat suitability of the remaining sedge vegetation after the cessation of land use (Tanneberger et al. 2008). Associated with an increase in vegetation height and density, the availability of potential prey for *Acrocephalus* warblers decreases (Poulin et al. 2000; Tanneberger et al. accepted). This has also been shown for habitats of other passerine species by Wilson et al. (2005).

Comparison with other Aquatic Warbler breeding sites

In the Aquatic Warbler core population, only a few reed-dominated and no annually winter cut sites exist. Most similar to the Rozwarowo habitats are sedge fen habitats with a sparse reed cover described from Biebrza Marshes in Eastern Poland (Trzcina Ławki, H. Bartoszuk, unpublished data), Belarus (parts of Zvanets mire, Kozulin and Flade 1999), and Lithuania (Kliosiai site, Z. Preiksa, unpublished data). Here, Aquatic Warbler density decreased in recent years (Kloskowski and Krogulec 1999; Kozulin and Flade 1999), which is attributed to the overgrowth with reed following changes in water regime and cessation of summer mowing (Kloskowski and Krogulec 1999). For Pomerania, Sellin (1989, 1990) described Aquatic Warbler occurrence in brackish grassland overgrown with reed following a decrease in grazing intensity. The vegetation structure was very similar to that in Rozwarowo Marshes (D. Sellin pers. comm.). Here, the birds disappeared either after re-intensification of land use or after cessation of grazing.

The species composition of the sedge vegetation in Rozwarowo Marshes resembles those of the main habitats of the current core population: still largely intact floodplain fens of the rivers Pripyat, Yaselda and Biebrza with *Carex elata* and *Carex appropinquata* sedge and brown moss communities (Kozulin and Flade 1999; Dyrcz and Zdunek 1993). In the latter sites, regular biomass removal by low-intensity agriculture or accidental burning have kept the vegetation sparse also during the last decades with increasing nitrogen deposition. In the sedge fens of the Rozwarowo Marshes (without Aquatic Warbler), the high cover of species sensitive to frequent mowing such as *Equisetum fluviatile, Carex elata, Peucedanum palustre, Lysimachia vulgaris*, and *Rumex hydrolapathum* (Koska et al. 2001) indicates the absence of summer mowing.

Management recommendations for Rozwarowo Marshes

Winter reed cutting is currently the main land use type in Rozwarowo Marshes. The ideal reed for high quality thatching is straight, fine, stable and rather short (c. 1.6 m, Rozwarowo reed cutters pers. comm.). Thatches made of such reed are durable and especially water-proof. Concerning the site conditions, Aquatic Warblers and reed cutters have largely similar "interests" (Table 5). High quality reed grows under mesotrophic to slightly eutrophic soil conditions (Boar et al. 1991) that are also preferred by the bird. Such conditions can be maintained by annual biomass removal (cf. Sieghardt and Maier 1985). In addition, the cutting of thatch in winter prevents the expansion of shrubs and removes dead reed material (Hawke and José 1996).

Table 5 'Interests' of reed cutters and Aquatic Warbler in Rozwarowo Marshes with regard to site conditions

'Interest'	Reed cutters	Aquatic Warbler
Loose reed 1–2 m	+	+
Dense reed 1–2 m	+	−
Absence of reed >2 m	+	+
Herbs between reed	±	+
Mesotrophic soil conditions	+	+
Absence of shrubs and trees	+	+
Water level >10 cm	+	−
Absence of eutrophic irrigation water	+	+
Winter reed cutting	+	+

Diverging 'interests' are printed in bold. + indicates any positive interest (e.g., preference, benefit), − indicates an avoidance

However, the "interests" of the Aquatic Warbler and the reed cutters differ with respect to the water level. The reed cutters stimulate the growth and expansion of reed by raising the water level by distributing water of adjacent rivers over the area. Water levels higher than 10 cm above-ground decrease the area suitable for Aquatic Warbler nests, which are built here close to the ground due to the absence of dead plant material. In addition, the eutrophic river water from Wołczenica river fertilizes the area, as is reflected in the high productivity proxy and low soil C:N values of type 5 vegetation and in the strong increase in vegetation height in areas of types 3 and 4 vegetation with high water levels (own observations). This may eventually make the area unsuitable both for growing high quality reed and as Aquatic Warbler habitat. In conclusion: whereas short-term water level demands of reed production and Aquatic Warbler conservation seem to be conflicting, on the longer run the interests may converge again. A Polish-German EU-LIFE Nature Project currently investigates optimal water levels with regard to economic and ecological needs.

The impact of commercial reed cutting on other plant and animal species is diverse. With regard to plant conservation, winter cutting can maintain (Güsewell and Le Nédic 2004) or increase species diversity as it substantially reduces the ruderal and nitrophilous character of the vegetation (Gryseels 1989) and benefits shorter and more species-rich vegetation (Cowie et al. 1992). For typical reedbed birds, Kube and Probst (1999) showed low population densities e.g., of Bearded Tits (*Panurus biarmicus*) in brackish reedbeds in Northeast Germany upto 3 years after cutting. A low abundance of early breeding passerines in cut reed beds has also been found by Poulin and Lefebvre (2002). In contrast, Hawke and José (1996) describe that the same species preferred recently cut brackish reedbeds (with rapid litter accumulation) in Southwest England above areas that had not been cut. Other characteristic reed species such as Reed Warbler (*Acrocephalus scirpaceus*) are apparently also able to rapidly recolonise cut areas (Hawke and José 1996). Bibby and Lunn (1982) see generally little conflict between harvesting activities and ornithological interests, as long as patches of uncut reed remain.

Often, the reduced abundance of potential prey for passerine birds is used as an argument against reed cutting, but reliable data to support this are not available. Although invertebrates wintering in reed stems and litter-dwelling species are likely to suffer from cutting, other groups (e.g., herbivores such as Homoptera) benefit from fresh green reed stems. During this study, we observed three successful broods of Aquatic Warblers in reed cut in the previous winter and we could not find differences in total biomass of potential prey between the Rozwarowo breeding sites (Table 4) and other Pomeranian breeding sites (Tanneberger et al. accepted). As the Aquatic Warbler is a species that due to uniparental care is particularly dependent on abundant food in the close vicinity of the nest (Schulze-Hagen 1991), this suggests that there is sufficient prey also for other passerine birds. Ditlhogo et al. (1992) found differences between cut and uncut sites only in a few invertebrate families, and this number declined with time after cutting. After one year, no soil invertebrates and only a few families of above-ground invertebrates showed any significant effects. According to that study and to (Schmidt et al. 2005, 2008), appropriate management for invertebrate conservation in reedbeds and fen meadows would include rotational burning or cutting, with parts of the bed left unmanaged, forming a mosaic of ages and allowing recolonization by cutting-sensitive invertebrates.

Conclusion and socio-economic perspective

The Aquatic Warbler is the only globally threatened species among the species of the Rozwarowo Marshes. Therefore, management favoring this species should have first priority. In recent decades, Aquatic Warblers used to breed in late summer mown sedges. The area of this habitat type has decreased for economical reasons and the birds have shifted to an alternative habitat–winter cut reed. As it maintains conditions suitable for Aquatic Warblers and is currently economically feasible, the continuation of the winter cutting regime is recommended as the main management measure. In order to maintain optimal habitat conditions, additional fertilization through eutrophic water during high and long flooding has to be avoided. Uncut stripes should be left to mitigate adverse effects on invertebrates and other bird species and to provide nesting space for Aquatic Warblers during the early season. In the last 3 years this policy has already been implemented voluntarily by the Rozwarowo reed cutters in some parts of the area. Summer mowing of Rozwarowo Marshes after the breeding season (i.e., in August/September as required by current Polish agri-environmental schemes) would probably have the same effects on vegetation and Aquatic Warbler as winter cutting, but is economically not viable. The EU-LIFE project is currently exploring this issue.

Currently, reed cutting in Poland is profitable and commercial and conservation interests run parallel. Considerable changes are, however, likely to occur in the next years along with the implementation of the Common Agricultural Policy, including decreasing economic interest in commercial reedbeds, rising wages, and increasing competition from low-wage countries outside the EU. Possibilities to safeguard reed cutting include (1) maintaining direct payment eligibility of commercial reedbeds and (2) adjusting the Polish agri-environmental schemes (AES) to allow supporting flexible conservation measures for Natura 2000 sites based on the recommendations in the Natura 2000 management plans. The EU-approved Polish Rural Development Strategy (2007–2013) includes the possibility of such ‘Natura 2000 payments’ to support tailor-made conservation schemes for unusual conservation situations like the one in Rozwarowo. To enable these Natura 2000 payments and other management decisions, sound monitoring of Aquatic Warblers, vegetation, water level, and potential prey (started within the LIFE project) should be continued and a management plan addressing the needs of Aquatic Warblers, other wildlife and the landowners has to be elaborated and approved by the authorities.

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